Renewal & Upgrading of Hydropower Plants

IEA Hydro Technical Report

Volume 2: Case Histories Report

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IEA Hydropower Agreement: Annex XI

AUSTRALIA JAPAN NORWAY USA

Table of contents（Volume 2）

【Japan】

【Norway】

【Finland】

【Australia】

【New Zealand】

【United States】

【Brazil】

【France】

【Switzerland】

【China】

ANNEX XI Renewal & Upgrading of Hydropower Plants

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

Category and Key Points

Main: 1-a) Energy Policies of Countries and States

Sub: 1-b) Investment Incentives (Feed-in-Tariff (FIT), Renewable Portfolio Standard (RPS), Subsidies, Financial Assistance, Tax Deductions, etc.

2-a) Technological Innovation & Deployment Expansion of Electro-Mechanical (E/M) Equipment

Project Name:

Houri No.2 Hydropower Project

Name of Country (including State/Prefecture):

Japan, Miyazaki Prefecture

Implementing Agency/Organization:

Miyazaki Prefecture, Public Enterprise Bureau

Implementing Period:

from 2010 to 2012

Trigger Causes for Renewal and Upgrade:

(C) Needs for higher performance

Keywords:

Power generation by ecological flow discharge

Abstract:

In order to effectively use ecological flow discharge which is aimed at maintaining the river environment, the construction of the hydroelectric power station which produces a small power output was planned, and the operation was started in April 2012.

This power station has contributed to the prevention of global warming though the effects are small.

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

The Houri Power Station and the Kami-Houri Power Station were constructed in the scheme of the Hourigawa general development project which was started in 1969, and its operation began in 1973.

After that, ecological flow discharge has been mandated so as to maintain the river environment, etc., and in 2001 ecological flow began.

Construction of the Houri No.2 Power Station was planned for the purpose of using ecological flow discharge effectively and preventing global warming, and the construction was started in December 2010 and the operation began in April 2012.

Locations of dam and powerhouse, and their specifications are shown in Figure 1 and Table 1.

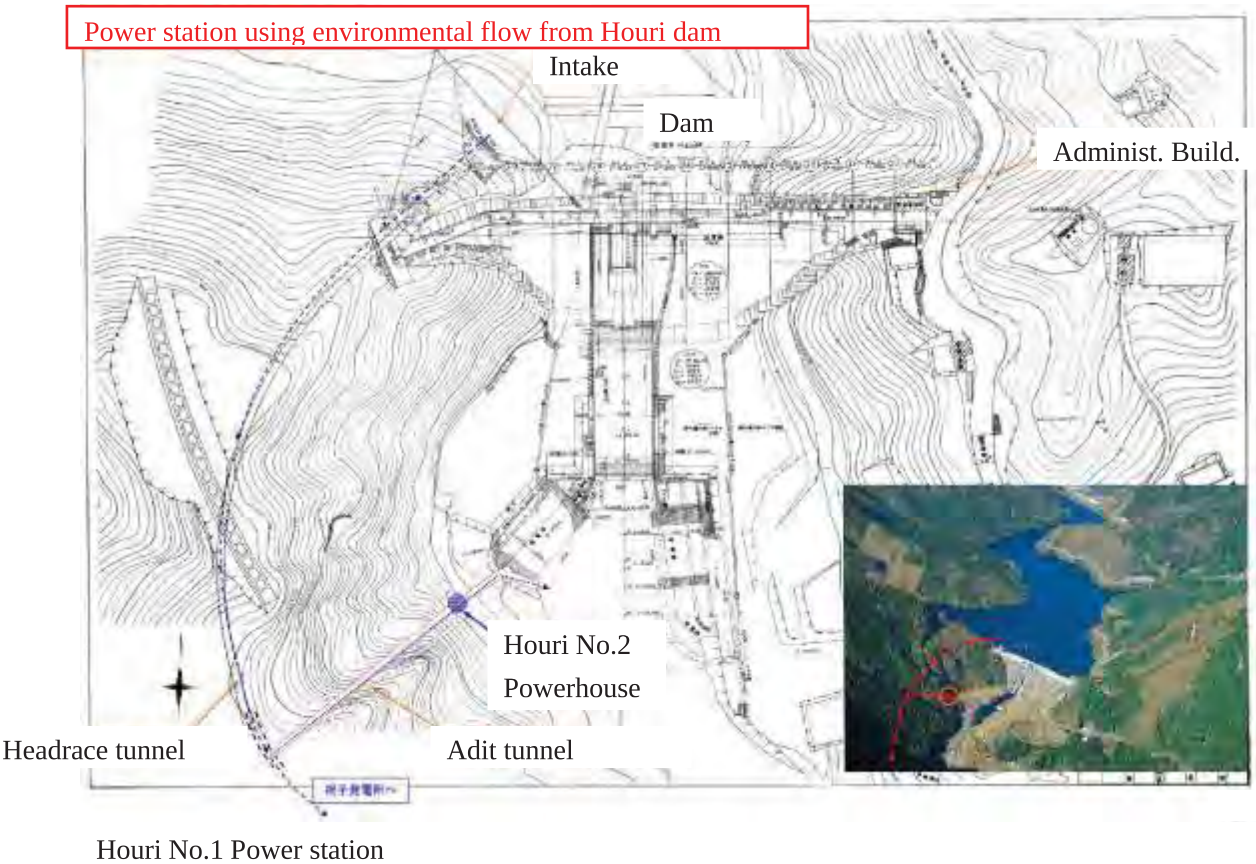


Figure 1 General Plan

Table 1 Specifications of Houri No.2 Power Station

Items		Specifications	
Powerhouse	Name of power station	Houri Second Power Station (new construction)	Houri Power Station (existing)
	Type	Horizontal Francis turbine	Vertical Francis turbine
	Maximum output	35 kW	16,800 kW
	Effective head	34.75 m	251.70 m
	Maximum plant discharge	0.14 m^3/s	8 m^3/s
	Revolving speed	1,200 r/min	720 r/min
	Power voltage	440 V	6,600 V
	Annual electricity generation	209 MWh	52,569 MWh

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

(None)

(2) Improvement of value (functions)

(C) - (a) Needs for higher performance – expansion

(3) Necessity in market

(None)

2.2 Process to Identify and Define Renewal and Upgrade Work Measure

April 1973:	Operation at Houri Power Station started
March 2002:	Facilities for ecological flow discharge was completed; discharge started
2008:	Survey on Houri No.2 Power Station started
August 2010:	Explanatory meeting with stakeholder et al.
September 2010:	Water rights were provided
December 2010:	Construction of Houri No.2 Power Station started
December 2011:	Certified through RPS system
April 2012:	Operation st Houri No.2 Power Station started.

2.3 Description of Work Undertaken (detail)

1-a) Energy Policies of Countries & States

1-b) Investment Incentives (Feed-in-Tariff (FIT), Renewable Portfolio Standard (RPS), Subsidies, Financial Assistance, Tax Deductions, etc.

As one of the strategic policies of 2010, Miyazaki Prefecture put in place a goal which aims at achieving a low carbon society by expanding and promoting the use of new environment- friendly energy, maximizing characteristics of Miyazaki region. Based on this goal, the "Project of new energy introduction by Public Enterprise Bureau" which aims to introduce photovoltaic generation and micro hydropower generation which utilizes ecological flow discharge from dams has started.

As a part of this policy, electric power generation using ecological flow discharge, which had not been used for generation, was determined to be introduced.

In the process of introduction, "Grant for promotion of regional new energy deployment" was provided and reduction of the initial investment cost was made. Generating equipment was given a certification by the RPS system which is a necessary condition for receiving the grant mentioned above.

2-a) Technological Innovation & Deployment Expansion of Electro-Mechanical (E/M) Equipment

The Houri Dam had been constructed for the purpose of flood control, power generation and industrial water supply, so water level of the reservoir is not constant.

In Houri Dam, ecological flow discharge has been through a pipeline which is branched from the headrace tunnel of Houri Power Station. Also, depending on the reservoir's water level, opening degree of a gate which is installed at the outlet of the pipeline was controlled manually at regular intervals, resulting in discharging much more than required.

While generating electricity by using the ecological flow at Houri No.2 Power Station, it is possible to increase water for electricity producing at Houri Power Station if the ecological flow discharge is automatically controlled within the required amount.

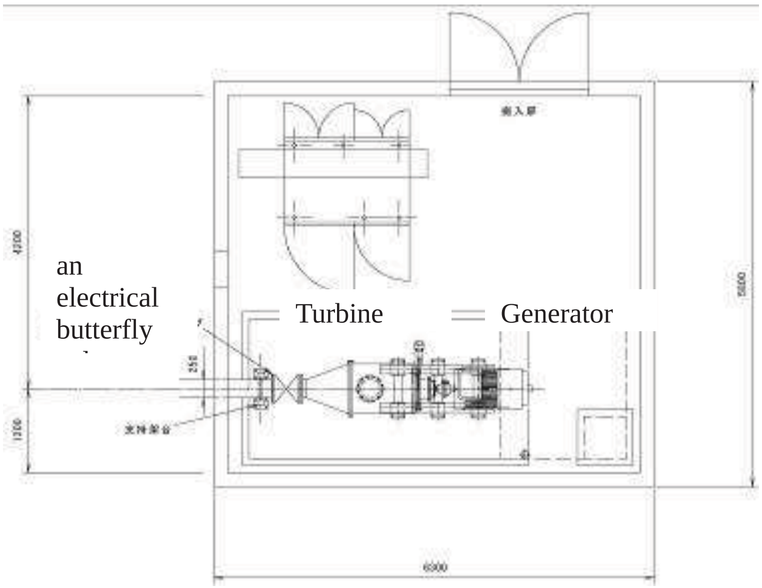


Figure 2　Equipment Layout

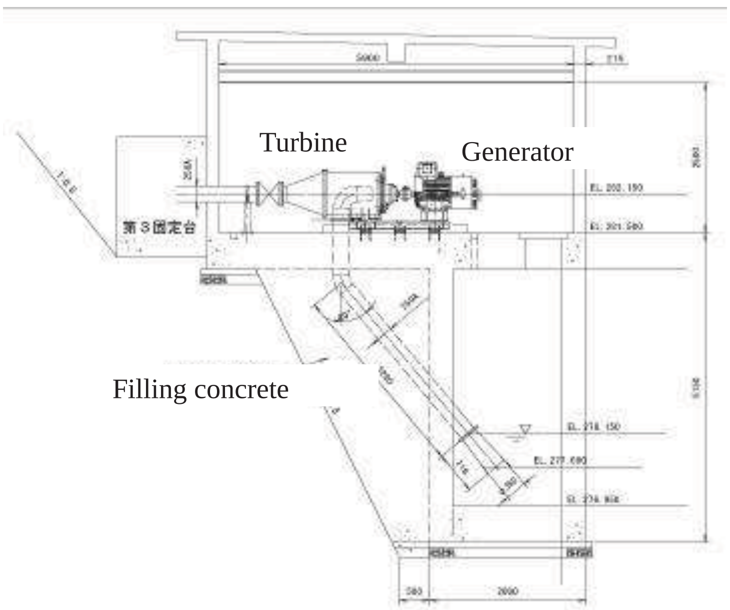


Figure 3　Cross-section of Equipment

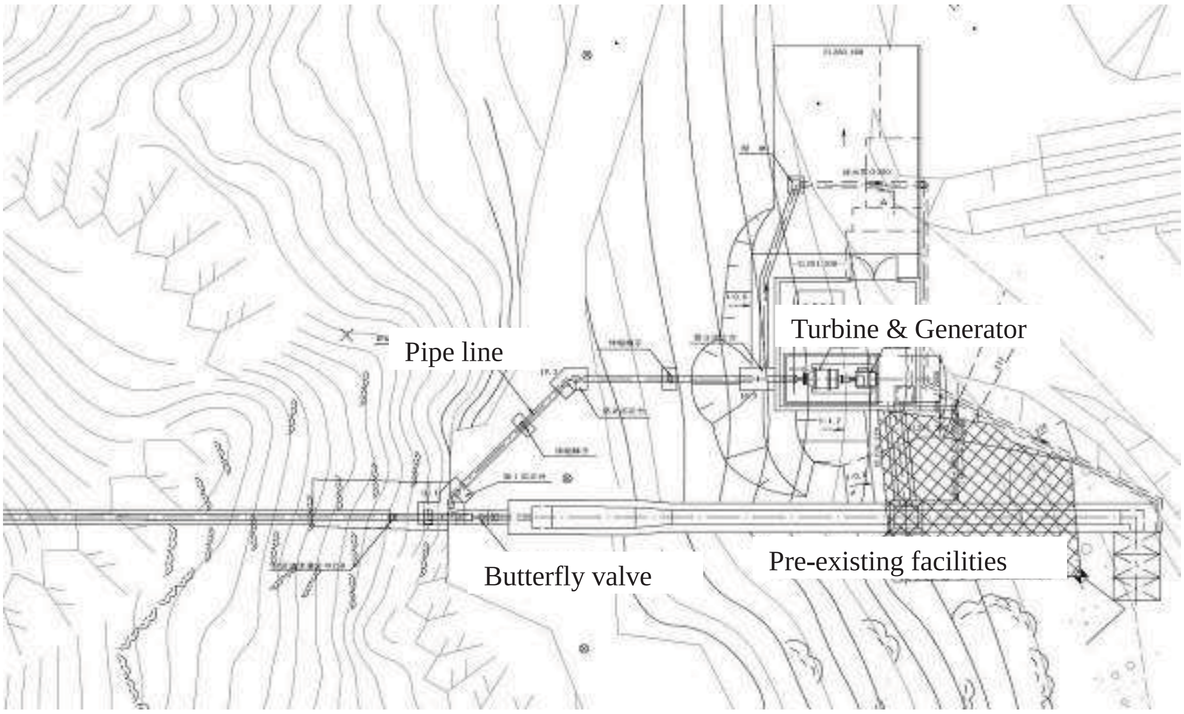


Figure 4　Plan of Waterway & Powerhouse

3. Feature of the Project

3.1 Best Practice Components

- Effective utilization of unharnessed energy

3.2 Reasons for Success

There is a space where a new powerhouse can be constructed near to the existing facilities for ecological flow discharge. Thus a headrace tunnel can be shortened and a tailrace tunnel for releasing in an emergency can be shared with the existing discharging facilities. Furthermore, a large head is obtained for the power station because of steep terrain.

4. Points of Application for Future Project

The amount of power plant discharge was designed to be the same as that of the ecological flow provided in the license for the Houri No.1 Hydropower Station. However, from the viewpoints of the tolerance for plant operation and the reduction of equipment cost, it is thought to be preferable to design power plant discharge related to ecological flow with as many margin as possible.

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

(None)

6. Further Information

6.1 Reference

(None)

6.2 Inquiries

Miyazaki Prefecture

URL: http://www.pref.miyazaki.lg.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.)

Project Name:

Construction (renewal) works of Kikka Power Station

Name of Country (including State/Prefecture):

Japan, Kumamoto Prefecture

Implementing Agency/Organization:

Kumamoto Prefecture, Public Enterprise Bureau

Implementing Period:

from 1998 to 2000

Trigger Causes for Renewal and Upgrade:

(A) Degradation due to aging and frequent failures

(C) Need for higher performance

(E) Needs due to third party factors

Keywords:

renewal, degradation due to aging, efficiency improvement, business transfer

Abstract:

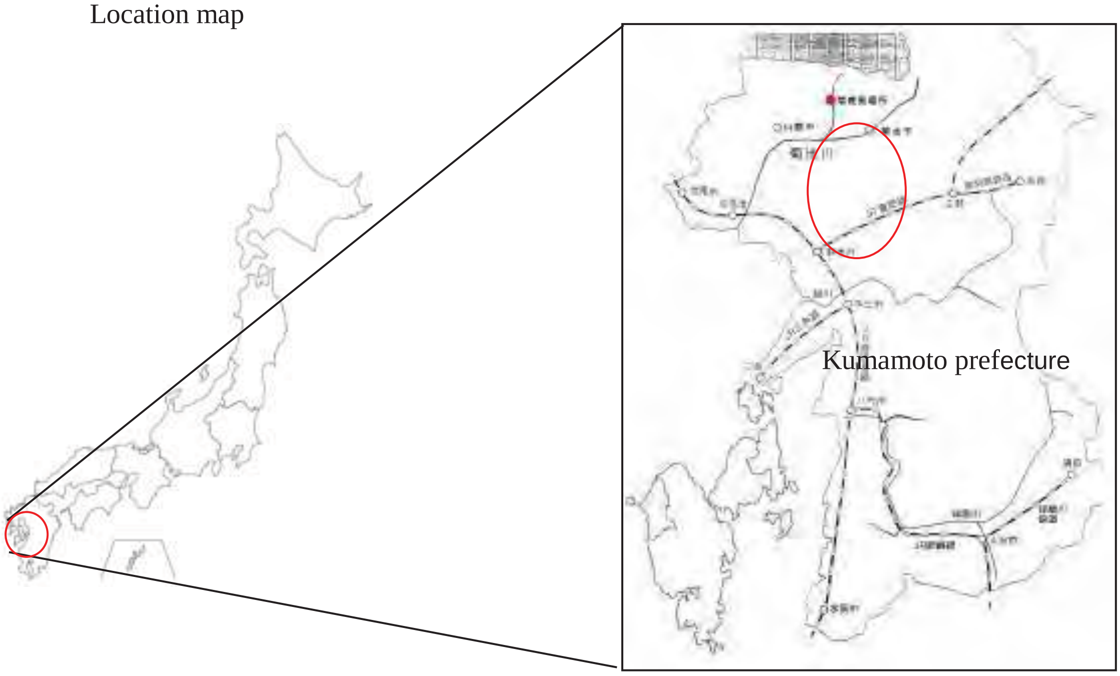
Fukase Power Station (located in Kikka Town, Yamaga City, Kumamoto Prefecture (former name was Uchida village)) owned by Uchida Electric Enterprise Association had been aging seriously in terms of their facilities, and major renovation was required. However, the owner, Uchida Electric Enterprise Association, was not able to continue its operation, so they and Kikka Town asked Kumamoto Prefecture to implement the renewal of the power station. Thus, this renewal projects was transferred to Kumamoto Prefecture by Uchida Electric Enterprise Association, then its construction works was started by the Prefecture.

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

Kikka Power Station (former: Fukase Power Station) is the run-of-river type with a waterway tunnel of hydroelectric power station located in Kikka Town, Yamaga City in the northern part of Kumamoto Prefecture. In June 1951, former Uchida Town was designated for a new agricultural village construction project by the Ministry of Agriculture and Forestry. Consequently, Uchida Town made a plan of a project to construct a power station as a part of plans based on the Act on the Promotion of Introducing Electricity into Farming and Fishing Villages. This Act intended to develop hydropower projects so that villages could receive electricity and to eliminate areas that had an electricity shortage. Furthermore this Act aimed to increase productivity and improve the quality of life and improve public welfare through the electrification of farming and mountain villages. Thus, development and construction of a small-scale hydroelectric power station was planned and implemented by the development of an unused small hydro resource.

Up until then, maintenance and operation of the power station had been conducted by Uchida Electric Enterprise Association.

Location map



Specifications of Power Station (before renewal/upgrading)

Name of power station	Fukase Power Station
Location of power station	617, Oaza,-Yatani, Kikka-machi, Kamoto Gun, Kumamoto Prefecture
Power generation output	maximum: 460kW, regular schedule: 160 kW
Plant discharge	maximum: 1.1m^3/s, regular schedule: 0.462 m^3/s
Effective head	maximum: 62m, normal: 63m
Dam	gravity type made of stones with concrete surface; height = 13 m, crest length = 43 m
Headrace	total: 1,643.2m, non-pressure concrete closed conduit and tunnel
Name of river for water intake	Uchidagawa River and Kuwazurugawa River in Kikuchigawa River system
Powerhouse	one-storied building made of wood and plaster with ribbed seam roofing; 79.2 m^2
Penstock	length: 115m, thickness: 6-9mm, inside diameter: 0.8m
Turbine	horizontal single wheel single flow centrifugal turbine 548kW, 1200rpm
Generator	horizontal three-phase AC synchronous generator: 500kVA, 3,450V
Main transformer	outdoor type three-phase: 500kVA, 3.3kV/6.6kV
Control system	semi-automatic demand responsive monitoring control (remote monitoring display panel installed)
Annual generation	2,605,000 kWh
Date of completion	March 1st, 1956
Total project cost	71,278,071 yen
Catchment area	13.9 km^2

2. Description of the Renewal and Upgrading of the Project

2.1 Trigger Causes and Drivers for Renewal and Upgrading

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

In March, 1956, Kikka Power Station (former Fukase Power Station) was constructed and operated by Uchida Village (currently Kikka Town). After that, the operator had changed to the Agricultural Cooperative, and then transferred to the Uchida Electric Enterprise Association. However the power station had been used for 38 years since its operations began, and facilities were aging seriously and renovation was required.

(C)-(a) Needs for higher performance

In the process of planning, it became clear that the output could be increased (20%) by improvement of the performance of the turbine and generator. Therefore, the project was eligible for the subsidy for the small to medium sized hydropower development, and so the project became economically viable.

(E)-(a) Needs due to third party factors

Fukase Power Station had been operated by Uchida Electric Enterprise Association and their generation facility had seriously aged and extensive renovation was required.

However, the owner had had a hard time in business and determined that full-scale renovation was impossible for them, and so the owner, Uchida Electric Enterprise Association and Kikka Town asked the Public Enterprise Bureau of Kumamoto Prefecture to carry out the renewal.

The background of the request made by the association was that with the effective use of clean hydropower, the investment effects by the renewal and local revitalization by the subsidies through the Three Laws for Power Plant Siting were expected.

In July 1998, agreement for the sale of the Fukase Power Station was concluded and the renewal project (construction of Kikka Power Station) had been pursued by the Public Enterprise Bureau of the Prefecture.

2.2 Process to Identify and Define Renewal and Upgrade Work Measure

March 1956:	Operation of Fukase Power Station began by Uchida Village (present: Kikka Town)
August 1993:	Kikka Town asked to renew the Fukase Power Station
September	1993: Public Enterprise Bureau started the survey of Fukase renewal project.
November 1996:	Survey on development acceleration of undeveloped hydropower projects was implemented by the national government
June 1998:	Basic agreement was concluded with Kyushu Electric Power Co.
July 1998:	Agreement on the electricity sale was concluded with Uchida Electric Enterprise Association
November 1998:	Construction of Kikka PS (former name was Fukase PS) was started.
April 2000:	Operation of Kikka PS begun.

2.3 Description of Work Undertaken (detail)

1-b) Investment incentives (FIT, RPS, subsidies, financial assistance, tax deduction, etc.)

In connection with renewal of Fukase Power Station, the survey of the degradation level of the existing headrace tunnel was requested of “the promotion and guidance project for the small to medium sized hydropower development” so as to investigate the soundness of the existing headrace tunnel for which there were concerns due to aging, and that request was accepted.

In that survey, compressive strength tests of the concrete, etc. were conducted and by their results, the evaluation of the headrace tunnel soundness was conducted. As a result, it became clear that the majority of the headrace was able to be used by sustaining periodic maintenance and repair. Consequently, it was decided that, paying attention to economic efficiency, the development of the power station utilizing the existing tunnel could be carried out.

After that, in this guidance project, the execution design of the power station was adopted, and based on that, the construction of Kikka Power Station (renewal) was decided to be carried out.

As for the hydraulic turbine of Kikka Power Station, the newest design turbine which enabled increasing efficiency was adopted and the effective head increased by changing the generator installation level resulting in an output increase of 20%. Consequently, this project became eligible for the "subsidy for small to medium sized hydropower development" and the renewal was able to be started holding down the copayment out of total project costs. In fact, thus, economic viability was able to be expected.

Specifications after renewal are as follows:

Items		before renewal	after renewal
Output of power generator	maximum	460kW	560kW
	normal schedule	160kW	140kW
Power discharge	maximum	1.1m^3/s	1.1m^3/s
	normal schedule	0.462 m^3/s	0.37 m^3/s
Effective head	maximum	62m	63.1m
	normal time	63m	64.11m

3. Characteristic of the project

3.1 Elements as preferable cases (exceptionable points)

Continuous generation of electricity by hydropower while maintaining profitability was able to be achieved by means of the subsidy system for development.

3.2 Reasons for Success

The reason why the project became successful was due to costs being able to be reduced by effective utilization of the existing facility, and profitability was maintained through effective utilization of the subsidy system for the development of power stations.

4. Points of Application for Future Project

Today, the subsidy system for development has converted into the Feed-in Tariff system of renewable energy, and the subsidy system for design and construction was abolished.

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

After the renewal, the internal inspections on the headrace, which had been utilized effectively, are conducted every three years, and so far no problems have been found.

6. Further Information

6.1 Reference

(None)

6.2 Inquiries

Kumamoto Prefecture

URL: http://www.pref.kumamoto.jp/Default.aspx

ANNEX XI Renewal & Upgrading of Hydropower Plants

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

Category and Key Points

Main: 1-c) Integrated Management of Water Resources and River Systems

Sub: 2-c) Technological Innovation, Deployment Expansion and New Materials used for Civil and Building Works

Project Name:

Hidaka integrated development

Name of Country (including State/Prefecture):

Japan, Hokkaido

Implementing Agency/Organization:

Hokkaido Electric Power Company

Implementing Period:

from 1956 to 2000

Trigger Causes for Renewal and Upgrade:

(C) Needs for higher performance

Keywords:

development of hydropower, changes of the river, peak electricity

Abstract:

In four river systems, that is, the Mukawa River which flows through the area spreading south-west from the Hidaka Mountains (called a backbone of Hokkaido) to the Pacific Ocean, the Sarugawa River, the Niikappukawa River and the Shizunaigawa River, hydropower development called the “Hidaka Integrated Development Project” had been conducted in a step-by-step manner and a total of 13 hydropower stations have been developed.

Characteristic of this project was that a large peak of electricity was able to be obtained using the whole water system by changing the broad river basin so as to effectively utilize water flow of small-to-medium rivers, and by storing water in various large and small reservoirs, and regulating reservoirs.

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

The Hidaka District is endowed with an abundant water resource with 2,000mm of annual rainfall, the largest rainfall in Hokkaido, because the Hidaka Mountains stretching from north to south frequently develop copious rain clouds.

On the other hand, because of the configuration of the terrain, the rivers flow from the Hidaka Mountains to the south west almost parallel to each other, and the basin area of each river is relatively small. In addition, the geological structure belongs to the old geological layer of the Jurassic and Cretaceous periods having large variations and the surface soil is thin, so it is hard to hold water and the difference between times of abundant water and scarce water is very large. Accordingly, this district is not necessarily an ideal site for hydropower development.

In addition, before World War II, the forests in the river basin of the Niikappukawa and Shizunaigawa Rivers were the property of the imperial family, therefore development was restricted, there were very few forest roads and the configuration of the earth's surface was precipitous. Thus, this district was a difficult site to even enter.

For these reasons, the Hidaka District was almost untouched in terms of hydropower development.

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

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

While petroleum and coal fired power generation were becoming the primary energy source, hydroelectric power stations are thought to be an important electric power supply to adjust system voltage. Under such considerations, hydropower development was started in 1953 extensively in various small to medium sized rivers in the Hidaka District.

(2) Improvement of value (functions)

(None)

(3) Necessity in market

(None)

2.2 Process to Identify and Define Renewal and Upgrade Work Measure

May, 1951:	The Japan Electric Generation and Transmission Company was split into nine companies and Hokkaido Electric Power Co., Inc. was founded
May 1952:	Academic planning for Hidaka integrated development was conducted
1995:	Interim report of the plan was compiled based on the results of field investigations
1955-1956:	Intensive survey was conducted and the Hidaka integrated development plan was established
July 1958:	(1) Operation of Iwachishi Power Station was started
August 1959:	(2) Operation of Iwashimizu Power Station was started
August 1961:	(3) Operation of Usappu Power Station was started
August 1963:	(4) Operation of Okuniikkapu Power Station was started
October 1963:	(5) Operation of Syunbetu Power Station was started

November 1966: (6) Operation of Shizunai Power Station was started
September 1969: (7) Operation of Shimoniikkapu Power Station was started
November 1974: (8) Operation of Niikkapu Power Station was started
September 1979: (9) Operation of Futakawa Power Station was started
July 1983: (10) Operation of Takami Power Station was started
February 1982: (11) Operation of Higashinosawa Power Station was started
April 1994: (12) Operation of Okusaru Power Station was started
April 1998: (13) Operation of Hidaka Power Station was started
Note: Numbers above are referred to those in Table 1 below.

2.3 Description of Work Undertaken (detail)

1-c) Integrated management of water resources and river systems

A development project was started in a manner that the order and date to begin construction of each site was decided respectively in relation to the demand and supply of electricity, grid conditions and the construction of other power stations. The development time schedule from 1956 to 1998 is shown in Table 1.

The location of individual equipment in the Hidaka Integrated Development Project is shown in Fig. 1. The watershed modification status and relationship of each facility is shown Fig. 2.

Table 1 Hidaka Integrated Development Project: Development Time Schedule

No.	Power station	start	最大出力 (MW)	最大使用水量 (m^3/sec)	最大有効落差 (m)	ダム高 (m)	総貯水量 ($\times 10^3 m^3$)	Schedule (31 … 63, H1 … 10)
1	Iwachishi	昭33.7	13.5	27.5	58.95	33.0	5,040	31 (10) – 33 (7)
2	Iwashimizu	昭34.8	15.0	15.0	118.50	30.0	1,814	32 (10) – 34 (8)
3	Usappu	昭36.8	25.0	15.0	193.90	29.0	1,330	34 (5) – 36 (8)
4	Okuniikappu	昭38.8	44.0	15.8	326.22	61.2	6,665	35 (7) – 38 (8)
5	Shunbetsu	昭38.10	27.0	29.5	107.92	27.0	1,430	36 (1) – 38 (10)
6	Shizunai	昭41.11 昭54.7	46.0	120.0	45.10	66.0	29,800	37 (8) – 41 (11); 53 (1) – 54 (7)（増設）
7	Niikappu	昭44.9	20.0	58.0	40.40	46.0	6,550	42 (10) – 44 (9)
8	Shimoniikappu	昭49.11	200.0	234.0	99.60	102.8	145,000	45 (8) – 49 (11)
9	Futakawa	昭54.9	7.3	73.0	12.50	30.5	1,620	53 (1) – 54 (9)
10	Takami	昭58.7 平5.4	200.0	230.0	104.50	120.0	229,000	53 (10) – 58 (7) – H5 (4)
11	Higashinosawa	昭62.2	20.0	19.0	124.50	70.0	9,560	58 (7) – 62 (2)
12	Okusaru	平6.4	15.0	6.1	291.20	30.0	530	H3 (12) – H6 (4)
13	Hidaka	H10.4	10.0	21.0	56.50	6.3	—	H7 (4) – H10 (4)
計		13地点	642.8					

Fig. 1　Location map of individual equipment in Hidaka Integrated Development Project

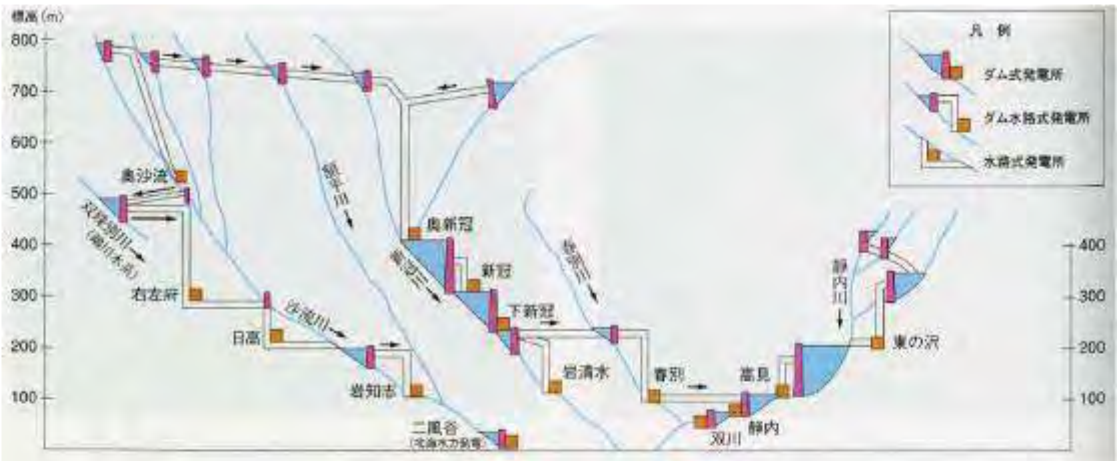


Fig. 2 Watershed modification status and altitude of each facility

Development had proceeded, roughly by the following four phases.

The first phase was the time of base development. In this phase, sites were selected where travel access to the facilities was good and the scale was relatively small, meaning in a short period of time, about two years, construction was able to be completed. Thus, Iwachishi (1) Power Station (13.5MW) which was located in the lowest downstream point of the Sarugawa River and Iwashimizu (2) Power Station (15.0MW) which was located in the lowest downstream point of the Niikappu River were constructed. (see Fig. 3)

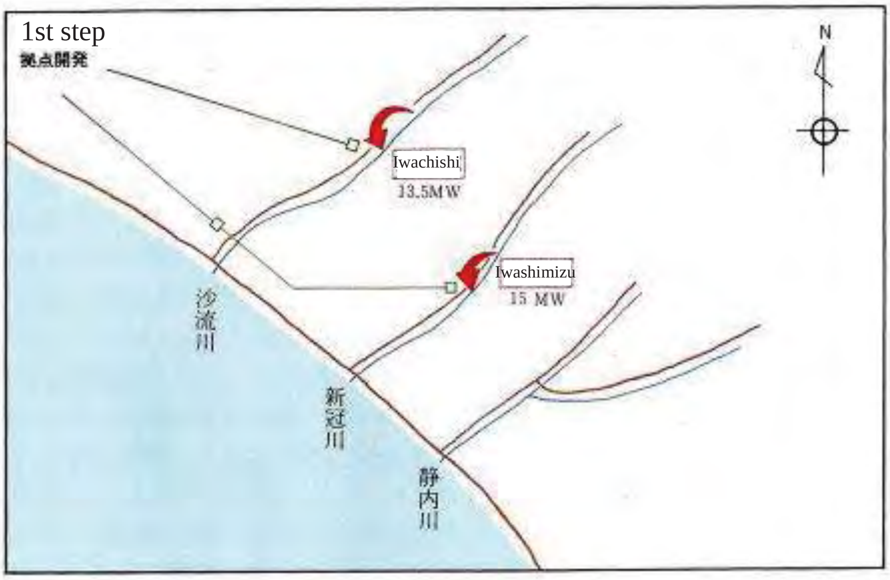


Fig. 3 Phased expansion plan (First phase, base development)

In the Second phase, river basins were changed in a manner that the Mukawa River → Sarugawa River → Niikappugawa River → Syunbetugawa River so as to make a grid connection. As a key site for conducting watershed modification, the following three power stations were constructed: Usappu (3) Power Station (Sarugawa River, 25.0MW) which used the water flow of the Mukawa River, Okuniikappu (4) Power Station (Niikappugawa River, 44.0MW) which used the water flow of the Sarugawa River, and Syunbetu (5) Power Station (27.0MW) which used the water flow of the Niikappugawa River. Though every power station was located far inland making for many construction difficulties, construction work was still completed in the short period of time of two to three years. (see Fig. 4)

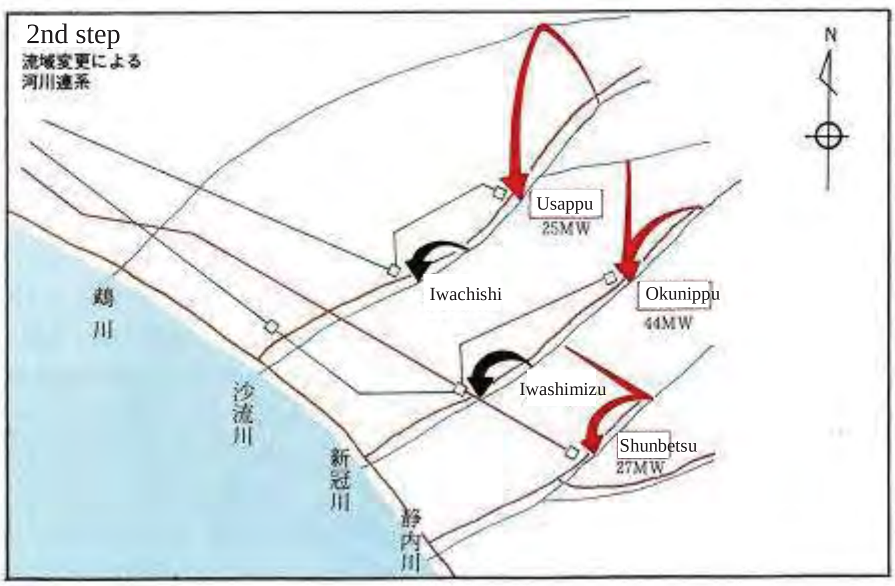


Fig. 4 Phased expansion plan (Second phase, watershed modification)

The third phase was the period when large scale reservoirs and sites for peak electrical generation were developed, and the key element of the Hidaka development project, that is pumped storage power stations in the Niikappu (8) Power Station (Niikappugawa River, 200.0MW) and Takami (10) Power Station (Shizunaigawa River, 200.0MW) were constructed. When peak operations are conducted in the Niikappugawa and Shizunaigawa rivers respectively, in order to equalize the volume of flowing water downstream, those power stations which have an equalizing reservoir function were constructed, that is the Shimoniikappu (7) Power Station (Niikappugawa River, 20.0MW), Shizunai (6) Power Station (Shizunaigawa River, 46.0MW) and Futakawa (9) Power Station (Shizunaigawa River, 7.3MW). (see Fig. 5)

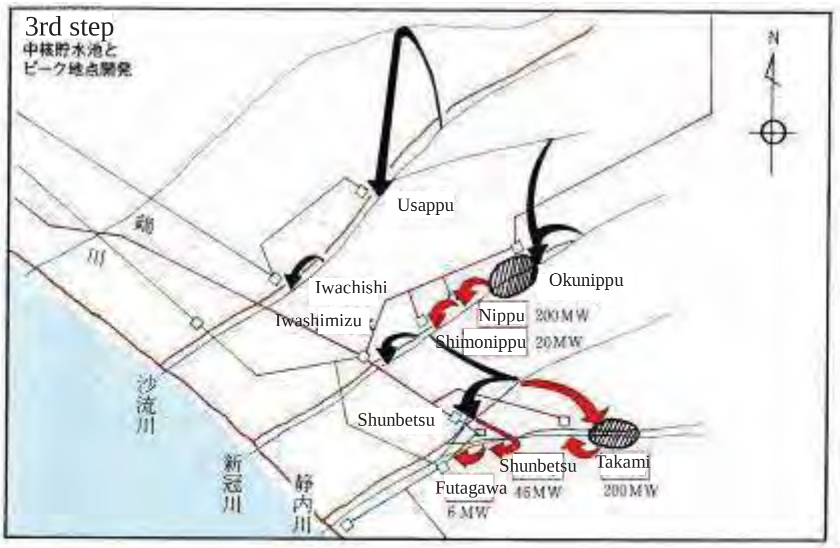


Fig. 5 Phased expansion plan (Third phase, development of large scale reservoirs)

In the fourth phase, the skeleton of the Hidaka Integrated Development Project was almost completed, and in this phase, the remaining important small to medium sites were developed and the whole system was completed.

In this period, while large scale electrical power sources such as petroleum and coal fired power stations and nuclear power stations were developed, Higashinosawa (11) Power Station (Shizunaigawa river, 20.0MW), Okusaru (12) Power Station (Sarugawa river, 15.0MW) and Hidaka (13) Power Station (Sarugawa river, 10.0MW) were constructed and a series of developments were completed. (see Fig. 6).

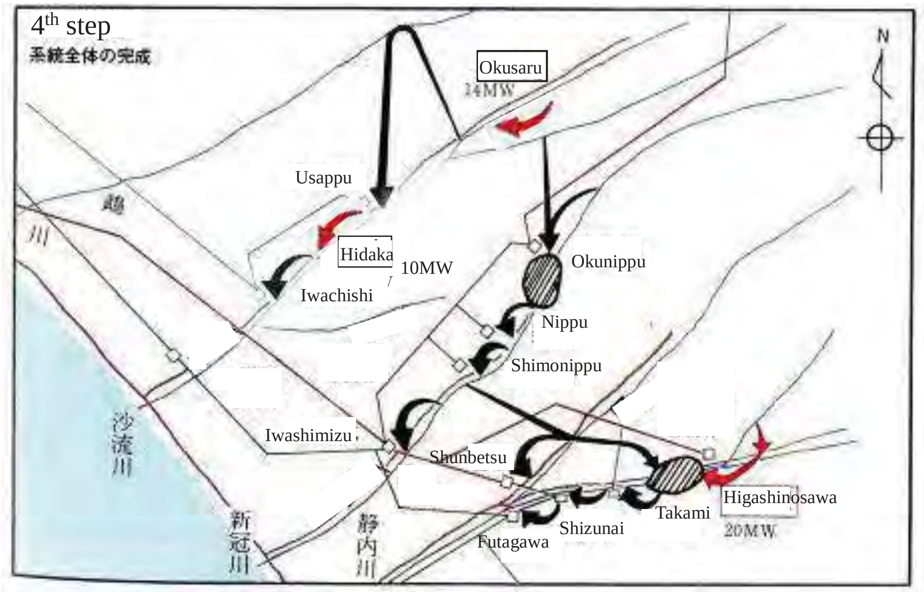


Fig. 6 Phased expansion plan (Fourth phase, completion of whole project)

In April 1998, operation of Hidaka (13) Power Station was started, and thus, the Hidaka Integrated Development Project which started in 1956 was completed. As a result of integrated development, a total of thirteen power stations were developed and a total installed capacity of 642.8MW of peak electrical power was available from the whole water system.

Growth of the available accumulated capacity from 1956 to 1998 is shown in Fig. 7.

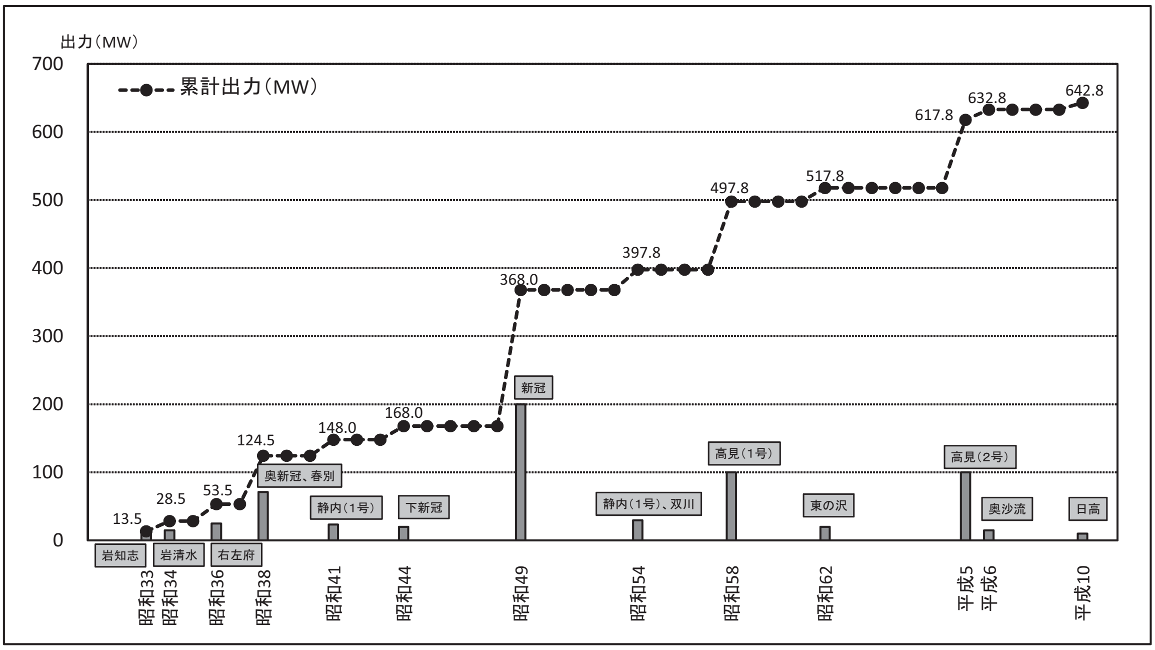


Fig. 7 Hidaka Integrated Development Project; progress of accumulated output

2-c) Technological Innovation, Deployment Expansion and New Materials used for Civil and Building Works

Hidaka integrated development was characterized by a series of ingenious developments which combined extensive watershed modification of small-to-medium rivers in the undeveloped areas of Hokkaido, and the construction of large reservoirs.

In the terrain of Hidaka district, individual rivers don't have as much potential as rivers on the mainland of Japan, therefore it is difficult to make a favorable hydropower development plan. However, in these projects, the development plans were formulated so that the flowing water which can be used for power generation was able to be increased by repeating watershed modification of the rivers. This was done by taking advantage of the terrain, in addition, at dam sites, large scale reservoirs were constructed by taking advantage of relatively low and flat terrain conditions.

Rivers in Hidaka flow parallel to each other with a small basin, and all of the rivers are small or medium scale. Therefore, the development project was formulated in a manner that watersheds were modified by connecting neighboring rivers with supplemental tunnels, and water was stored in large scale reservoirs so as to be able to generate electricity during peak demand.

In addition, it is pointed out as an excellent characteristic that the total head of water of 670.4m from the Okuniikappu regulating reservoir located at the most upstream point of the river (Normal water level of 723m) to the Futakawa Power Station at the lowest point of the river (Discharge water level of 52.6m), is effectively utilized for hydropower generation by eliminating waste of head.

By the Hidaka Integrated Development Project, various peak power stations and facilities were constructed using a wide range of civil engineering technologies; for example: the Okuniikappu Power Station which has a long tunnel (length 31km) (premier in Japan for only one power station), many tunnels constructed in serpentine rock or in fault areas, a long, large diameter aqueduct bridge, multi-purpose dams with flood control function, and various types of dams adapting to individual terrain conditions of each site (arch-type concrete dam, rockfill dam, concrete gravity dam), etc.

3. Feature of the Project

3.1 Best Practice Components

- Effective water usage by means of extensive watershed modification over wide areas.
- Connection between large scale reservoirs and many regulating reservoirs with tunnels which enables response to peak load demand

3.2 Reasons for Success

Watershed modifications by the Hidaka Integrated Development Project extended over wide areas including several towns and villages, and this watershed modification included different water systems, therefore in the fields of public administration, and agriculture and fisheries industries, their interests were affected by this Project. However, in July 1955, a catastrophic flood occurred in the Shizunaigawa and Niikappugawa rivers, and since then, the desire for flood control increased in those local communities. Consequently, the cooperation and understanding for hydropower development and the compensatory negotiations then proceeded smoothly.

4. Points of Application for Future Project

(From the view point of the regional characteristics)

- In Hokkaido, there are not many cities, towns and villages along rivers and their populations are also small. This characteristic of Hokkaido is one of the main reasons for the success of watershed modification.
- Before the development, rivers in this district were utilized only by lumber producers for conveying timber by flowing water, and hydropower development was virtually non-existent.

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

(None)

6. Further Information

6.1 Reference

1) Hokkaido Electric power Co., Inc.; “*A Development of Hidaka District – 30 years history of the development of power sources”*.

2) Hokkaido Electric power Co., Inc.; “*Keep Lighting the Northern land - 50 years of Hokkaido Electric Power”*

6.2 Inquiries

Hokkaido 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: 1-c) Integrated Management of Water Resources and River Systems

Sub: 1-a) Energy Policies of Countries and States

2-c) Technological Innovation, Deployment Expansion and New Materials used for Civil and Building Works

Project Name:

The Consistent Development in Kurobe River System

Name of Country (including State/Prefecture):

Japan, Toyama Prefecture

Implementing Agency/Organization:

Kansai Electric Power Co., Inc.

Implementing Period:

from 1961 to 2000

Trigger Causes for Renewal and Upgrade:

(B) Environmental deterioration,

(C) Needs for higher performance,

(F) Accidents/Disasters

Keywords:

Consistent development of the whole river system, Improvement of river flow duration, Management of inflowing sediment

Abstract:

The consistent development of the whole river system means the project to obtain a large peak output from the whole water system at the same time, by constructing a reservoir at the upper most portion of the river so as to improve the annual river flow durations, and by fully utilizing the available water quantity and water head. In Japan, there is a philosophy that one river is developed by one business operator, and this philosophy greatly promotes a scheme for the consistent development of the whole river system. As one example, the Kurobe River system is known as an exceptionally heavy rain zone in Japan and a torrential river, and so since early times, the Kurobe River system has been recognized as a likely site for hydroelectric power development. In the Kurobe River system, the hydroelectric development was initiated with the construction of the Yanagigawara Power Station in 1927 first, and development was then to be conducted from downstream to upstream. After World War II, we constructed the large reservoir (Kurobe Dam) at the most upstream part of the river so as to make it a

keystone for the consistent development of the whole river system. By completion of the Kurobe Dam, downstream conditions were greatly improved, and afterwards to make an effective use of this condition, contrary to the original plan, development proceeded from upstream to downstream.

In this river system, there is a large volume of in-flowing sediment, and the dam has suffered from excessive sediment buildup. Consequently, in the case of the construction of the Dashidaira Dam, as drastic sediment solution measures, a sediment discharge gate was constructed to conduct a sediment flushing operation. As for sediment problems also, by conducting sediment flushing discharge in cooperation with the Unazuki Dam downstream, the measures to alleviate sediment problems are conducted with the whole water system.

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

The Kurobe River system is a river system with a total length of 85km and a large water volume which begins its flow from collecting mountain streams, from the headstream of Mt. Washibadake (2,924m) located in the center of the North Japan Alps, through and between the Tateyama mountain range and Ushirotateya mountain range, into the Sea of Japan (Fig.1). The area around the Kurobe River is a leading heavy rainfall zone (annual rainfall: 4,000mm) in Japan, and in addition, the average river slope of 1/40 is very steep. From early times it was known as a suitable place for hydroelectric power development.

Around 1920, the Kurobe River attracted attention, and a survey was started. After then, as a first development, the Yanagigawara Power Station was completed in 1927. Next, upstream, the Kurobe River No. 2 Power Station (1936), and the Kurobe River No. 3 Power Station (1940) respectively, were constructed. After World War 2 by electricity restructuring, we, the Kansai Electric Power Co., Inc. were established. Since then, the majority of electric generation sources have shifted to advanced fossil fuel generation, and water resources have just been used to respond to peak load demands from large reservoirs. From these conditions, we made a plan to construct a very large reservoir upstream (Kurobe Dam) and made it a keystone for consistent water system management.

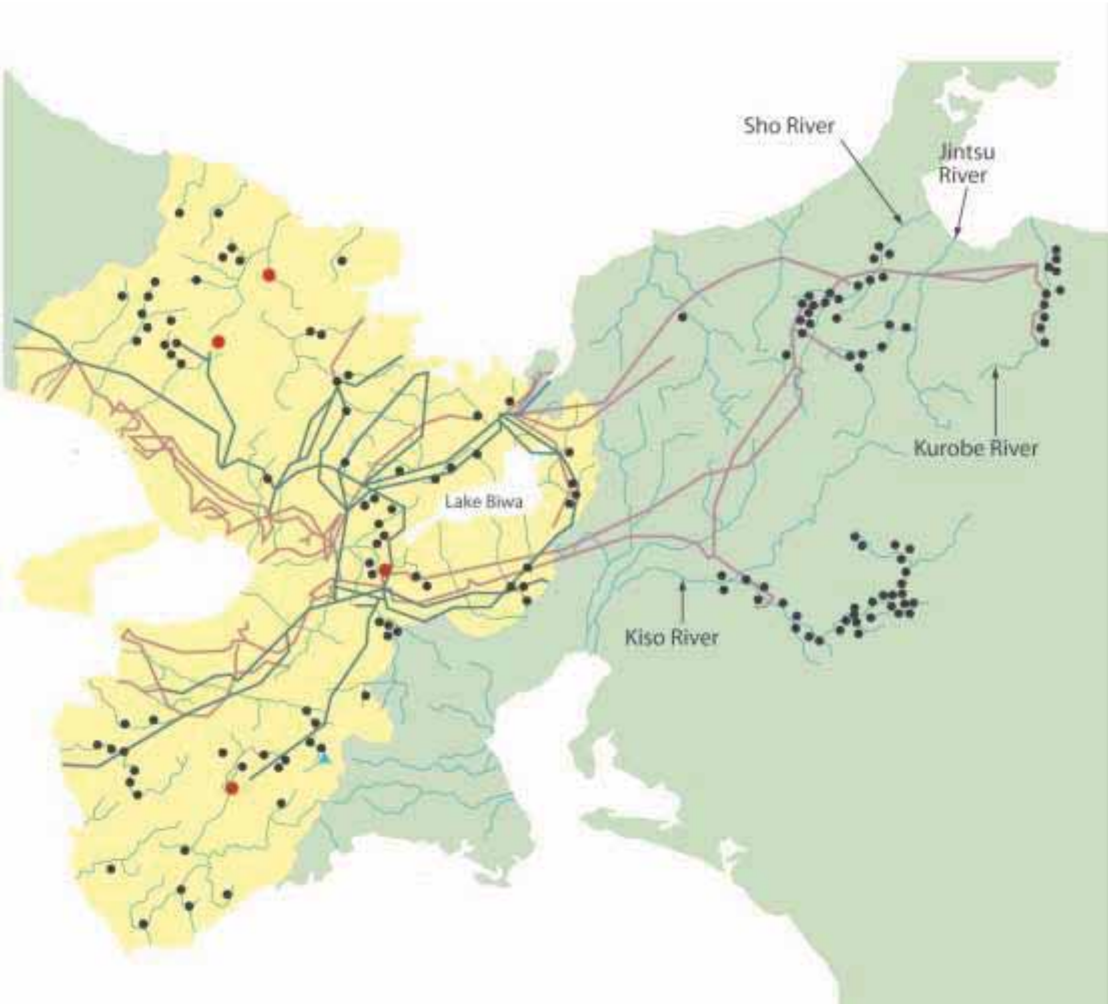


Fig. 1 Location map of the Kurobe River water system

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) - (a) Environmental deterioration – Sedimentation reduction

Sediment outflow of the Kurobe River system is annually about 1.4 million m3, and for construction of the Dashidaira Dam, in-flowing sediment amounts were very large when compared to stored water volume and so, if excavation and dredging was conducted, due to the terrain restrictions of the canyon, transportation of removed sediment is difficult. These conditions could cause a variety of problems such as erosion of the streambed, shore erosion and others if left untreated. Therefore it was necessary to develop an effective method of sediment control with a review of the whole river system.

(F) - (a) Accidents/Disasters - Recovery

In 1995, when the catastrophic flood occurred, an estimated 3.4 million m3 of sediment flowed into the Dashidaira Dam. The streambed of the Kurobe No.2 Power Station rose by about 10m, and the discharge outlet was filled making power generation impossible.

(2) Improvement of value (functions)

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

The expansion plan was made so as to utilize the water volume and head of the water system at a maximum, emphasizing output (kW), so that hydroelectric power generation can be used to respond to peak load power demands.

(3) Necessity in market

(None)

2.2 Process to Identify and Define Renewal and Upgrade Work Measure

1927:	Operations of Yanagawara Power Station began
1936:	Operations of Aimoto Power Station began
1936:	Operations of Kurobe River No. 2 Power Station began
1940:	Operations of Kurobe River No. 3 Power Station began
1947:	Operations of Kuronagi No. 2 Power Station began (development in Kuronagi River and its subsidiary stream)
1961:	Operations of Kurobe River No. 4 Power Station began
1963:	Operations of Shin-Kurobe River No. 3 Power Station began
1966:	Operations of Shin-Kurobe River No. 2 Power Station began
1985:	Operations of Otozawa Power Station began
1991:	In Dashidaira Dam, first sediment flushing was conducted
1993:	Operations of Shin-Yanagawara Power Station began (Yanagawara Power Station was retired)
1995:	Kurobe River System had a massive catastrophic flood. At the Dashidaira Dam,emergency sediment flushing was conducted.
2000:	Operations of Unazuki Power Station began
2001:	At the Dashidaira Dam and Unazuki Dam, cooperative sediment flushing was conducted.

2.3 Description of Work Undertaken (detail)

1-a) Energy Policies of Countries and States

In the “Hydraulic Power Feasibility Survey (fourth edition) compiled by the Ministry of International Trade and Industry, Bureau of Public Works” compiled from the survey for 1956 to 1959, effective utilization of water resources by integrated development of whole water system was proposed as the method to calculate potential hydroelectric energy which is possible to economically develop.

1-c) Integrated Management of Water Resources and River Systems

In 1951, electric power companies were reorganized to the current structure. Then, the philosophy of “development of one water system to be conducted by one company so that integrated development can be expected” was set. Also the idea of the “water system belongs to the electric company located in the area where generated power is consumed (tidal doctrine)” was adopted, and with this policy, the Kansai Electric Company has effectively promoted development. Downriver from the Aimoto Power Station, one power station (530kW) in the Aimoto new service water improvement district, and 6 power stations (33,200kW) owned by Hokuriku Electric Power have been operated to generate power from the point of view of effective utilization of river water.

2-c) Technological Innovation, Deployment Expansion and New Materials used for Civil and Building

Since the reservoir of the Dashidaira Dam has an abundance of in-flowing water against reservoir capacity, it is easy to lower and recover the reservoir water level. In addition, this reservoir is in a relatively small space and the river slope is steep, so flushing sediment discharge is effective (Fig. 2). Thus, here, in a time of flooding, sediment is discharged by flushing using a flushing gate. When flushing was conducted, cooperative flushing with the Unazuki Dam downstream was carried out. An image representing the operation is shown in Fig. 3.

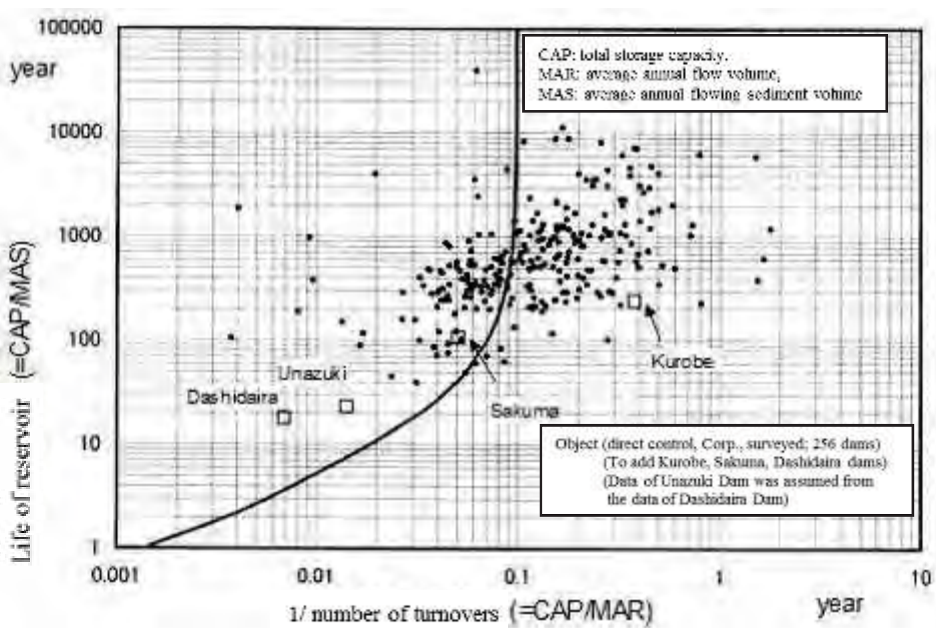


Fig. 2 Probabilistic assessment of flushing sediment discharge

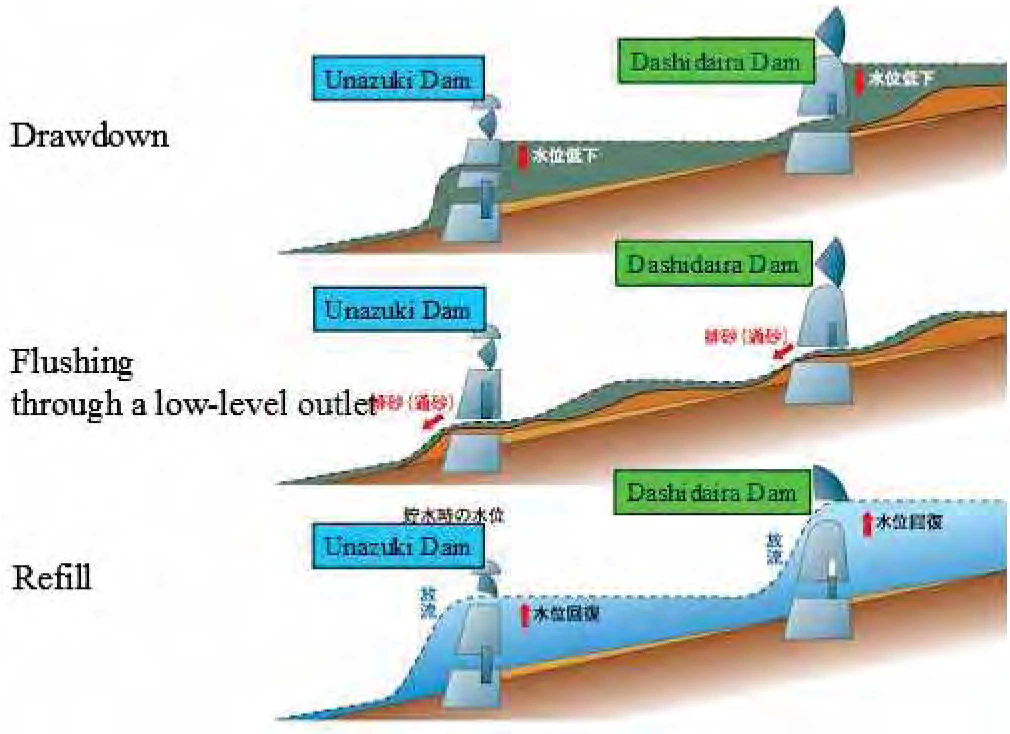


Fig. 3 Mechanism of cooperative flushing and sediment sluicing

- With the aim of inspection, maintenance, water cutoff and control of flowing water and sediment, the sediment discharge facility combining slide gate, radial gate and roller gate was developed as shown in Fig. 4.

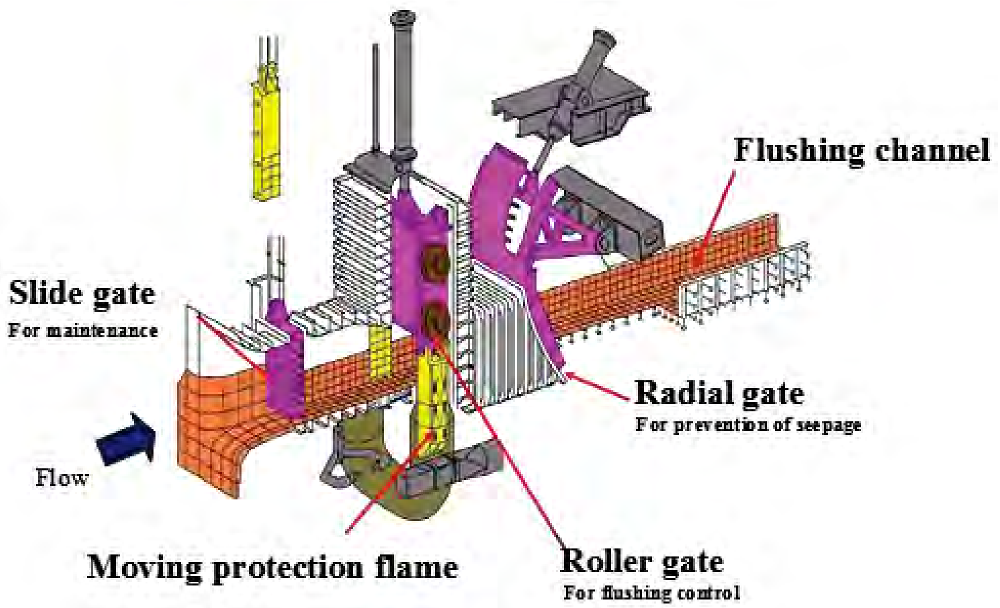


Fig. 4 Diagram of the sediment discharge facility for the Dashidaira dam

- As fundamental sediment measures, the sediment control method was designed with the following actions: in facilities, shifting of the discharge tunnel, relocation of the outlet, improvement of the discharge yard, installation of a protective barrier, and in operation, sediment discharge during flooding, and annually removing sediment in the reservoir, combining these measures so as to control sediment (Fig. 5).

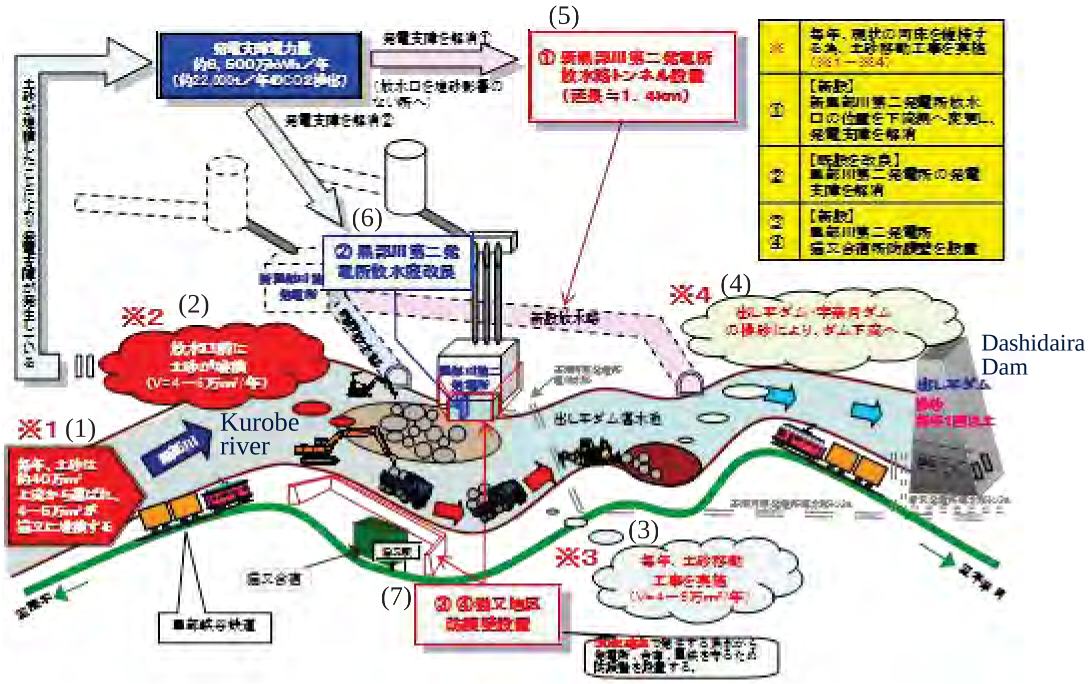


Fig. 5 Comprehensive sediment control method

(1) Annually about 400 thousand m^3 of sediment are conveyed to here from upstream and 40–50 thousand m^3 is deposited at Nekomata.

(2) In front of the outlet, sediment is deposited (V=40-50 thousand m^3/year)

(3) Every year, sediment conveying work is conducted (V=40-50 thousand m^3/year)

(4) Sediment is discharged from the Dashidaira Dam and Unazuki Dam downstream

(5) Construction of water discharge tunnel of the Shin-Kurobe River No. 2 Power Station (length: about 1.4km)

(6) Improvement of the water discharge yard of the New Kurobe River No.2 Power Station

(7) Construction of protective barrier for Nekomata District

3. Feature of the Project

3.1 Best Practice Components

- Development was effectively conducted based on the philosophy of "one river system is developed by one developer"
- Sediment flushing has a significant advantage in terms of flow volume, water storage capacity and in-flowing sediment volume
- Cooperative flushing with the downstream dams and integrated sediment control over the whole river system was conducted.

3.2 Reasons for Success

The consistent development of the Kurobe River system succeeded because the development was based on the philosophy of "one river is developed by one business developer" and proceeded so as to respond the demands of the times. We, the Kansai Electric Power Co., Inc. which was established by the restructuring after World War 2 understood that in Japan, the majority of electric power supply would move from hydropower to the new fossil fuel fired power stations.

Also hydropower became the electric source to supplement peak load demands with large reservoirs. Based on this situation, we made a plan to build a large scale reservoir at the most upstream point as the keystone of the consistent development project. The construction of the Kurobe Dam which creates that large scale reservoir came under the spotlight as the largest construction project in the century, and in 1963, was completed as a grand integration of all civil engineering technology of the time. By completion of the Kurobe Dam, the down-stream's condition was greatly improved. Consequently, so as to make an effective use of this from upstream to downstream, in reverse order of the original development direction, the New Kurobe River No. 3 Power Station and the New Kurobe River No. 2 Power Station were constructed.

In this water system, there is an extremely large quantity of in-flowing sediment, and we have suffered with significant sediment deposition in the dam, therefore, when the Dashidaira Dam was built, as a drastic measure against sediment deposition, a flushing gate was constructed so as to discharge sediment when needed. Various measures were investigated for sediment removal, and as a result, it became clear that effective sediment discharge was possible utilizing a large turnover of water in the reservoir (in-flowing water is large versus reservoir capacity) and by utilizing the steep slope of the river, flushing type sediment discharge was adopted. Until now, since the completion of Dashidaira Dam, a large sediment volume equivalent to the total water storage capacity was able to be discharged by flushing.

In addition, now we are pursuing the establishment of an integrated sediment control method for the whole river system, considering the cost-benefit performance, so as to resolve the electric generation trouble by in-flowing sediment and to reduce flood damage in time of a catastrophic flood.

4. Points of Application for Future Project

- The philosophy of the effective and efficient development by the consistent development of the whole river system
- Whether it is good or bad to construct a large scale reservoir on the most upstream part of the river
- Characteristics which enable taking advantage of flushing sediment discharge
- Formulation of the integrated sediment control method of the whole river system considering cost-benefit performance.

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

In a catastrophic flooding of the Kurobe River system in 1995, an estimated 3.4 million m3 of sediment flowed into the Dashidaira Dam. This was more than 1/3 of the total water storage capacity of the dam, and emergency sediment removal was required for 3 years beginning in 1995. In 2000, Unazuki Dam was completed, and since 2001 cooperative sediment discharge by the Dashidaira and Unazuki dams began. Since the operation start of the Dashidaira Dam, it has been possible to discharge sediment equivalent to the total water storage capacity by flushing sediment discharge. (Fig. 6)

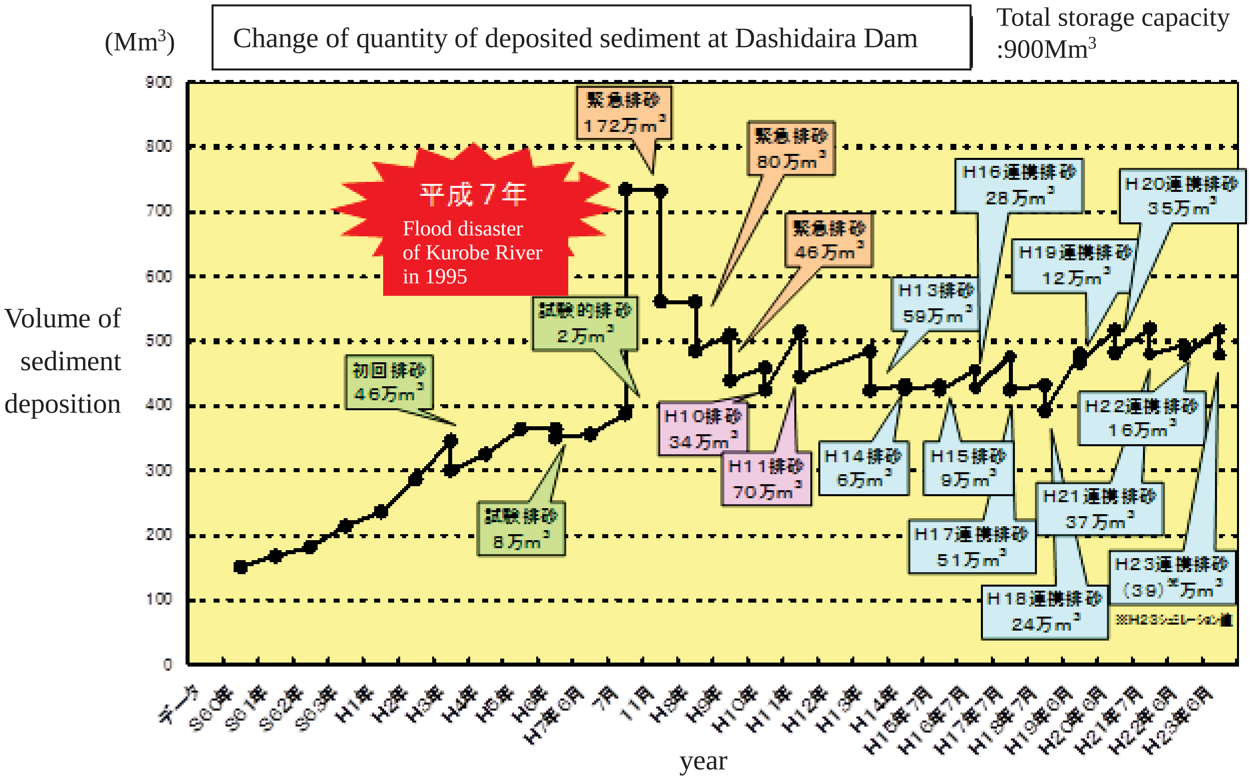


Fig. 6 Actual performance of Sediment Sluicing and Flushing of Dashidaira Dam

6. Further Information

6.1 Reference

- “The cases of sediment discharge of dams by Kansai Electric Power Co., Inc.”, *Journal of Electric power Civil Engineering*, March, 2000
- “The sediment discharge efficiency of flushing in dam reservoirs.”, *Journal of Dam Technology*, 2000
- “The sediment flow in the Kurobe River basin.”, *Journal of Electric power Civil Engineering*, January, 2007
- “Summary of environmental surveys regarding cooperative sediment discharge and sediment sluicing through the collaboration between Dashidaira Dam and Unazuki Dam.”. *Journal of Electric power Civil Engineering*, March, 2008

6.2 Inquiries

Kansai Electric Power Company

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

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

Category and Key Points

Main: 1-c) Integrated Management of Water Resources and River Systems
Sub: 1-a) Energy Policies of Countries & States
1-f) Environmental Conservation and Improvement
2-b) System and Reliability Improvement in Protection & Control (P & C)
2-c) Technological Innovation, Deployment Expansion and New Materials used for Civil and Building Works

Project Name:

The Consistent Development of the Kiso River system

Name of Country (including State/Prefecture):

Japan, Nagano Prefecture and Gifu Prefecture

Implementing Agency/Organization:

Kansai Electric Power Co. Inc.

Implementing Period:

from 1942 to 2011

Trigger Causes for Renewal and Upgrade:

(C) Needs for higher performance

Keywords:

Consistent development of the whole river system, Improvement of river flow duration

Abstract:

The consistent development of the whole river system means the project to obtain a large peak hydroelectric power output from the whole water system at the same time, by constructing a reservoir at the upper most portion of the river so as to improve the annual flow duration, and by fully utilizing the available water quantity and water head. In Japan, there is a philosophy that one river should be developed by one business operator, and this greatly promotes a scheme for the consistent development of the whole river system.

The Kiso River system is one of the largest rivers in Japan with a stream length of 227km and a basin area of 9,100km^2 (see Fig. 1). In 1942, with a view to improve the annual flow duration, the Miura Dam (effective reservoir capacity of 61.6 million m^3) was constructed at the most upstream point of the river. Afterwards, the power station complex, consisting of a total of 33 power stations with a total output of about 1,040MW, was developed by effectively adding state-of-the-art power stations to the existing old type power station group, such as with waterway type or dam type in both the main river and tributaries.

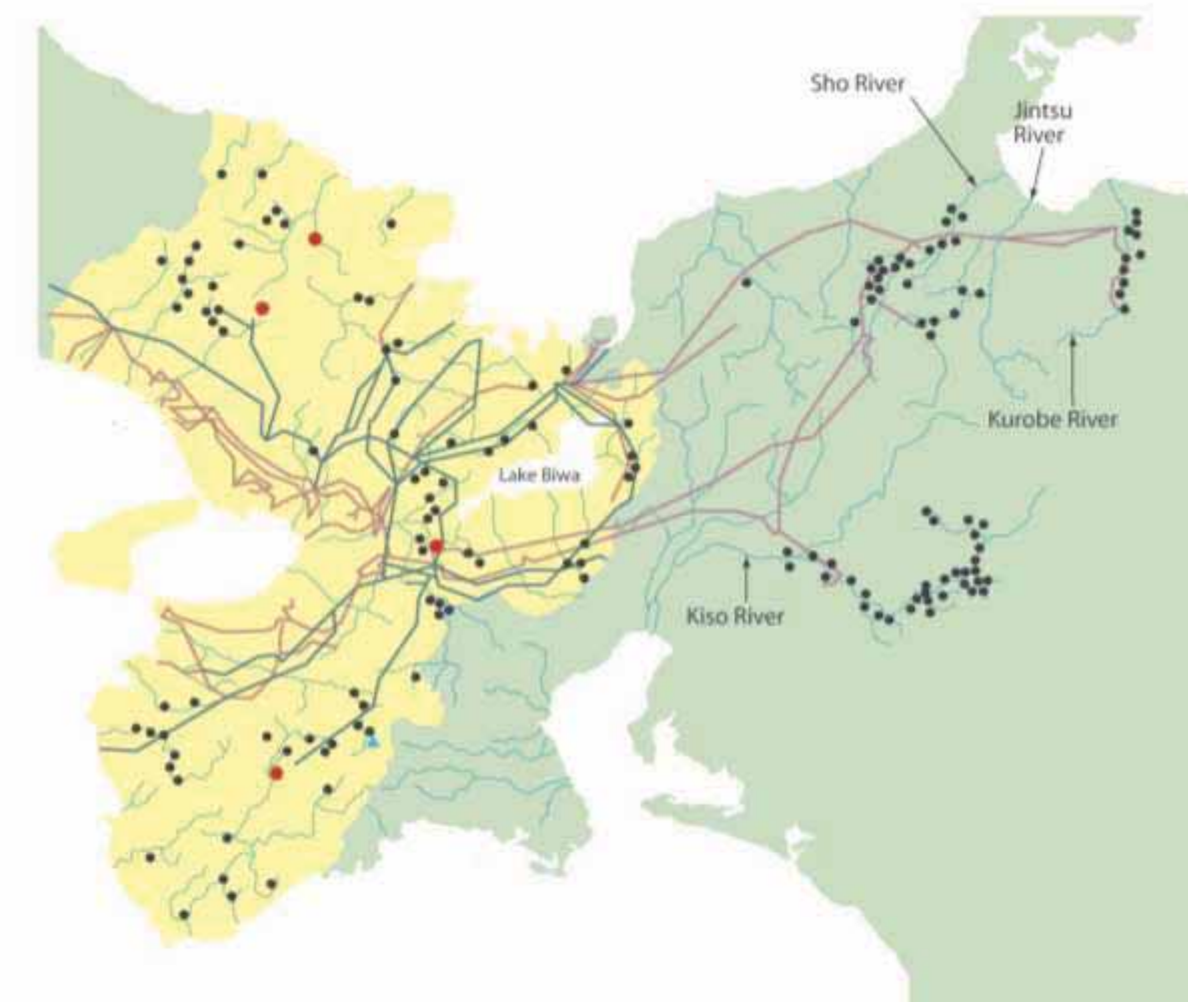


Fig. 1 Location map of Kiso River System

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

The Kiso River is a large river with a main stream length of 227km, a basin area of 9,100km^2 and an annual average rainfall of 2411mm (1986) which starts to flow from the south foot of Mt. Hachimoriyama located in Nagano Prefecture, in Kiso River system. At a point 70km from the river mouth, the Kiso River joins with the largest subsidiary stream, the Outaki River, flows through the Kiso valley collecting various other tributary rivers, and continues through the Noube Plain into Ise Bay. The Kiso River has the largest class of potential hydropower, and Nagoya Electric Power Co., Inc. noted this fact, and as a first development, construction of the Yaotsu Power Station was started in 1911.

After that, based on the philosophy advocated by the president of the Daido Electric Power Company "one river by one company policy", from the beginning, in the Kiso main and branch rivers, effective hydropower developments which were not seen in other water systems were conducted. In the Taisho Era, on the middle river, the Shizumo, Okuwa, Suhara, Momoyama, Yomikaki, Ooi, and Ochiai power stations were developed by the Daido Electric Power Company. The power stations which were constructed from the first until the Yomikaki Power Station which was completed in December, 1923 were all waterway types. The construction of the flowing water regulation type of power station was started from the Ooi Power Station (1924). The building of the Ooi Power Station was a landmark event in Kiso River development history. It was the first full-fledged dam waterway type of power station, and contributed greatly as well in a pioneering role in terms of dam construction technology (height: 53.37m).

After the construction of Ooi Dam, so as to resolve the water right problems downstream, in March, 1939, the Imawatari Power Station with equalizing reservoir was constructed at the lowest point of the river by the Aiki Water Power Company which was established by the Daido Electric Power Company and Toho Electric Power Company which had been developing the Hidagawa river system.

Even after the Showa period started, the developments by Daido Electric Power Company continued, and the Kasagi Power Station (1936) was constructed downstream and the Nezame Power Station (1938) was constructed upstream.

In 1935, Daido Electric Power Company made a plan for the construction of the Miura Dam (height: 83.2m) as a keystone for the consistent development of the Kiso River, and started construction. However the times had changed to the national government controlling the electricity, thus the Japan Electric Generation and Transmission Company took over the project and completed it in 1942. At the time, the Miura Dam had the largest pondage in the East (total capacity: 62.22 million m^3) and, in collaboration with the Makio Dam, contributed to improving the flow duration of the Kiso River and to promote the enhancement of the power station complex downstream.

The Japan Electric Generation and Transmission Company constructed the Tokiwa Power Station (1941), the Miura Power Station (1945), the Ontake Power Station (1945) and the Agematsu Power Station (1947) upstream, and the Kanayama Power Station (1943) downstream.

From the point of view of the effective utilization of the remaining head and water flow volume downstream, the Maruyama Power Station attracted attention, and the Japan Electric Generation and Transmission Company started construction in 1943, but afterwards, electricity restructuring was implemented and the Kansai Electric Power Co., Inc. took over this project and completed it in April, 1954. By this project, the complete utilization of the total water head in the Kiso River was achieved.

However, an imbalance in the volume of water consumption for generation existed between power stations upstream and downstream, and we, Kansai Electric Power scheduled to proceed with the development so as to achieve higher water utilization. Upstream, the Takigoshi Power Station (1951), and midstream the Yamaguchi Power Station (1957) were developed as the redevelopment of the waterway type power station group followed by the expansion work of the Yomikaki Power Station (1960). Upstream, in 1963, the Mio Power Station of the multiple-use type pumped storage power stations which utilized the Makio Dam was developed.

In 1968, the Kiso Power Station which bypasses the waterway type of power stations was constructed so as to effectively utilize both the Miura Reservoir and the Makio Reservoir.

In the late 1960's (1965), the expansion of the Maruyama Power Station was planned so as to respond to the peak electricity demand in the summer season, and in 1971, the Shin-Maruyama Power Station was developed. In addition, after the first energy crisis, the trend of the times had changed from a kW oriented policy to a kWh oriented policy, and so, hydropower sites were re-examined, and on the downstream end the Shin-Ochiai Power Station (1980) and the Shin-Ooi Power Station (1983) were constructed. On the subsidiary river upstream, the Inagawa Power Station (1977) and the Inagawa No. 2 Power Station (1986) were constructed.

Thus, now, we have 33 power stations along the Kiso River (as of 2012) with a total output of 1.04 million kW.

In 1961, the Makio Dam (height: 104.5m) was constructed on the Outaki River as a reservoir for the Aichi Waterworks by the Aichi Waterworks Corporation (currently: Japan Water Agency). The Aichi Waterworks is a project which responds to the demand for clean water and industrial water mainly for the Nagoya district, and also supplies water to compensate for shortages of agricultural water for the area from Gifu Prefecture to the east of the Owari plain and Chita Peninsula. Water for the Aichi Waterworks is taken at the point of the Kanayama Power Station, and the Makio Dam was constructed so as to supply the deficit water at the intake site.

The improvement status of the river flow duration of reservoirs by the Miura Dam is shown in Fig. 2. The case for the Kiso Power Station which was redeveloped by bypassing other power stations, and the newly constructed Yomikaki No. 2 Power Station (Yomikaki Power Station No. 4 system) are shown in Fig. 3.

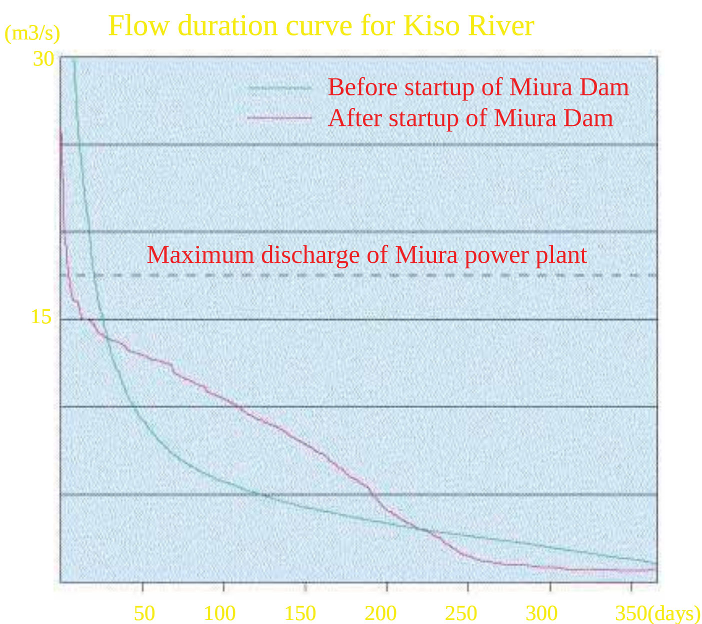


Fig. 2 Duration curve of the Kiso River (basin area: 73.5km^2)

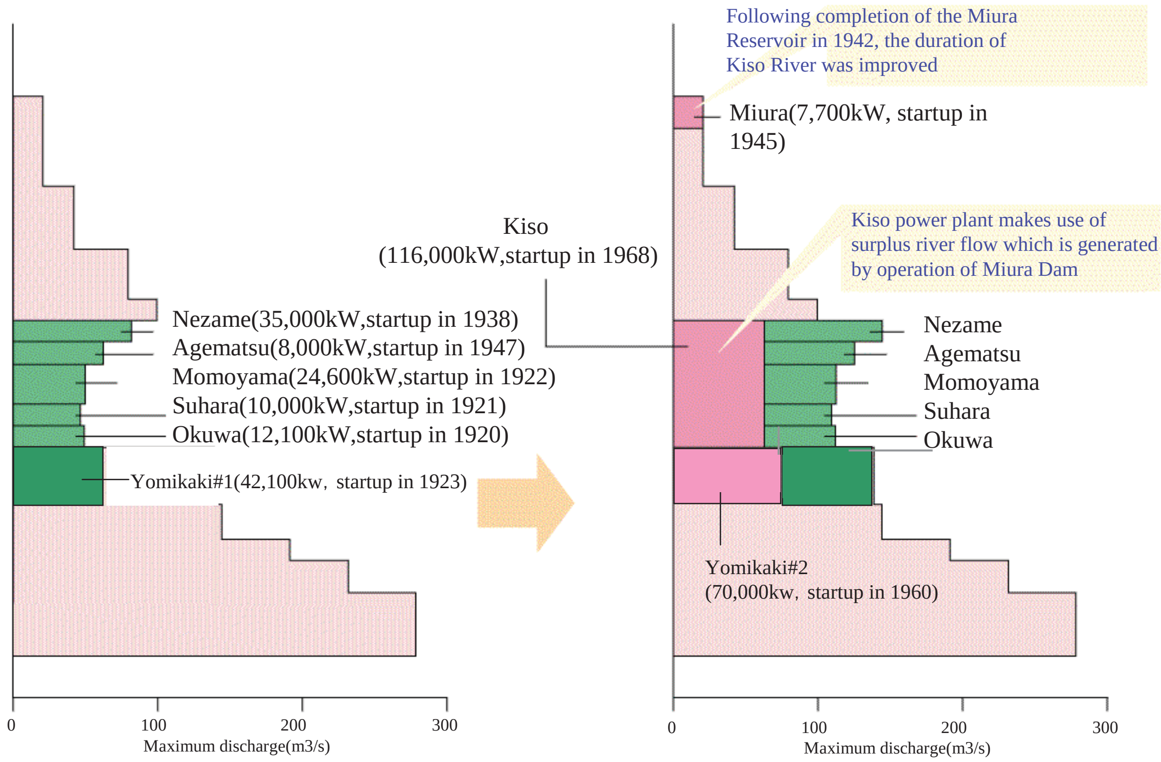


Fig. 3 The case of the Kiso Power Station and the Yomikaki Power Station

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

(None)

(2) Improvement of value (functions)

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

The enhancement of the hydropower station was planned so as to respond to the peak load, which utilizes head and flowing water quantity at a maximum in the river system emphasizing output (kW).

(3) Necessity in market

(None)

2.2 History

November 1911	Operation of the Yaotsu Power Station began (1974, abolishment)
July 1919	Operation of the Shizumo Power Station began
March 1921	Operation of the Okuwa Power Station began
November 1922	Operation of the Suhara Power Station began
November 1923	Operation of the Momoyama Power Station began
December 1923	Operation of the Yomikaki Power Station began (No. 1-3 systems) (November, 1960 operation of No. 4 system was started)
December 1924	Operation of the Tako Power Station began
December 1924	Operation of the Ooi Power Station began
November 1925	Operation of the Araragigawa Power Station began
December 1926	Operation of the Ochiai Power Station began
December 1926	Operation of the Yogawa Power Station began
February 1929	Operation of the Hashiba Power Station began
November 1934	Operation of the Tsumago Power Station began
November 1936	Operation of the Kasagi Power Station began
March 1938	Operation of the Ainosawa Power Station began
September 1938	Operation of the Nezame Power Station began
March 1939	Operation of the Imawatari Power Station began
September 1941	Operation of the Tokiwa Power Station began
December 1943	Operation of the Kaneyama Power Station began
January 1945	Operation of the Miura Power Station began
June 1945	Operation of the Ontake Power Station began
February 1947	Operation of the Agematsu Power Station began
November 1951	Operation of the Takigoshi Power Station began
April 1954	Operation of the Maruyama Power Station began
December 1957	Operation of the Yamaguchi Power Station began
May 1963	Operation of the Mio Power Station began
January 1958	Operation of the Kiso Power Station began
May 1971	Operation of the Shin-Maruyama Power Station began
November 1977	Operation of the Inagawa Power Station began
February 1980	Operation of the Shin-Ochiai Power Station began
April 1983	Operation of the Shin-Ooi Power Station began
February 1986	Operation of the Inagawa No. 2 Power Station began
May 1995	Operation of the Minokawai Power Station began
June 2011	Operation of the Okuwanojiri Power Station began

2.3 Description of Work Undertaken (detail)

1- a) Energy Policies of Countries & States

In the “Hydraulic Power Feasibility Survey (fourth edition) compiled by the Ministry of International Trade and Industry, Bureau of Public Works” from the survey for 1956 to 1959, effective utilization of water resources by consistent development of a whole water system was proposed as the method to calculate hydroelectric energy potential which is economically feasible.

1-c) Integrated Management of Water Resources and River Systems

In 1951, electric power companies were reorganized to the current structure. Then, the philosophy of "development of one water system to be conducted by one company so that integrated development can be expected" was set. Also the idea of the "water system belongs to the electric company located in the area where generated power is consumed (tidal doctrine)" was adopted, and within this policy, the Kansai Electric Company has effectively promoted development.

1- f) Environmental Conservation and Improvement

On the Kiso River, there is a famous "Nezame no Toko" designated as the national beauty spot which is equivalent to a cultural asset. In this river, maintenance flow is discharged from the Kiso River Dam on upstream.

In order to conduct power generation using maintenance flow from the Yomikaki Dam, the Okuwanojiri Power Station was newly constructed.

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

Downstream from the Kiso Dam (Outaki River), the Outaki River joins the Kiso River. At that location, the Nezame Power Station is located which takes in water from the Outakigawa Dam and Kisogawa Dam through a gravity feed tunnel so as to combine this water in a head tank and furthermore this water is fed to the upper head tank. Along with the new construction of Kiso Reservoir, two water inlets were installed on the top and bottom of the Kiso regulating reservoir. The top water inlet was reconstructed to lead to the Nezame Power Station, and the bottom water inlet was reconstructed to lead to the Kiso Power Station. As a result, it became possible to give priority to the highly effective Kiso Power Station in normal times, and when flowing water is abundant or during peak load times, two power stations became able to operate simultaneously. The positional relation between the two power stations is shown in Fig. 4.

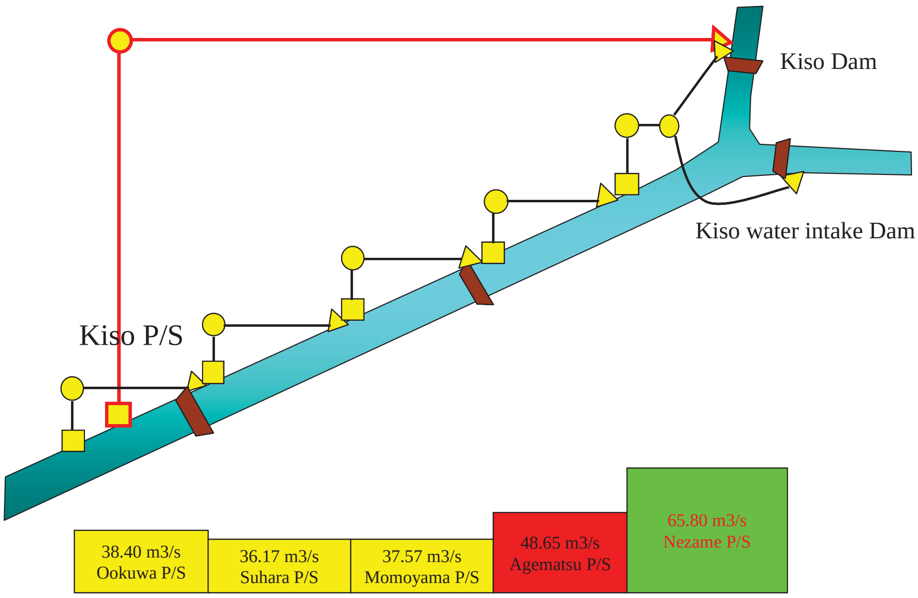


Fig. 4 Kiso Power Station and Nezame Power Station

2-c) Technological Innovation, Deployment Expansion and New Materials used for Civil and Building

In the redevelopment of the Kiso River, downstream of the water intake dam of the Yomikaki No. 1 power station (currently the Yomikaki Power Station No. 1 to No. 3 systems), the reservoir was prepared by the construction of the dam, and the Yomikaki No. 2 Power Station (currently the Yomikaki Power Station No. 4 system) was constructed.

The existing Yomikaki No. 1 Power Station (currently the Yomikaki Power Station, No. 1 to 3 systems) had been renovated from the waterway type to the dam type. The headrace tunnel of the Yomikaki No. 1 Power Station (currently the Yomikaki Power Station, No. 1 to 3 systems) was designed to be a non-pressurized (gravity feed) type. As shown in Fig. 5, by installing the drop wall and air pressure relief duct on the point of the water inlet so that the headrace tunnel doesn't receive new pressure, the headrace tunnel which was designed to be a non-pressurized type, can be used as it is without any modification.

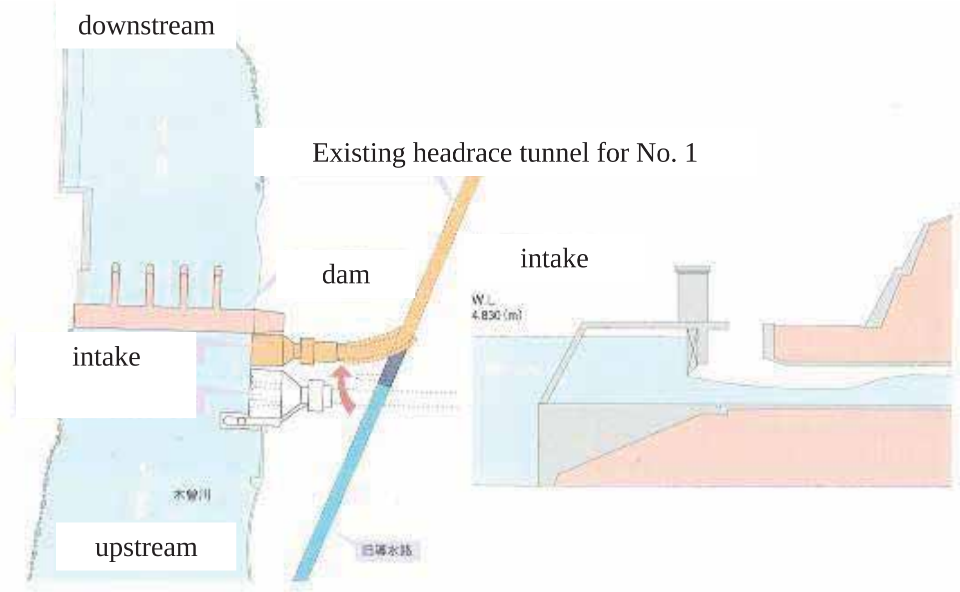


Fig. 5 Plan and Cross-section of Yomikaki Power Station

3. Feature of the Project

3.1 Best Practice Components

- Development was effectively conducted based on the philosophy of "one river system is developed by one developer"

3.2 Reasons for Success

The consistent development of the Kiso River system succeeded because the development was based on the philosophy of "one river is developed by one business developer" and proceeded so as to respond to the demands of the times. We, the Kansai Electric Power Co., Inc., which was established by the restructuring after World War 2, understood that in Japan, the majority of electric power supply would move from hydropower to the new fossil fuel fired power stations. Also, hydropower became the electric source to supplement peak load demands with large reservoirs. Based on this situation, we made a plan to build a large scale reservoir at the most upstream point as the keystone of the consistent development project. By completion of the Miura Dam, the down stream's condition was greatly improved.

4. Points of Application for Future Project

- The effective and efficient development by the consistent development of the whole river system
- Whether it is good or bad to construct a large scale reservoir on the most upstream part of the river

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

- In the Kiso River system, from 1990, with a view to improve the river environment, maintenance flow has been discharged. In June, 2011, as our first power station which utilizes this maintenance flow, the Okuwanojiri Power Station, has started its operation and furthermore effectively pursues utilizing river water.

6. Further Information

6.1 Reference

- "The hundred years history of the hydropower technologies of the Kansai Electric Power Co., Inc."
- "The history of the hydropower development by the Kansai Electric Power Co., Inc. – Miracle accommodating economic growth", Company brochure
- "The Summary of the new construction works of the Shin-Ooi hydropower Station.", *Journal of Electric power Civil Engineering*, July, 1981
- "The automatic control system interfacing with a computer, and the simulation of water intake regulation by the system which combines the hydraulic model". *Journal of Electric power Civil Engineering*, January, 1972

6.2 Inquiries

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, Lifecycle Cost Analysis

Sub: 2-c) Technological Innovation, Deployment Expansion and New Materials used for Civil and Building Works

Project Name:

The efforts to prevent risks caused by surplus waste water of Ontake Power Station

Name of Country (including State/Prefecture):

Japan, Nagano Prefecture

Implementing Agency/Organization:

Kansai Electric Power Co., Inc.

Implementing Period:

from 2010 to 2014 (scheduled)

Trigger Causes for Renewal and Upgrade:

(D) Needs for safety improvement

(E) Needs due to third party factors

Keywords:

Abrupt flow through a spill channel, Risk management, The frequency of spill (trip)

Abstract:

In a hydroelectric power station, a power overload trip occurs suddenly and the accompanying abrupt discharge from the outlet of a spill channel causes a rapid change to a river flow. Therefore a serious impact on third parties such as people who enter into or onto a river is feared. Until now, we have tried to reduce the potential risk by an abrupt flow through a spill channel so as to secure public safety. This time, based on the environmental changes around the power station site (places for people to enter river, changes of head-count) we have again reviewed the risk by an abrupt flow through a spill channel.

As for the Ontake Power Station, the impact on the river by a sudden discharge is particularly large, and it was judged that a higher priority should be given to conducting countermeasures. Consequently the installation of an energy dissipator on the outlet was investigated. Since this was necessary, in a company's own limited field, to install the energy dissipator with a dissipating effect sufficient so as to make a safe discharge possible, we reviewed existing facilities of the same type. Based on that review we have prepared the basic design and by conducting hydraulic model tests and we have settled on the optimum design.

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

The Ontake Power Station is the dam channel type power station with a maximum output of 66MW. The location and their specifications are shown in Fig. 1 and Table 1.

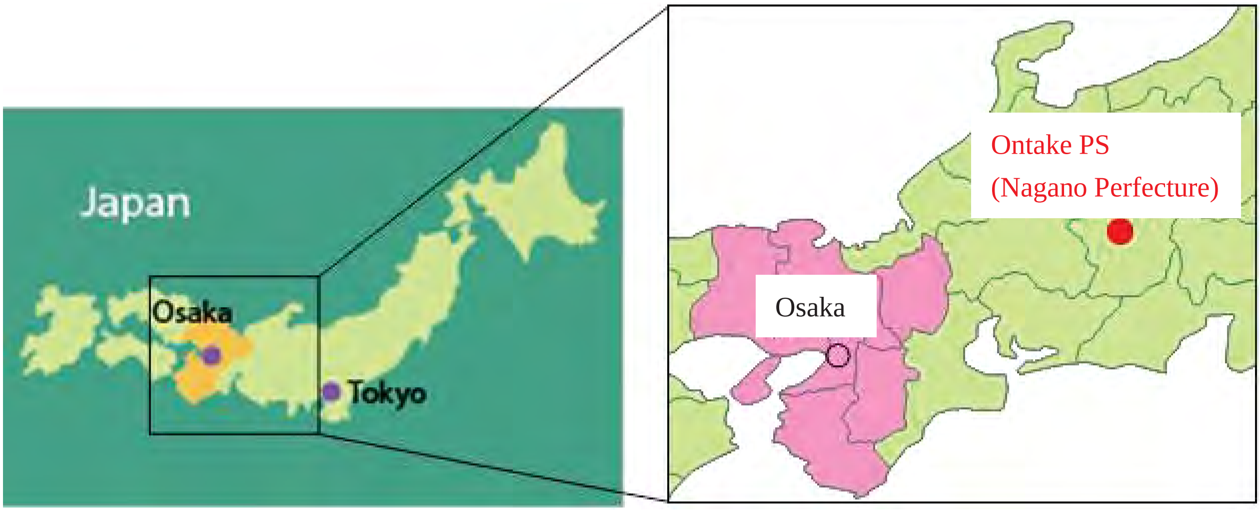


Fig. 1 Location map of the Ontake Power Station

Table 1 Specifications of the Ontake Power Station

Items		Specifications
Power Station	Name of power station	Ontake Power Station (operation start: 1945)
	Maximum output	66,000kW
	Maximum plant discharge	34.400m^3/s
	Effective head	229.000m
Dam	Name of dam	Otakigawa Dam
	Name of river	Kiso River system, Otaki River
	Basin area	114.22km^2
	Type	Gravity type movable barrage made of concrete
	Height	18.200m
	Length of dam top	80.000m
	Dam volume	10,150m^3
Reservoir	Total pondage	589,200m^3 (when constructed)
	Effective pondage	209,400m^3 (when constructed)
	Used water depth	1.600m

The Ontake Power Station was judged to be one of the power stations which is the most dangerous and necessary to have measures on a priority basis and it was determined that the improvement works of the outlet of the spill channel (installation of a energy dissipator) were to be conducted. The layout of facilities of the Ontake Power Station is shown in Fig. 2, and the status of the abrupt flow through a spill channel is shown in Fig. 3.

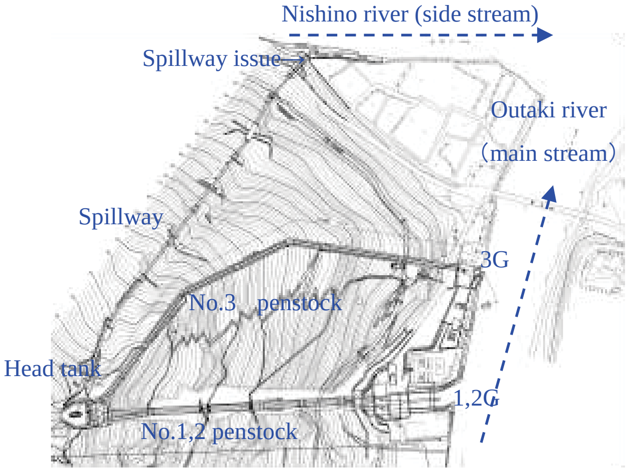


Fig. 2 The layout of facilities of the Ontake Power Station

Fig. 3. Status of the abrupt flow through a spill channel

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 – Sustainable operation(sometimes accompanied by power reduction)

Based on the environmental changes around the facilities (places for people to enter river, changes of head-count), the risk evaluation of the abrupt flow through a spill channel was conducted again and this place was judged to be one of the power stations which is highly dangerous.

(2) Improvement of value (functions)

(D)-(a) Needs for safety improvemwnt - Needs due to third party factors -

By installing the energy dissipator on the outlet of the spill channel, water flow rate at the time of sudden flow is able to be reduced greatly when compared to the current condition, and it is expected to increase the facility's safety. The expected dissipating effect was confirmed by the hydraulic model test.

(3) Necessity in market

(None)

2.2 Process to Identify and Define Renewal and Upgrade Work Measure

1945:	Operation of the No. 1 system was begun
1948:	Operation of the No. 2 system was begun
1954:	Operation of the No. 3 system was begun
April 2005:	Increase of the frequency of trips by stopping of system operating power
January 2006:	Field survey and risk assessment of effluent flow through spill way was started
November 2010:	Implementation of the improvement work of a spill channel was determined
August 2011:	The basic design of the energy dissipator was completed
March 2012:	The hydraulic model test was completed (the shape of energy dissipator was set)
July 2012 :	Detail investigation of the work was completed
March 2013:	Construction work is scheduled to be started
March 2014:	Construction work is scheduled to be completed

2.3 Description of Work Undertaken (detail)

1-d) Asset Management, Strategic Asset Management, Lifecycle Cost Analysis

- Selection of a power station which needs these measures

Power stations for which it is necessary to conduct improvement work such as a spill channel (an energy dissipator) were selected on a priority basis by evaluation of the risk matrix in which the impact of the discharge from a spill channel is measured by the index of “frequency of trip occurrences” and “the level of damage”. The detail is shown below.

a. Process flow of the measures

The process flow to select the power station which is necessary to take safety measures is shown in Fig. 4.

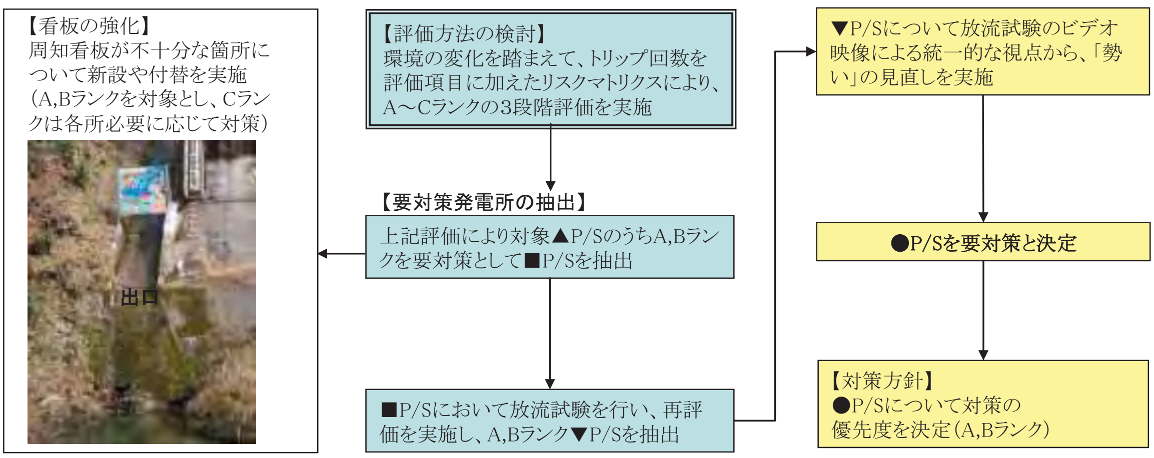


Fig. 4 Process flow of the measures

b. Risk table

Risk matrix is shown in Fig. 5 and points of each risk are shown in Fig. 6

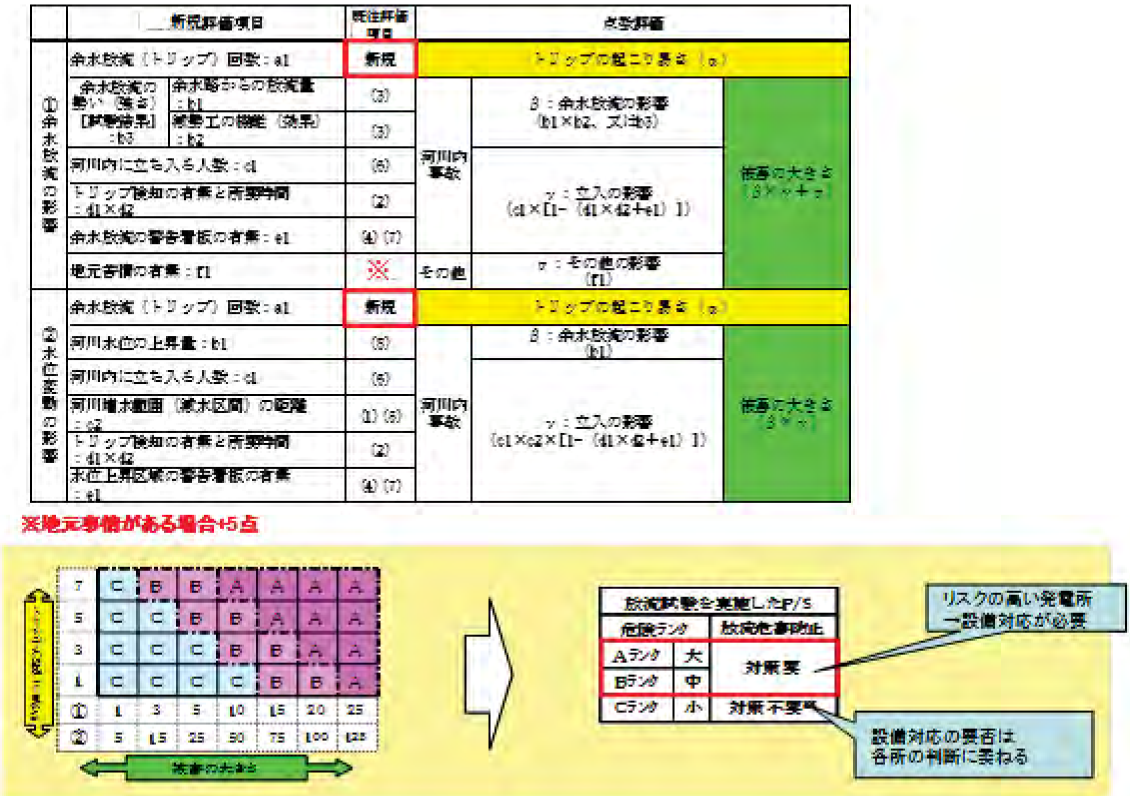


Fig. 5 Risk matrix

	トリップの起こり易さ	被害の大きさ		
	α：放流回数の影響	[β：余水放流の影響]×[γ：立入りの影響]+[δ：その他の影響]		
①余水放流の衝撃に巻き込まれる	α＝a1 a1：トリップ回数 7 | 5回(10回)/年以上 5 | 3～5回(6-9回)/年 3 | 1-3回(4-6回)/年 1 | 1回(4回)/年未満 ※1 10ヵ年平均 or（10ヵ年MAX）	β＝b3 b3：放流の勢い 5.0 | 大(鉄砲水) 2.5 | 中(流れ強い) 0 | 小(流れ弱い) 《捕捉》 大：人命に関わる程度 中：人命には関わらないが怪我をする程度 小：影響を受けない程度	γ＝c1×[1－(d1×d2＋e1)] c1：立入りの影響 5 | 5人(50人)以上 3 | 2～4(11～49人) 1 | 1人(10人) ※日MAX(年間累計) d1：トリップ検知 1 | 有り 0 | 無し d2：放流までの所要時間 0.5 | 5分以上 0.3 | 3～5分 0.1 | 1～3分 0 | 1分未満 e1：警告看板 0.2 | 有り 0 | 無し	δ＝f1 f1：その他の影響 5 | 地元苦情あり 0 | 地元苦情なし
②水位上昇（増水）により流される。	同上	β＝b1 b1：水位上昇 5 | h≧100cm 3 | 30＜h＜100cm 1 | h＜30cm	γ＝c1×c2×[1－(d1×d2＋e1)] c2：水位上昇範囲 5 | L≧100m 3 | 30≦L＜100m 1 | L＜30m c1：立入りの影響 d1：トリップ検知 d2：放流までの所要時間 e1：警報看板 上表に同じ。	

Fig. 6 Point of each risk

By conducting desk evaluation with the risk matrix of Fig.5, A and B rank power stations were selected and on every one of these sites, actual discharge tests were conducted and their danger was confirmed. In order to prevent the fluctuation of evaluations for each site, all information was unified, confirming all video footage, and by evaluation from an integrated point of view, the sites for which action is necessary and their order of priority was decided.

2-c) Technological Innovation, Deployment Expansion and New Materials used for Civil and Building Works

- Ontake Power Station: improvement plan for a spill channel

a. Summary of the spill channel

The spill channel of the Ontake Power Station has a head of 229.0m from head tank to the river and a slope of 1/3.81 - 1/1.04. The discharged water passes through a steel pipe of ϕ2.2m with a maximum flow rate of 34.4m^3/s and a velocity of 33m/s, and is then discharged into the river maintaining that high velocity.

Of all power stations subject to investigation, the Ontake Power Station has the strongest discharge energy and was judged to be necessary to have countermeasures conducted with the highest priority, and so the investigation for the improvement of the outlet of the spill channel (installation of energy dissipator) was carried out.

As for the shape of the energy dissipator, first, based on the actual past performance of the same type of renovation work, the basic design shape was set, and then by conducting a hydraulic model test, and by confirming the power reduction effect and with some improvement, the final shape was determined.

b. The basic design of the energy dissipator

For the Ontake Power Station, because of the terrain and site limitations, the energy dissipator for the outlet of the spill channel was decided to be basically the impact type energy dissipator. In addition, since the flow volume is large at 34.4m^3/s, the layout was improved to be the shape shown in Fig. 7.

The dissipator room was laid out to meet the site configuration and its structure was designed so that water passing through the spill channel has its strength reduced in the first dissipator room, and after then passes through the second dissipator room and discharging yard, finally joining the river flow.

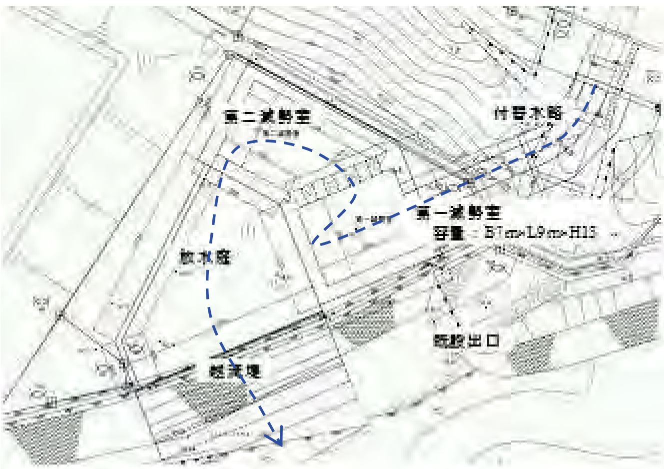


Fig. 7 Layout map of the energy dissipator

c. Hydraulic model test

The shape of the spill channel decided by the basic design was tested in terms of its energy dissipating effect and confirmed by hydraulic model tests, and by repeating improvements. Finally the optimum shape which enables a maximum reduction of the discharge flow rate was determined.

The model was investigated in accordance with the Froude similarity rule. With consideration for the repeatability of hydraulic conditions and actual performance of similar cases, the contraction scale of the model was decided to be 1/22. The range of model reproducibility was determined to be upper from the 50m to lower 200m points from the outlet of spill channel so as to be able to confirm the effect after the surplus water rejoins the river. Table 2 shows the model equivalent of reproducible specifications, and Fig. 8 shows the model reproducible range.

Table.2 model equivalent of reproducible specifications

項　目		実　物	模型 縮尺1/22
河　川	再現長（m）	250	11.36
	河川幅（m）	100	4.55
余水路	再現長（m）	133.6	6.07
	再現高（m）	68.48	3.11
	管　径（m）	2.2	0.1
	放流量（m^3/s）	34.4	0.0152
	粗度係数 n	0.015	0.009

Fig. 8 The model reproducible range

The experiment flow is shown in Fig. 9. First, the necessity for the second energy dissipating room and discharge yard was confirmed. Then the necessary capacity of each energy dissipating room was considered. In addition, as shown in Fig. 10, by considering the prevention of unauthorized persons from entering into the energy dissipating room from the river, the shape of overflow weir and baffle block were tested, and finally the optimum shape was determined.

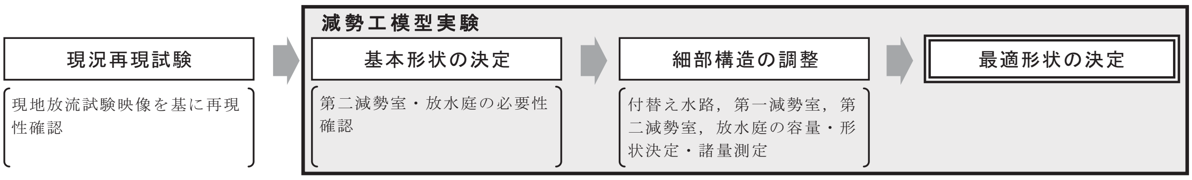


Fig. 9　Experiment flow

Before test　　　　After test

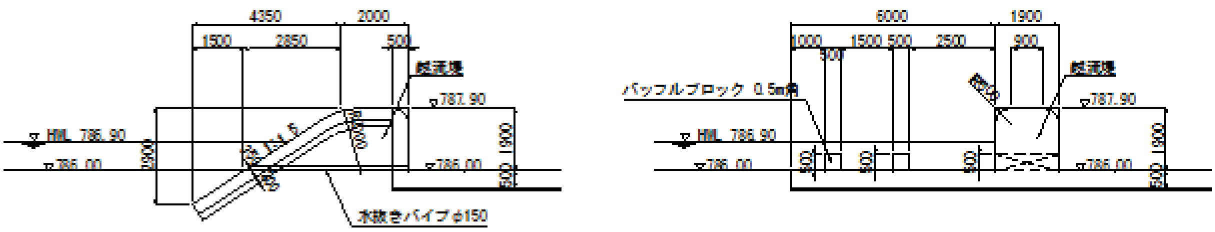


Fig. 10 The shape of overflow weir

With the optimum shape, flow rates were measured at the outlet of the spill channel and downstream, and the reduction effects were confirmed. The flow rate at the outlet of the spill channel was reduced to 2.1m/s (maximum: 3.6m/s) of average flow rate from the current rate of about 33m/s, amounting to almost 1/15 of the previous rate and achieving a big improvement. Before, at even a point 50m lower from the discharge point where the flow rejoined the river, the flow rate was more than 10m/s, but it was reduced to about 2.6m/s. Flow rate measurement points and the changes of flow rate between before and after installation of the energy dissipator are shown in Fig. 11.

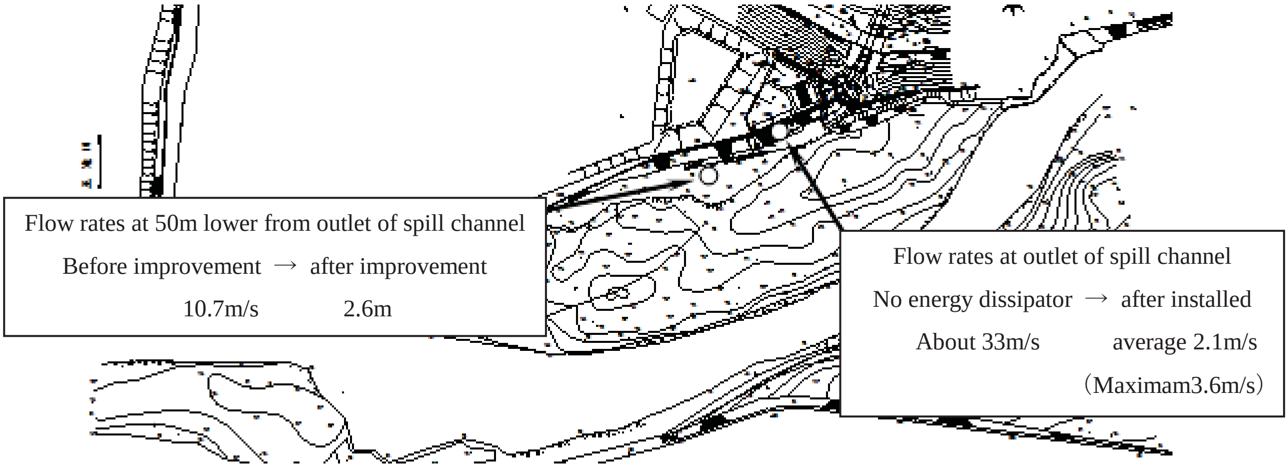


Fig. 11 Measurement points and changes of flow rate

3. Feature of the Project

3.1 Best Practice Components

(1) Selection of the sites where the measures are necessary

For every site judged as dangerous by the desk evaluation, the actual discharge tests were conducted and their risks were confirmed. In order to prevent the fluctuation of evaluations for each site, all information was unified, all video footage confirmed, and by evaluation from an integrated point of view, the sites for which action is necessary and their order of priority was decided.

(2) Plan of improvement work

As for the shape of the energy dissipator, effect of energy dissipating was confirmed by the hydraulic mode test and improved. Finally, the energy dissipator was designed to be the shape which enabled installation in a limited space and enabled obtaining the maximum energy reduction effect. Thus, renovation costs were able to be held.

3.2 Reasons for Success

(The construction work is scheduled to be completed in March, 2014, and we plan to confirm the effect of the renovation by a field verification test.)

4. Points of Application for Future Project

(1) Selection of the sites where the measures are necessary and priority order to conduct measures.

It is necessary to investigate the measurement work and to decide its order of priority by not only desk evaluation but also by conducting actual field discharge tests and by confirming the risks from abrupt discharge of surplus water at that site. Also, to prevent the fluctuation of risk evaluations by power stations, it is thought to be necessary to conduct evaluations using video footage from the integrated points of view.

(2) Design of improvement work

For design of the energy dissipator, it is necessary to fully consider the terrain of the site and the characteristics of the discharge conditions and, based on cases of the same type of works, to decide on the basic shape and scale, and also by using hydraulic model test the optimum shape should be determined.

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

The construction work is scheduled to be completed in March, 2014. After that, we plan to confirm the effect of the energy dissipator and the reproducibility of the hydraulic mode test by field verification.

6. Further Information

6.1 Reference

1) K. Kaneko “Way of thinking for the spill channel improvement and construction works cases” *Workshop report regarding the small-medium hydropower generation technology by the New Energy Foundation.* pp. 217-250, 2005

2) Y. Toge, S. Nakamura, M. Yamada “Adoption of the closed impact type energy dissipator for the spill channel on the head tank of the Nezame Hydropower Station” *Journal of Electric power Civil Engineerin*g, volume 333, pp.111-113, (2002)

3) S. Maeyama, H. Arimizu, Y. Sueoka “Hydraulic model test and the abrupt flow through a spill channel test by the actual systems accompanied by the improvement of head tank water channel of the Kanidera Power Station ” *Journal of Electric power Civil Engineerin*g, volume 288, pp.32-35 (2000)

6.2 Inquiries

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, Lifecycle Cost Analysis

Sub: 1-a) Energy Policies of Countries and States

1-b) Investment Incentives (Feed-in-Tariff (FIT), Renewable Portfolio Standard (RPS), Subsidies, Financial Assistance, Tax Deductions, etc.)

1-f) Environmental Conservation and Improvement

2-c) Technological Innovation, Deployment Expansion and New Materials used for Civil and Building Works

Project Name:

The upgrading project of Shin-Kuronagi No. 2 Power Station

Name of Country (including State/Prefecture):

Japan, Toyama Prefecture

Implementing Agency/Organization:

Kansai Electric Power Co., Inc.

Implementing Period:

from 2012 to 2013

Trigger Causes for Renewal and Upgrade:

(C) Needs for higher performance

Keywords:

Enlargement of electric energy, Utilization of existing waterway

Abstract:

We are pursuing the expansion of electric energy by hydraulic power generation so as to further promote low-carbon electric generation, and as a part of this policy, we planned to construct a new power station.

We planned to construct a new hydropower station with a maximum output of 1,900kW, annual electric energy of about 12 million kWh/year (equivalent to annual electricity usage for 3,300 normal households) on the site adjacent to the existing power station. This was to be accomplished by increasing the quantity of water intake for the power generation by 1.7 m^3/s from 6.2m^3/s to 7.9m^3/s, by utilizing surplus passing water from the water intake dam, headrace, head tank and steel hydraulic pipes which were already installed for the existing Kuronagi No. 2 Power Station.

In some parts, there are places where there is no surplus passing water, so by conducting the expansion of pipe cross section area, the capacity of passing water for the headrace will be secured.

By this project, we aim to reduce about 5,000t of CO_2 annually (calculated by the CO_2 emission coefficient [0.414kg- CO_2/kWh]) as the standard of our company of 2011).

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

Existing Kuronagi No. 2 Power Station is a run-of-river type power station located in Unazuki-machi, Kurobe City, Toyama Prefecture which includes a national park, and this site belongs to the National Park Class 3 Special Zones. The location map and specifications of this power station are shown in Fig. 1 and Table 1.

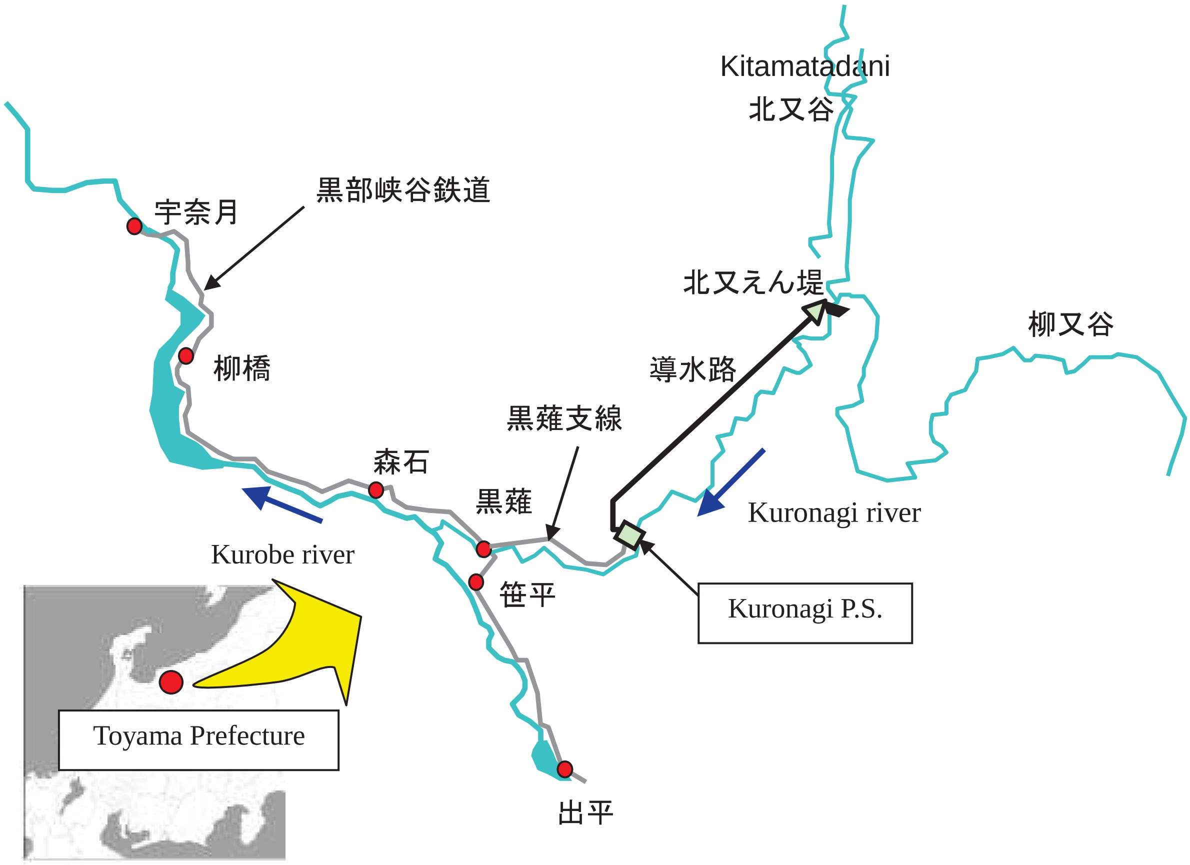


Fig. 1 Location map of Kuronagi Power Station

Table 1 Specifications of the Kuronagi Power Station

Name of power station	Kuronagi No. 2 Power Station
Location	Unazuki-machi, Kurobe City, Toyama Prefecture
Water system, name of rivers	Kurobe Water System, Kuronagigawa River, Inogashiradanigawa River
Generation method	Run-of-river type
Output	7,600kW
Maximum water discharge	6.2m^3/s
Effective head	152.07m

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

(None)

(2) Improvement of value (function)

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

With the view to develop a new hydropower site, we investigated the effective utilization of the existing facilities, and we found that there was surplus water flow capacity in the existing driving channel and we found that it was possible to share use of the majority of the existing facilities, therefore we made a construction plan on that basis.

(3) Necessity in market

(None)

2.2 Process to Identify and Define Renewal and Upgrade Work Measure

1942:	Water utilization permission of 10m^3/s was obtained
December, 1947:	Under water utilization permission of 10m^3/s, the operation was started using water flow of 6.2 m^3/s which matched to the conditions of diverting of hydraulic steel pipes, water turbine and generators from the other existing power stations and generating output of 7,000kW.
February, 1977:	Output was increased to 7,600kW by an efficiency increase by replacing water turbine, casing.
2005:	With RPS law enforcement, consultation with Ministry of Land, Infrastructure, Transport and Tourism for the new construction project (RPS 1,000kW) was started
2008:	Capacities of the new construction was revised to 1,900kW of the optimum scale
January, 2010:	Renewal of the water utilization permission period for Kuronagi No. 2 Power Station was approved.
August, 2011:	Water utilization permission for the Shin-Kuronagi No. 2 Power Station was approved.
April, 2012:	Construction of Shin-Kuronagi No. 2 Power Station was started.
December, 2012:	Operation of Shin-Kuronagi No. 2 Power Station was started.

2.3 Description of Work Undertaken (detail)

With this project, a hydroelectric power station with a maximum output of 1,900kW was constructed on the upstream site adjacent to the existing Kuronagi No. 2 Power Station. The project aims to reduce CO_2 emission by 5,000t annually. In this project, by utilizing the existing power station facilities, construction was conducted, but for the existing headrace tunnel, there are some places where there is no surplus passing water capacity, so cross-section expansion work to secure the necessary passing water capacity was conducted.

The schematic view, specifications and photo of completed facility of newly constructed power station are shown in Fig. 2, Table 1 and Photo 1.

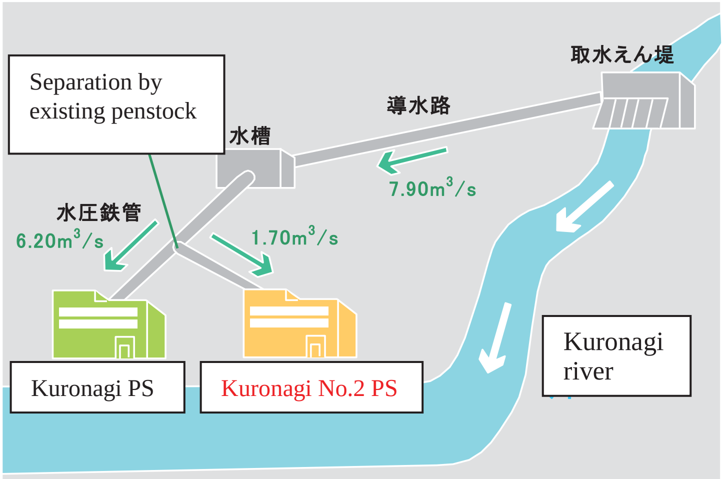


Fig. 2 Schematic view of power stations

Table 2 Specifications of Kuronagi Power Station

Name of power station	Shin-Kuronagi No. 2 Power Station	Kuronagi No. 2 Power Station
Location	Unazuki-machi, Kurobe City, Toyama Prefecture	Unazuki-machi, Kurobe City, Toyama Prefecture
Water system, name of rivers	Kurobe Water System, Kuronagigawa River, Inogashiradanigawa River	Kurobe Water System, Kuronagigawa River, Inogashiradanigawa River
Generation method	Run-of-river type	Run-of-river type
Output	1,900kW	7,600kW
Maximum water discharge	1.7m^3/s	6.2m^3/s
Effective head	142.13m	152.55m
Generated electricity	8,635MWh	58,613MWh (average of actual values)

Photo 1 Completed facility

1-a) Energy Policies of Countries and States

This project contributes to the electric source zero emission ratio in the national "Basic Energy Plan" which was decided in June, 2010.

1-b) Investment Incentices (Feed-in-Tariff (FIT), Renewable Portfolio Standard (RPS), Subsidies, Financial Assistance, Tax Deductions, etc.)

Subsidy for a small-medium hydroelectric generation development project was applied to New Energy and Industrial Technology Development Organization (NEDO) and New Energy Promotion Council (NEPC), and used for the projects.

	中小水力発電開発事業	
出　　力	1，000kWを超え 5，000kW以下	5，000kWを超え 30，000kW以下
対　　象 事業者	一般電気事業者、公営電気事業者等卸供給事業者、卸電気事業者、特定規模電気事業者等	
補助率	新設の場合	
	20%以内	10%以内
	経済性が著しく低い事業については、さらに10%を加えた率を申請できる。	

1-d) Asset Management, Strategic Asset Management, Lifecycle Cost Analysis

For the case that only water turbines and generators are replaced, (1) when the system is connected, the transformer needs to be replaced due to insufficient capacity, (2) while construction work is conducted, there is a large decrease in electric generation capacity, (3) the project is ineligible for subsidies. When the existing power station is expanded (by utilizing the existing facility, to construct new power station), by connecting new and old power stations to other systems, for accident or trouble system stability increases.　Thus, with all things considered, we concluded that the expansion of the existing power station was the better choice.

1-f) Environmental Conservation and Improvement

By maximum utilization of the existing facilities, it is possible to suppress new loads on the environment.

2-c) Technological Innovation, Deployment Expansion and New Materials used for Civil and Building Works

Examination method of the tolerance of the cross-section of headrace, branching method of the existing hydraulic steel pipe.

3. Feature of the Project

3.1 Best Practice Components

- Effective utilization of the existing water intake dam, headrace and hydraulic steel pipes

3.2 Reasons for Success

Since the existing facilities such as the water intake dam, headrace and hydraulic steel pipes were effectively utilized, the construction costs were able to be reduced by 60% when compared to the case that the same type of power station is newly constructed alone.　In addition, by use of the subsidies, the cost of power generation can be reduced by 12%.

4. Points of Application for Future Project

- Effective utilization of the existing structure as much as possible is thought to lead the cost reductions.
- While operating the existing power station, construction works such as earth excavation for the understructure of the power station had to be conducted in the vicinity of the existing hydropower station, therefore the construction work had to be conducted considering vibration regulations. It means that from the time of design, it is necessary to consider the requirements of various regulations.
- In the expansion work to widen the headrace at this site, the bedrock at lining points was poor and the schedule was delayed. So it is necessary to make a construction schedule plan assuming in advance that the bedrock at lining points may be bad.

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

- In December 2012, this power station has just begun operations. From now on, we intend to monitor and confirm the operation conditions and whether trouble would occur.
- Since July 1, 2012, "the Feed-in Tariff Scheme for Renewable Energy" has been started, and now application for the subsidy system is now discontinued.

6. Further Information

6.1 Reference

(None)

6.2 Inquiries

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-e) Project justified by the non-monetary valuation of stabilizing unstable power systems in the up-coming Low-carbon society

Project Name:

The project to upgrade the Okutataragi No. 1 & 2 hydropower stations into adjustable speed generator motors

Name of Country (including State/Prefecture):

Japan, Hyogo Prefecture

Implementing Agency/Organization:

Kansai Electric Power Co., Inc.

Implementing Period:

from 2008 to 2019 (plan)

Trigger Causes for Renewal and Upgrade:

(C) Needs for higher performance

Keywords:

Adjustable speed control, Frequency control, Pump-turbine runner with splitter vanes, Widening of the existing tunnel

Abstract:

The frequency control of the electric power systems in the late night hours has been accomplished by, among others, adjustable speed generator motors of pumped storage hydropower stations and the fossil fuel fired power units which have AFC (Automatic Frequency Control). However, as for Okawachi No. 3 & 4 hydropower units which have adjustable speed generator motors, due to serious aging, extensive renovations are planned, and there is concern of a degradation of frequency control functions in the late night hours. Therefore, making use of the opportunity when the large scale renovation is accomplished of Okutataragi No. 1 & 2 hydropower units whose generators are of the constant speed type, variable speed pumped storage systems will be introduced to secure the frequency control functions.

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

1.1 Outline of the Project Site (before Renewal/Upgrading)

In April, 1971, the construction of Okutataragi Hydropower Station was started, and from June, 1975, all 4 units began their operation as the largest class pumped storage power station in Japan with a maximum output of 1,212MW (303MW×4 generators).

Fig.1 Location map of the Okutataragi hydropower station

Afterwards, in order to respond to the increase of electricity demand and to improve electric supply reliability, while using the Kurokawa Dam (upper regulating reservoir) and Tataragi Dam (lower regulating reservoir) as is, new water channels and No. 5 & 6 units (360MW×2 units) were constructed, and in June, 1998 operations were started. Now, this hydropower station is operated as a pumped-storage hydropower station with a maximum output of 1,932MW.

The Location map of the hydropower stations is shown in Fig. 1. Specifications of the Okutataragi No. 1 & 2 units which are subject to the adjustable speed modification work are shown in Table 1 for before construction and after construction.

Table 1 Facilities specifications of Okutataragi No. 1 & 2 units

		Before renovation (constant speed system)	After renovation (adjustable speed system)
Authorized output	Generating operation	303MW (power factor 0.95)	System: 303MW (power factor 0.95)
	Pumping operation	320MW (power factor 1.0)	System: 320MW (power factor 1.0)
Pump turbine	Type	Vertical Francis type pump turbine	Vertical Francis type pump turbine
	Turbine output Pump input	Turbine output : 310MW Pump input : 314MW	Turbine output : 311.7MW Pump input : 311.7MW
	Discharge	$94m^3/s$	$94m^3/s$
	Effective head (normal)	383.4m	383.4m
	Rated rotational speed	$300min^{-1}$	$285 – 315min^{-1}$
Generator motor	Type	DC [direct-current] excitation Three-phase AC generator motor	AC [alternating-current] excitation Three-phase AC generator motor
	Machine type	Revolving-field Totally- enclosed Externally- ventilated Type	Revolving-field Totally enclosed Self- ventilated Type
	Capacity	320MVA	350MVA
	Rated rotational speed	$300min^{-1}$	$285 - 315min^{-1}$

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) Necessity for higher performance

(b) Role change of hydropower generation. Addition of new function

- Degradation of frequency control functions in the late night hours.

As for No. 3 & 4 units of Okawachi pumped storage hydropower station which have adjustable speed systems, due to serious aging of the generator motors, extensive renovations are planned, so there is concern for the degradation of frequency control functions for electric power systems in the late night hours. If the proportion of the fossil fuel fired power stations with AFC functions is increased to handle this problem, economic efficiency worsens due to fuel cost for operation.

(3) Necessity in market

With increasing use of renewable energy such as solar power generation and wind power generation for which the output can fluctuate depending on the weather, it is assumed that the frequency control function for electric sources will become insufficient.

2.2 History

September, 2006:	Study of "the proposal of modification of the existing pumped-storage system into adjustable speed system" was started.
February 2008:	Study of "the modification of Okutataragi No. 1 & 2 hydropower units into adjustable speed system" was completed.
December 2008:	Work office was built
April, 2009:	On-site construction office was built
August 2009:	Preparation construction was started
March 2010:	Building work was started.
May 2010:	Investigation work was started.
July 2010:	Investigation work was completed and civil engineering works was started
May 2011 :	Civil engineering work was completed
November 2011:	Building work was completed
October 2015:	Main construction was started
December 2017:	No. 2 hydropower unit is scheduled to start
February 2019:	No. 1 hydropower unit is scheduled to start

2.3 Description of Work Undertaken (detail)

1-e) Project justified by the non-monetary valuation of stabilizing unstable power systems in the up-coming Low-carbon society

- Improvement of frequency control function by upgrading to a adjustable speed hydropower unit

The frequency control of the electric power systems in the late night hours has been conducted mainly by the fossil fuel fired power stations which have the AFC function and especially among others, by the Ookouchi No. 3 & 4 hydropower units which have the adjustable speed generator motors. However, in the late night hours, due to the decrease of electricity demand, it is necessary to reduce the electrical power sources which have a frequency control function. Thus, the frequency control function decreases. Under these conditions, the Ookouchi No. 3 & 4 hydropower units, which have the adjustable speed pumped storage system so as to enables AFC operation even when pumping up water, are operated at high rate. However, in the near future, extensive renovation which needs a long period of time is planned and so in that period, the diminished frequency control function is a concern. Thus, as an alternative, a new adjustable speed pumped storage hydropower unit is required.

This project is intended to modify the 303MW generator motor, which has been used for 38 years since its start of operation in 1974, from the constant speed system (300min^{-1}) to the adjustable speed system (285 - 315min^{-1}), at the same time as the full scale renovation (renovation due to aging) of the Okutataragi No. 1 & 2 units. By modification into the adjustable speed system, the fuel cost in the night hours is expected to be reduced due to restrain fossil fuel power generation to be connected to the electric power system. Also the generating efficiency of an adjustable speed unit at a partial load is expected to improve, and thus the stability of the electric power system can be anticipated by this project.

In general, the AFC capacity of fossil fuel power stations is 1.5% - 5% for a single unit, however, the adjustable speed systems of Okutataragi No. 1 & 2 hydropower stations have about 30% AFC capacity for a single unit, contributing greatly to the stability of the electric power system. In the future, even if the renewable energy source portion increases, with its large output fluctuation, this system has the capability for its frequency control function to overcome these problems, and so it is expected that demand from the market will increase.

Comparison of specifications of generator motors and excitation systems of before work and after work are shown in Table 2.

Table 2 Specifications of Generator motors and Excitation system of Okutataragi No. 1 & 2 units

Item			Before renovation (Constant speed system)	After renovation (Adjustable speed system)	(Reference) Okawachi (Adjustable speed system)
System power conditioning range			-	90MW	160MW
Generator motor	Capacity		320MVA	350MVA	395MVA
	Rotational speed		$300 min^{-1}$	$285 - 315 min^{-1}$	$330 - 390 min^{-1}$
	Stator	dimension	Height: 3,230mm Diameter: 8,300mm	Height: 3,540mm Diameter: 8,800mm	Height: 4,300mm Diameter: 8,700mm
		mass	413t	374t	502t
	Rotor	dimension	Height : 3,340mm Diameter: 6,394mm	Height : 4,900mm Diameter : 6,480mm	Height : 6,000mm Diameter : 6,500mm
		mass	590t	479t (Hoisting load of crane 490t)	750t
Exciter	Capacity		720kVA	35,800kVA	72,000kVA
	Output voltage		375V	5,580V	5,200V
	Output current		1,920A	3,700A	8,000A
Thyristor elemennt	Voltage		-	5,200V	4,000V
	Current		-	5,400A	3,000A
	Element composition		-	2S1P 72 arm	3S3P 72 arm
	Element size		-	110mm	90mm

- Modification to adjustable speed system by using the existing facilities

This project is the modification by converting existing facilities; the main parts of generator motor shown in Fig. 2, such as stator base, lower bracket, lower haft and foundation base. In addition, in order to reduce stator weight by an electromagnetic structure design so that the mass falls within the rated hoisting load of the existing overhead crane, thus the conversion using the existing overhead crane was achieved. Besides, the existing main transformers, phase reversing switches and synchronous circuit breakers are also reused as well, and the main circuit before construction work is shown in Fig. 3 and after construction work in Fig. 4.

Improvement range of the generator motors

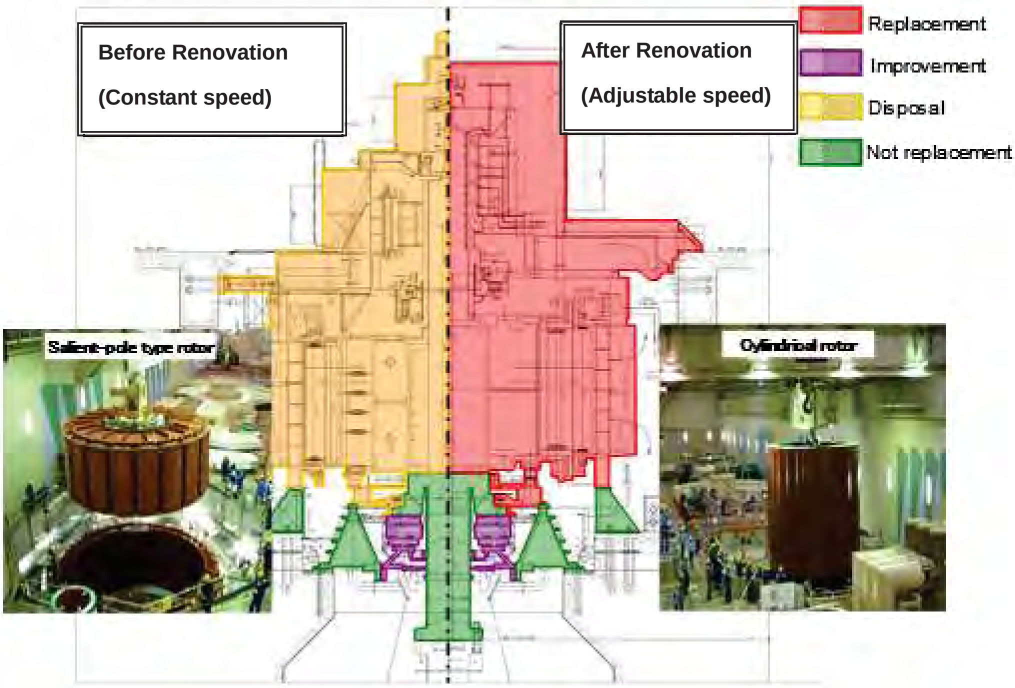


Fig. 2 Construction range of the generator motors of Okutataragi No. 1 & 2 units

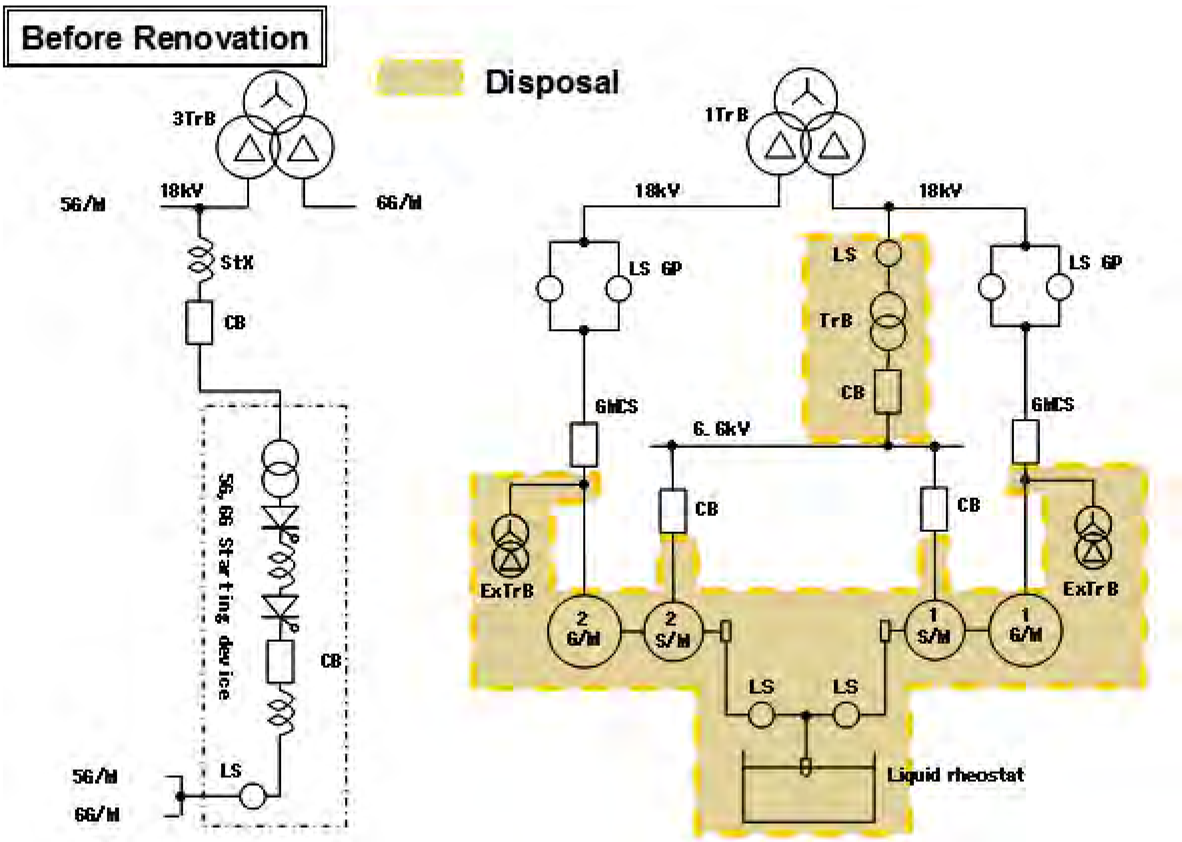


Fig. 3 Main circuit of the generator motors of Okutataragi No. 1 & 2 units (before renovation)

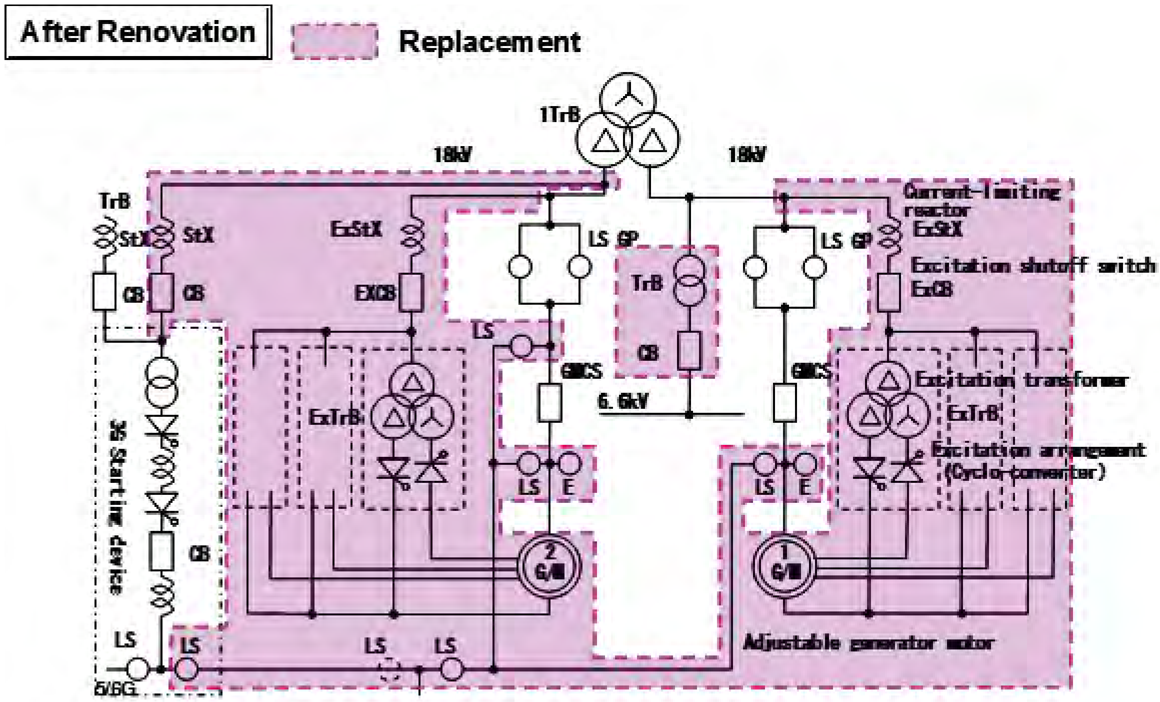


Fig. 4　Main circuit of the generator motors of Okutataragi No. 1 & 2 units (after renovation)

- Runner with splitter vanes

In the planning process for the replacement of the pump turbine runner, the following points were investigated; that is, "partial load efficiency properties" which pursue a high efficiency for a wide range of operations, "the interrelation between the existing guide vanes and a new runner" so as to avoid abnormal vibration caused by interference with the existing guide vanes, and "runner dual partitioning measures" by transport restriction. In addition, the design was planned so that the upper limit of the operating range of adjustable speed wouldn't exceed the main transformer capacity, and the maximum pump input was reduced from 320MW to 280MW. To perform this reconstruction, the diameter of the upper draft tube was reduced, making maximum use of the adjustable speed operation range of ±45MW (90MW).

On the premise of above conditions, the adjustable speed property and cavitation properties were analyzed by CFD, and also performance was confirmed by model test. As a result, the pump turbine runner which has 280MW splitter vanes (from the existing 6 vanes to a total of 8 vanes consisting of 4 vanes + 4 splitter vanes) was chosen. By upgrading the runner, an increase of efficiency, especially an increase in the partial load area is achieved, and an increase of generated power energy can be expected.

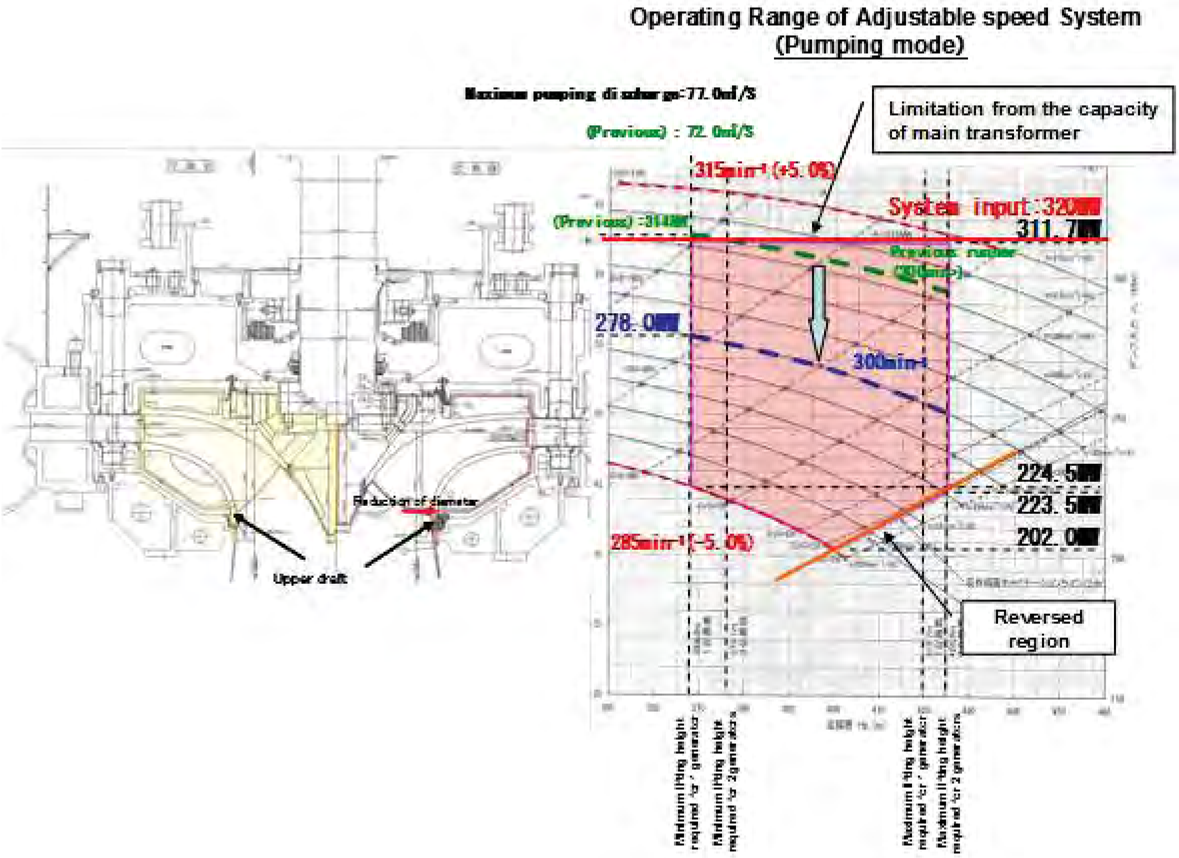


Fig. 5 Adjustable speed operation range of generator motors of Okutataragi No. 1 & 2 units

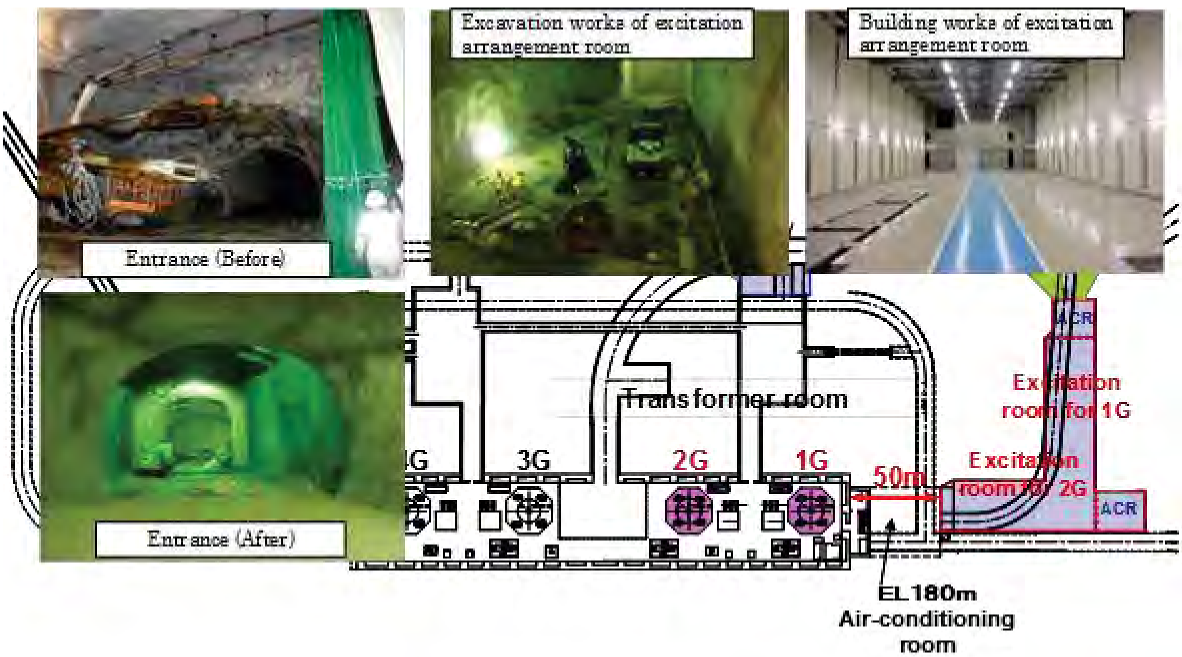


Fig. 6 Work status of modifying the Okutataragi No. 1 & 2 units into adjustable speed systems

- Securing the widening space by the excavation of the existing tunnel

In order to install the excitation systems which increase the function for adjustable speed operation, it was necessary to secure a large space in the underground powerhouse. Unlike the case when a new power station is constructed, it had been a big challenge from the early stages of the plan to secure a large space in the underground powerhouse while operating. As shown in Fig. 6, the existing tunnel was broadened so as to secure the installation space for the excitation systems. The existing adit, which is 50m apart from the generator motor, was excavated by blasting to enlarge so as to prepare the room for the excitation systems.

- Rationalization of design for rotor coil insulation in terms of high voltage, and high mechanical and thermal strength

Since the rotor coil of a adjustable speed unit is used as the AC excitation with large current and applied high voltage, its structure is different from the ordinary constant speed system and requires the same structure as the stator coil. However, a rotor coil is subject to a large centrifugal force while the operation and is exposed to a heat cycle caused by frequent increases and decreases of excitation current. Consequently, a rotor coil is not possible to have the same insulation design as the stator coil. It is necessary to design so as to have an excellent proof strength against mechanical and heat cycle deterioration of a rotor coil in a adjustable speed unit.

Therefore, based on the actual operation performance of the Okawachi Hydropower Station where the adjustable speed systems have already been used, we have reviewed the insulation design of a rotor coil and conducted test verification. We plan to adopt a much better designed rotor coil which has a greater resistance to mechanical and heat cycle deterioration for the generator motors of the Okutataragi No. 1 & 2 units.

3. Feature of the Project

3.1 Best Practice Components

- Modification from the constant speed to a adjustable speed system by making use of the exciting stator base, lower bracket, lower axis and fundamental base.
- Adoption of a runner having splitter vanes for the purpose of improving partial load efficiency and to expand adjustable speed operation range.
- Securing of the space for installation of the excitation system in the underground powerhouse while paying attention to the existing generator motors which are being operated.
- Development of the rotor coil insulation design in terms of a high voltage, and high mechanical and thermal strength so as to be able to resist mechanical and heat cycle deterioration of the rotor of the adjustable speed unit.

3.2 Reasons for Success

First, we intended to conduct an excavation by machinery for preparation of the space for installing excitation systems in the underground powerhouse, but it became clear that it was too expensive and required too much time, so we conducted excavation by blasting.

Since the blasting point was close to the generator room and there was concern for having a bad impact on the existing generator motors, we adopted a multistage blasting by using a nonelectrical detonator with ignition tubes for excavation. The nonelectrical detonator enabled finer control of the blasting than by electrical detonator and was effective to reduce blasting vibrations. In addition, because of firing by ignition tube, it is effective for prevention of accidental detonation from stray electrical current in the powerhouse area.

With adopting multistage blasting by this nonelectrical detonator with ignition tubes to optimize the blasting process, without producing damaging vibration on the existing generator motors, we were able to excavate without stopping the existing operating generator motors.

4. Points of Application for Future Project

- Restriction of output change rate caused by the water inertia time constant

By introduction of the adjustable speed system, response of input and output is improved, and contributes to the stabilization of the electric power system. This is because Kansai Electric Power Co. Inc., adopted an effective power priority control as a power control method for the adjustable speed system, so when a change command of input and output is received, it is able to respond instantly electrically by adjusting the internal phase angle by changing a phase of the exciting current.

After an electrically instantaneous response, it is necessary to balance turbine input quickly by opening and closing of guide vanes so as to compensate turbine input following the output of the generator. However, Okutataragi Hydropower Station has a large water inertia time constant because of its long water channel (total 3,972m), causing a delay in the response of water turbine input. If the response is extremely delayed, it is not able to follow an electric response as a generator output, and rotational speed drops excessively and consequently there is a possibility for rotational speed to depart from its operation range. For this reason, for the setting of output change rate, it is necessary to consider the response of the turbine input. Also when the water inertia time constant is large, it is necessary to consider that it impacts the water level fluctuation of the surge tank leading to a large burden on the equipment because of increase of opening and closing action of wicket gate as well. Thus, for rapid commands for output change, it is necessary to consider optimum output change rates whose burden on the equipment is small and which don’t depart from the defined rotational speed operation range.

- Consideration of usage of existing facilities

In the case of changing existing constant speed systems into adjustable speed systems, it is important to fully investigate compatibility with facilities such as brackets, guide vanes and basement which are to be reused.

In this project, the most important point necessary to keep in mind is the support stiffness of the upper bearing of the rotor. In accordance with the changing to a adjustable speed system, the type of the rotor changes from the salient pole type of the constant speed unit to a cylindrical type, and so the axial direction dimension becomes longer. So when facilities around the pump turbine below the rotor are reused, the supporting point for the upper bearing shifts toward the upper end. Therefore, it becomes necessary to reinforce the bearing support so as to maintain its position. In the design process of whole facility structure make up, including dimensions and stiffness of facilities which are to be reused, it is necessary to consider the elements which are not required in the case of new construction.

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

(Not applicable)

6. Further Information

6.1 Reference literature

(Not applicable)

6.2 Contact

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: 1-f) Environmental conservation and improvement

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

Project Name:

Sand discharging bypass facility project at the Asahi Dam Reservoir

Name of Country (including State/Prefecture):

Nara, Japan

Implementing Agency/Organization:

The Kansai Electric Power Co., Inc.

Implementing Period:

1994-1998

Trigger Causes for Renewal and Upgrade:

(B) Environmental deterioration

Keywords:

sedimentation, prolonged turbid water, bypass tunnel

Abstract:

Effects of deforestation in the upstream areas have become apparent at the studied site despite various measures implemented to prevent turbid water from flowing into the reservoir during a discharge. The measures included operation of a selective water intake system, installation of a filtration bank immediately downstream from the dam, and civil engineering works to prevent collapses of hillsides around the reservoir. In addition, as a fundamental measure to prevent exacerbation of sedimentation which was expected to occur at a larger scale than initially planned, a sand discharging bypass facility which would discharge turbid water to the downstream from the Asahi Dam via the 2,350 meters bypass tunnel was constructed. The operation of the facility started in 1998. The bypass feature of this facility is activated only during a discharge. The facility is being useful in preventing prolonged turbid water, restricting sedimentation in the reservoir, recovery of the river environment through the supply of sediment to the downstream section of the dam, and preventing eutrophication in the reservoir when discharge is not conducted.

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

The Asahi Dam is the lower dam of the Okuyoshino Power Plant (maximum output 1,206 MW, start of a full construction in April 1975, start of a full operation in April 1980), a re-circulating pumped storage power plant located in Totsugawa village in Nara, Japan where national and quasi-national parks are located. The plant is located within a national and quasi-national park. See Fig. 1 and Table 1. about allocations and specifications of the plant and the dam.

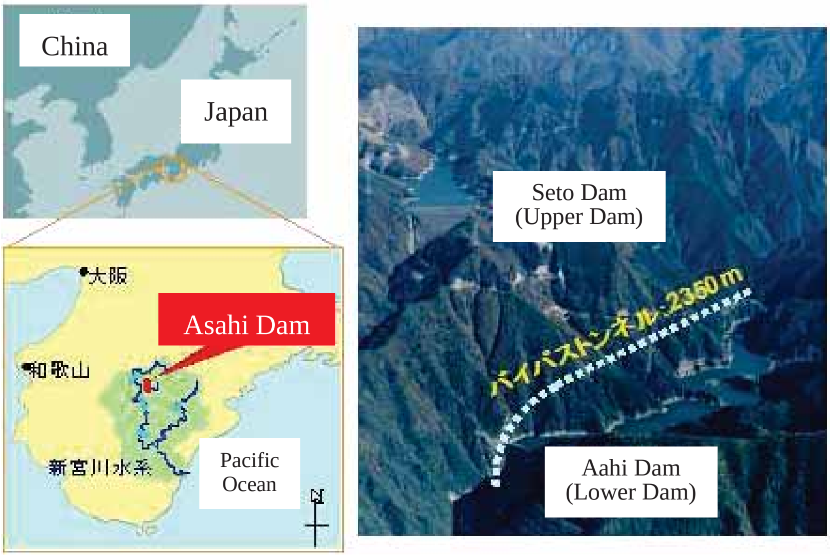


Fig. 1 Location of Asahi Dam

Table 1 Specifications of the Okuyoshino Power Plant

Category		Specification	
Power Plant	Name of the power plant	Okuyoshino Power Plant	
	Maximum output	201 MW/unit x 6 units	
	Discharge for maximum power	288.0 m^3/s	
	Effective head	505.0 m (during a discharge for maximum power)	
Dam	Name of the dam	Seto Dam (upper dam)	Asahi Dam(lower dam)
	River name	The Setodani River in the Shingu River watershed	The Asahi River in the Shingu River watershed
	Basin area	2.9 km^2	39.2 km^2
	Type	Rock-fill type	Dome-shaped arch type
	Height	110.5 m	86.1 m
	Crest length	342.8 m	199.41 m
	Dam volume	3,740,000 m^3	147,300m^3
Reservoir	Gross capacity of the reservoir	14.79 x 10^6 m^3(at construction)	15.47 x 10^6 m^3(at construction)
	Active storage capacity	11.28 x 10^6 m^3(at construction)	12.63 x 10^6 m^3(at construction)
	Available depth	34 m	32 m

2. Description of the Renewal and Upgrading of the Project

2.1 Trigger Causes and Drivers for Renewal and Upgrading

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

(B) **-** (a) Environmental deterioration — sedimentation deduction

Sedimentation was found to be exacerbating at a faster rate than initially planned since the start of the operation. The sedimentation would negatively affect the water intake function of the power plant unless some measures are implemented.

(B) **-** (b) Environmental deterioration—improvement of river environment

Collapses of mountains are increasing at the studied area, and problems of prolonged turbid water caused by collapses of hillsides during large-scale discharges due to typhoons and other factors have become apparent. Especially, a prolonged turbid water lasted for about 200 days when a large discharge was conducted in the typhoon in 1990 and greatly affected the downstream rivers (Fig. 3).

(ii) Improvement of the value (function)

(not applicable)

(iii) Necessity in the market

(not applicable)

2.2 Process to Identify and Define Renewal and Upgrade Work Measure

1991	Start of a thorough consideration of this project
Apr. 1994	Contracted major civil engineering works and started them
May 1995	Started drilling of the bypass tunnel
Oct. 1996	Completed digging a bypass tunnel and started casting concrete in the bypass tunnel
Jan. 1997	Started constructing the rim of the dam
Mar. 1997	Completed constructing the dam
Sep. 1997	Completion of concrete casting in the bypass tunnel
Dec. 1997	Completion of main civil engineering works
Feb. 1998	Completion (ceremony)
Apr. 1998	Start operation

2.3 Description of Work Undertaken (detail)

1-f) Environmental conservation and improvement

Collapses of mountains have been increasing at the studied site, and problems of turbid water flowing into the reservoir have been occurring during discharges since the dam started its operation (1978). Various measures such as operation of selective water intake facilities, installation of a filtration bank immediately downstream of the dam, and civil engineering works to prevent collapses of hillsides around the reservoir were implemented by 1990. Still, conditions in the upstream areas such as deforestation began to affect the dam. Especially, prolonged turbid water became a problem due to collapses of hillsides during a large discharge due to typhoons in 1989 and 1990, and residents in the downstream areas expressed a strong demand to improve the conditions.

The prolonged turbid water lasted for about 200 days after a large discharge due to the typhoon in 1990 and greatly affected downstream rivers (Fig. 3). In addition, the need for a fundamental solution increased due to the rising concern for sedimentation which was occurring at a faster rate than initially planned.

Therefore, as a result of consulting with local communities and relevant government agencies, a decision was made to construct a sand discharging bypass facility as a concrete measure against the problem. (Social demand for improvement of the environment)

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

The sand discharging bypass facility consists of four main facilities (dam, water intake, aqueduct tunnel, and outlet). The dam with the height of 13.5 m and the length of 45.0 m located in the upstream end of the reservoir takes the water in, and turbid water is discharged to the downstream section of the Asahi Dam through the 2,350 m bypass tunnel. This facility started operating in 1998 (Table 2, Fig. 2). The sand discharging bypass facility is designed based on the maximum discharging capacity of 140 m^3/s, which is capable of discharging almost all water on prolonged days in turbid water* which occurs at the rate of 200 m^3/s, the probabilistic flow for a year. In addition, the facility is capable of letting almost all bed load flow even in case of the largest flow (560 m^3/s) recorded by the time of the construction. This facility is operated to bypass water only during discharges. The facility is being useful in preventing prolonged turbid water, restricting sedimentation in the reservoir, recovery of the river environment through the supply of sediment to the downstream section of the dam, and preventing eutrophication in the reservoir when discharge is not conducted.

The intake part of the bypass tunnel was designed for efficient intake of bed load by also installing a debris dam (Fig. 4). The bed load transport efficiency at the intake was increased by adopting orifice method to regulate the flow and maintain stable condition of the open channel. This mechanism also has the function of decreasing the flow capacity inside the tunnel and returning to a condition without sediment accumulation when sediment accumulates inside the tunnel by increasing the water level at the front of the intake and decreasing the sediment flow into the tunnel.

* prolonged days in turbid water: number of days taken from the day on which the inflow water returns to clear water to the day on which the water at a water quality standard point becomes clear

Table 2 Main specifications of the sand discharging bypass facility

Dam	Dam height x crest length	13.5 m x 45.0 m
	Structure	Steel structure
Water intake	Height x width	14.5 m x 3.8 m
	Length	18.5 m
	Structure	Reinforced concrete structure with steel lining
	Gate	1 gate
Aqueduct tunnel	Height x width	3.8 m x 3.8 m (hood type)
	Length	2,350 m
	Gradient	about 1/35
	Maximum flow capacity	140 m^3/s
	Structure	Reinforced concrete pile
Outlet	Width x length	8.0 m - 5.0 m x 15.0 m
	Structure	Reinforced concrete structure

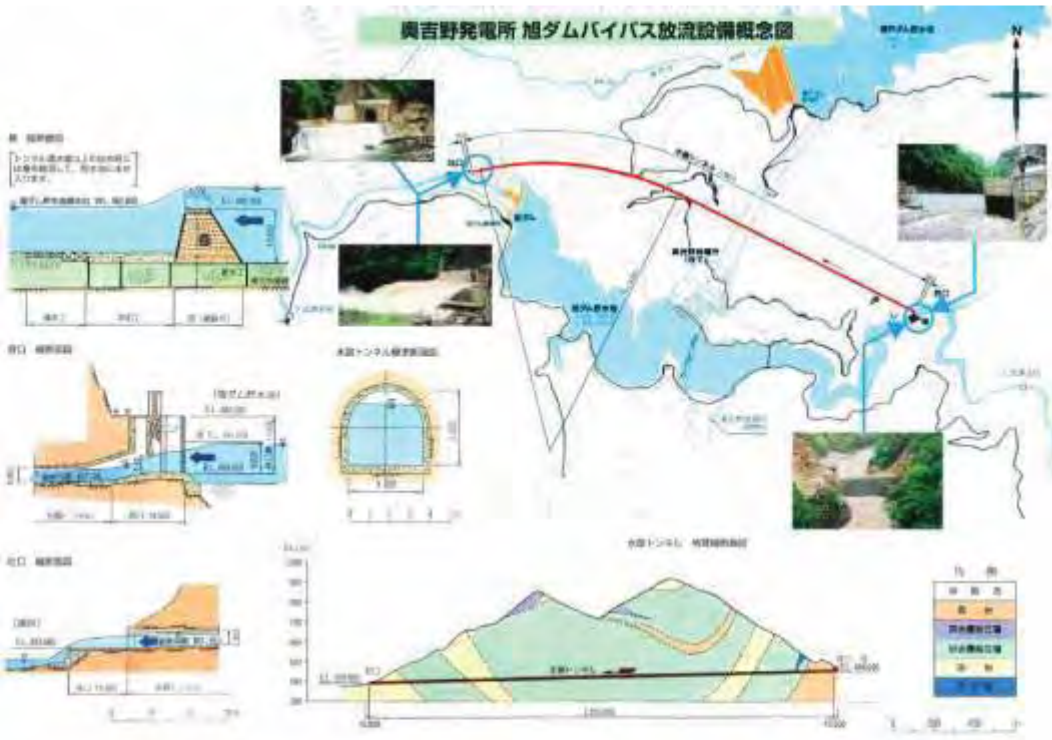


Fig. 2 Overview of the Asahi Dam sand discharging bypass facility

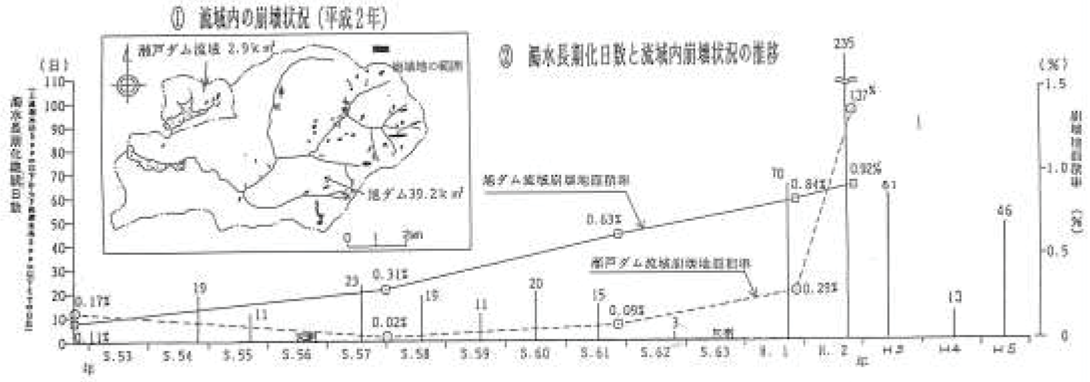


Fig. 3 Changes in the prolonged days in turbid water and collapses in the watershed

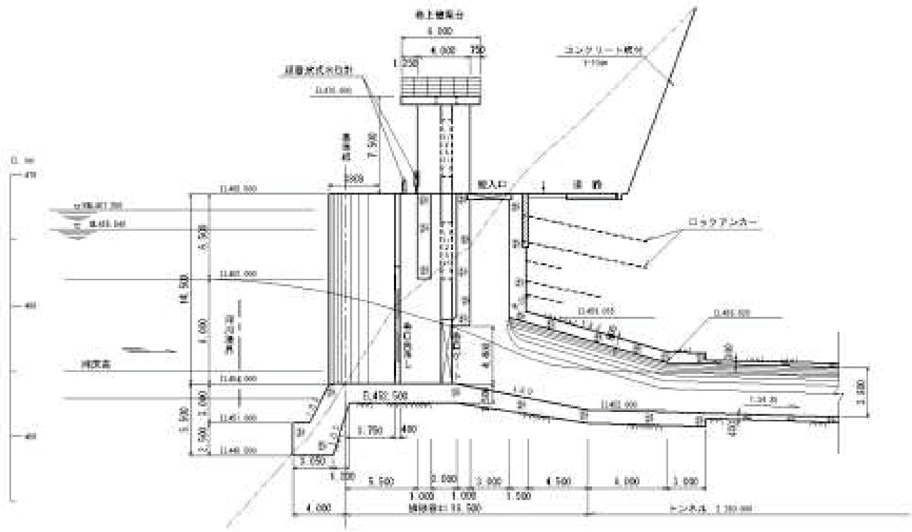


Fig. 4 Vertical cross-sectional view of the intake part of the bypass tunnel

3. Feature of the Project

3.1 Best Practice Components

-Fundamental measure to eliminate prolonged turbid water

-Turbid water flow treatment using stable flow in a open channel

3.2 Reasons for Success

The factor for the success of this project was the implementation of fundamental measures. The sand discharging bypass facility is a system which uses natural mechanisms and is compatible with nature. In addition, the facility is easily recognizable as a system to reduce the effect of a dam to natural rivers. Despite all these benefits, there was no construction example of such a facility in Japan, and no systematic study was conducted either. Under such circumstances, examinations of the following problems have been increasing the certainty of solving problems through implementing measures discussed here. Specifically, the examinations explored technical issues for commercialization such as how the facility would reduce prolonged turbid water and sedimentation, whether the facility could eliminate large amount of sediment released during a discharge without problems, economical sizes of the facility, and how hydraulic calculations should be performed. These issues are examined based on simulations and hydraulic tests. One of the factors for the success was that the project team consulted with local communities and relevant government offices from the planning phase of the implementation and shared awareness for problems.

4. Points of Application for Future Project

[Perspective of a construction cost increase]

- The tunnel length can be shortened (the tunnel length in this project was 2,350 m)
- The maximum flow capacity of the tunnel can be set lower (the maximum flow capacity in this project was 140 m^3/s).

[Perspective of operation]

- The reduced flow to the reservoir due to the use of bypass tunnel can be permitted (this point was made possible in this project due to the use of lower reservoir in the pumped storage power plant).

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

- Fig. 5 shows the annual records of operation from 1999 to 2009. The sand discharging facility has been directly discharging 65% of the total amount of inflow in average to the downstream section.

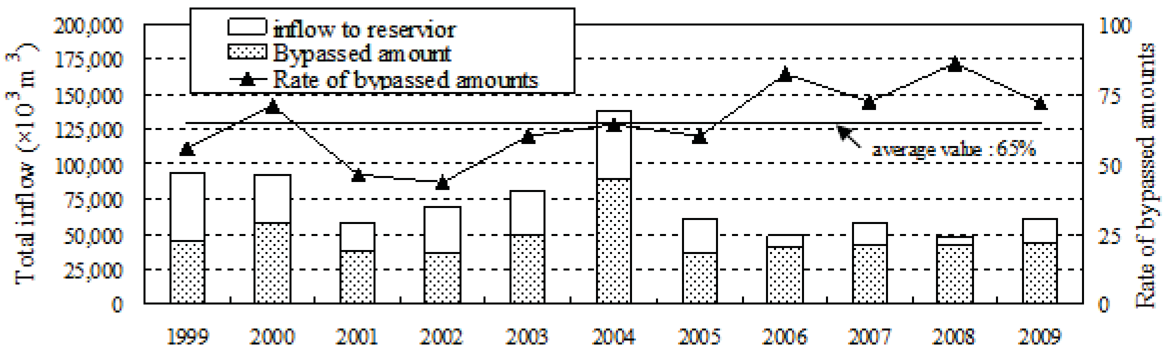
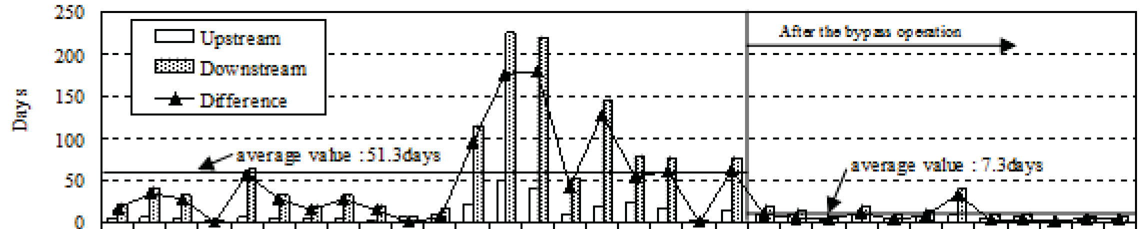


Fig. 5 Record of annual operations

- The upstream flow gauge station of the Asahi Dam Reservoir (about 4.3 km upstream from the dam) and the downstream flow gauge station (about 1.6 km downstream from the dam) are measuring turbidity once a day. The upstream and downstream stations are counting days on which the turbidity is 5 ppm or higher to evaluate the effect of the sand discharging facility in reducing prolonged turbid water. The difference in the number of days counted is evaluated as prolonged days in turbid water. As shown in Fig. 6, the prolonged days in turbid water before operating the sand discharging facility was about 50 days in average. Yet, it has been reduced to about seven days in average since the facility started operating in 1998. The scale of the prolonged turbid water which occurred in 2004 was smaller than before the operation although discharges which exceeded the annual probabilistic flood (200 m^3/s) were conducted five times.

Based on above conditions, the sand discharging bypass facility can be evaluated as effective in greatly reducing prolonged turbid water in downstream rivers.



	'78	'79	'80	'81	'82	'83	'84	'85	'86	'87	'88	'89	'90	'91	'92	'93	'94	'95	'96	'97	'98	'99	'00	'01	'02	'03	'04	'05	'06	'07	'08	'09
Upstream	5	6	5	4	6	5	5	5	4	6	10	21	49	40	9	18	25	16	1	14	10	9	2	8	5	6	8	5	6	2	1	2
Downstream	22	41	32	4	63	33	19	33	19	6	17	115	226	219	52	146	79	76	1	76	19	14	6	19	8	14	40	8	10	4	6	6
Difference	17	35	27	0	57	28	14	28	15	0	7	94	177	179	43	128	54	60	0	62	9	5	4	11	3	8	32	3	4	2	5	4

Fig. 6 Prolonged days in turbid water at upstream and downstream flow gauge stations

- In 1998, 20 years since the start of the power plant operation, the sedimentation rate of the Asahi Dam Reservoir was 4.3% which is low, meaning that sedimentation had seldom exacerbated. Yet, the intake and discharge outlet could be buried due to the progress in sedimentation in the future despite the low sedimentation rate because of the location of the intake and discharge outlet near the center of the reservoir as shown in the shape of sedimentation in the reservoir (Fig. 7). As shown in Fig. 7, the shape of sedimentation in the reservoir has seldom changed after the start of the operation of the sand discharging facility compared to before the operation. This indicates that the operation of the sand discharging facility has blocked sediment inflow to the dam reservoir.

Fig. 8 shows changes in the amount of sedimentation before and after installing the sand discharging facility. It shows that 80 to 90% of expected sediment inflow (estimated based on numerical simulations) is flowing downstream due to the sand discharging bypass facility after the start of the operation. Based on this finding, we conclude that a large amount of sediment inflow from the upstream section of the reservoir is flowing downstream of the dam without flowing in and accumulating in the dam reservoir due to the use of the sand discharging bypass facility. Also, nearly natural amount of sediment which is equivalent of the condition before the construction of the dam is being supplied to the downstream section of the dam.

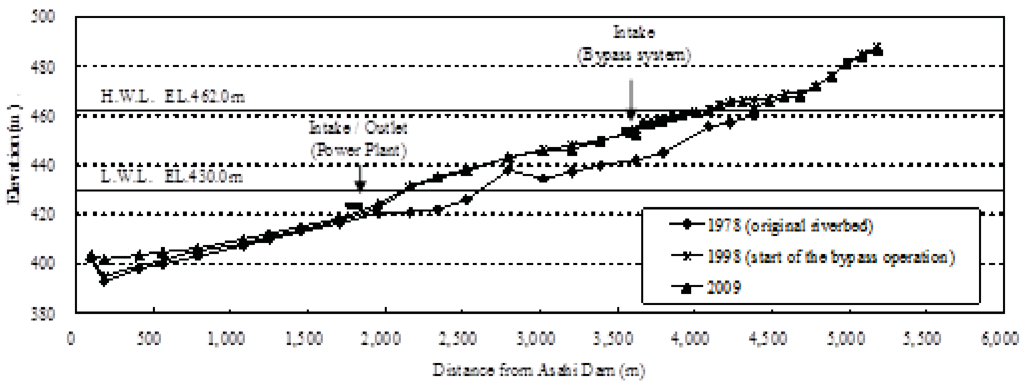


Fig. 7 Changes in the shape of sedimentation in the Asahi Dam Reservoir

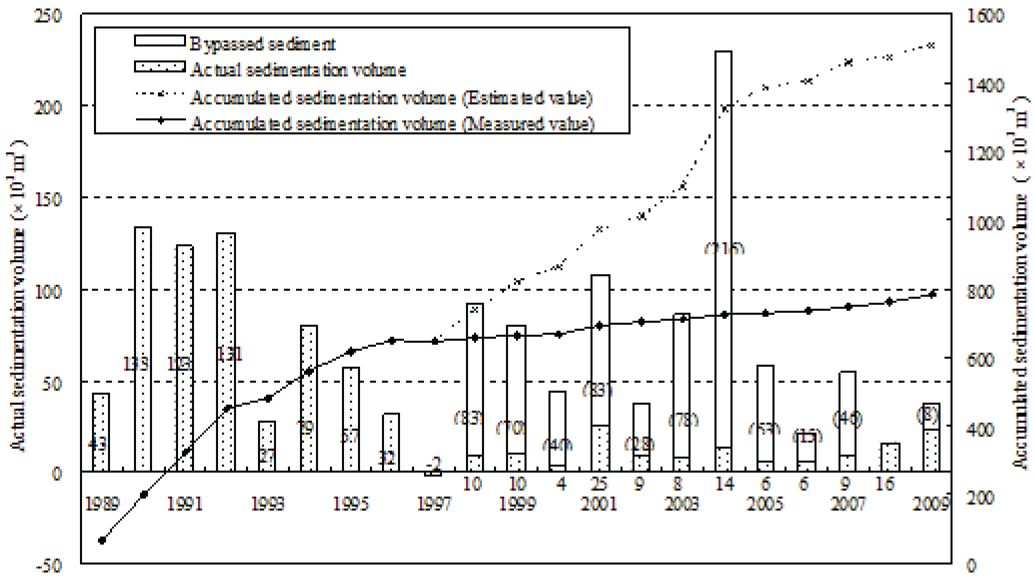


Fig. 8 Changes in the amount of sedimentation in the Asahi Dam Reservoir

6. Further Information

6.1 Reference

1) IEA/ANNEX-8: Hydropower generation: Successful cases (environmental mitigation measures and conveniences) List of successful cases of hydropower generation

KI-5 Water quality 1. Asahi Dam (IEA Implementing Agreement for Hydropower Technologies and Programmes Annex-8 Report)

2) M. Harada, et al, Operational results and effects of sediment bypass system, 20th ICOLD, Beijing, 2000.

3) H. Doi, Reservoir sedimentation management at the Dashidaira and Asahi Dams, International Workshop on Sediment Management for Hydro Projects, India, 2005.

4) H. Fukuroi, Effect of sediment bypass system as a measure against long-term turbidity and sedimentation reservoir, 23trd ICOLD, Brasilia, 2009.

6.2 Inquiries

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-f) Environmental conservation and improvement

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

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

Project Name:

Installation project of the screen which prevents descending sweetfish from entering by the new construction of the Shin-Takatsuo Power Station.

Name of Country (including State/Prefecture):

Japan, Wakayama Prefecture

Implementing Agency/Organization:

Kansai Electric Power Co., Inc.

Implementing Period:

from 1997 to 1999

Trigger Causes for Renewal and Upgrade:

(A) Degradation due to aging and recurrence of malfunction

(B) Environmental deterioration

Keywords:

Descending sweetfish, Screen which prevents fish from entering

Abstract:

The hydropower station which was located in one of the most famous sweetfish habitats in Japan was aging seriously, and so, a new power station was to be constructed. Along with the construction of the new power station, so as to reduce the impact on sweetfish, this project was conducted to install a prevention screen which prevents descending sweetfish from entering the water intake opening by means of converting some facilities including the water intake.

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

Since the Takatsuo Power Station (constructed in April, 1918, maximum output 5,800kW, maximum plant discharge 14.4m^3/s) was aging, Kansai Electric Power Co. Inc. constructed the new Shin-Takatsuo Power Station (maximum output 14,500kW, maximum plant discharge 32m^3/s) by converting some parts of the facilities (dam, water intake, headrace and others) and increased output. In May, 1997, the construction was started and the operation began in July, 1999. The specifications of the power station are shown in Table 1.

This case explains the screen, which prevents descending sweet fish from entering, that was installed at the water intake, along with the construction of the Shin-Takatsuo Power Station. (see Fig. 1)

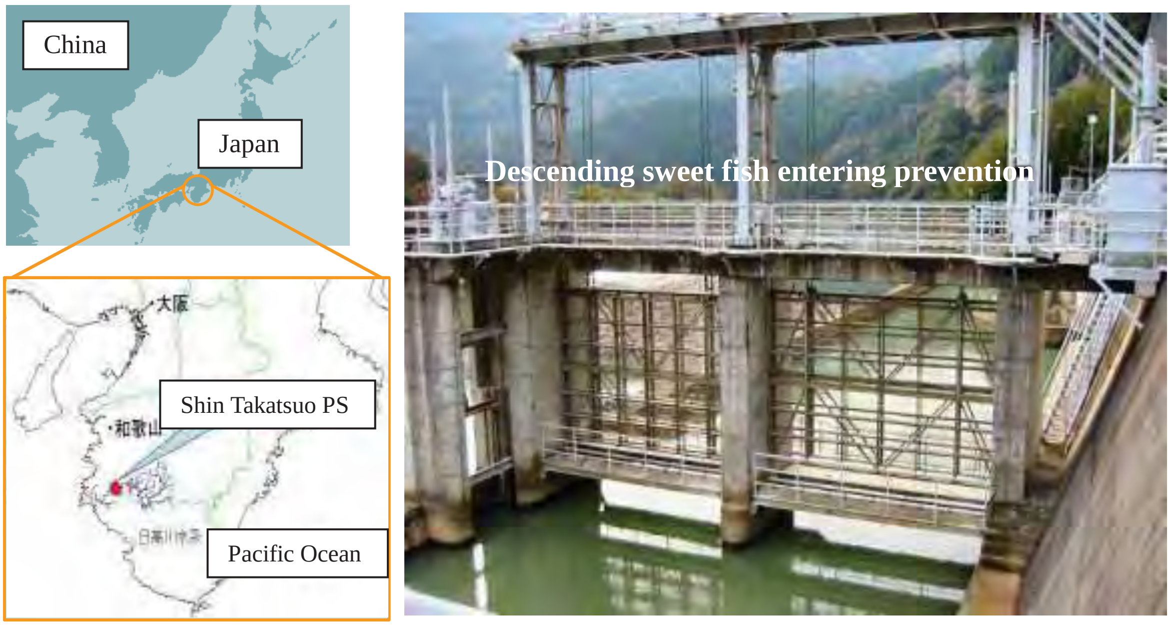


Fig. 1 The location map of the Shin-Takatsuo Power Station

Table 1 Specifications of the Shin-Takatsuo Power Station

Items		Specifications
Generation specification	Name of river	Hidakagawa water system, Hidaka River
	Name of power station	Shin-Takatsuo Power Station
	Maximum output	14,500kW
	Maximum water discharge	32.0 m^3/s
	Effective head	51.0 m (at maximum discharge)
Facilities	Intake dam	Uedahara water intake dam (gravity overflow type)
	Water intake	Lateral intake type
	Settling basin	Single flat type
	headrace	(current facility) 2,207m (new construction) 2,126m
	Penstock pipes	length 313.133m
	Discharge channel	length 23m

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

Since the Takatsuo Power Station (constructed in April, 1918, maximum output 5,800kW, maximum plant discharge 14.4m^3/s) was aging, the new Shin-Takatsuo Power Station (maximum output 14,500kW, maximum plant discharge 32m^3/s) was newly constructed by converting some parts of the facilities (dam, water intake, headrace and others) and increased output.

(B)-(b) Environmental deterioration – improvement of river enviorment

The Shin-Takatsuo Power Station is located in the midstream of the Hidakagawa River which is one of the most famous sweetfish habitats in Japan and so, the fish pass was installed in the dam to reduce the difficulty of sweetfish’s moving. With the previous fish pass, sweetfish were able to run to upstream without any problems, but when sweetfish run downstream to the river mouth so as to lay eggs, sweet fish mistakenly enter the water intake opening of the power station and pass through the channel to the water turbine, resulting in many fish deaths. For this reason, along with the construction work of the Shin-Takatsuo Power Station, the facility which prevents sweetfish from entering the water intake in error was to be installed.

(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

May 1996:	Certificate of consent for the construction was obtained from the local Hidakagawa River Fishermen's Union
June, 1996:	Certificate of consent for the construction was obtained from the local Nakatsu Village
July, 1996:	Electric Power Development Coordination Council approved the project inNo.133 session.
May, 1997:	Electricity Business Act provided approval
May, 1997:	The Takatsuo Power Station was abolished.
May, 1997:	The construction works of the Shin-Takatsuo Power Station was begun.
June, 1997:	The River Act provided approval
March, 1998:	Study of the design of the descending sweetfish entering prevention system was conducted.
July 1998 to July 1999:	The descending sweetfish entering prevention screen was installed.
July, 1999:	The completion test by the River Act was passed.
July, 1999:	The pre-operation test by the Electricity Business Act was passed
July, 1999:	The operation began

2.3 Description of Work Undertaken (detail)

1-f) Environmental conservation and improvement

The lifecycle of sweetfish is as follows: from late November to late December; Spawning season. After spawning to late March; sweetfish grow in river mouth or along the shore. From early March to early June; sweetfish run upstream. After then to mid-September; sweetfish growth phase. From mid-September to mid-December; sweetfish run down downstream to around river mouth for spawning again. This sweetfish running down to downstream is called "descending sweetfish".

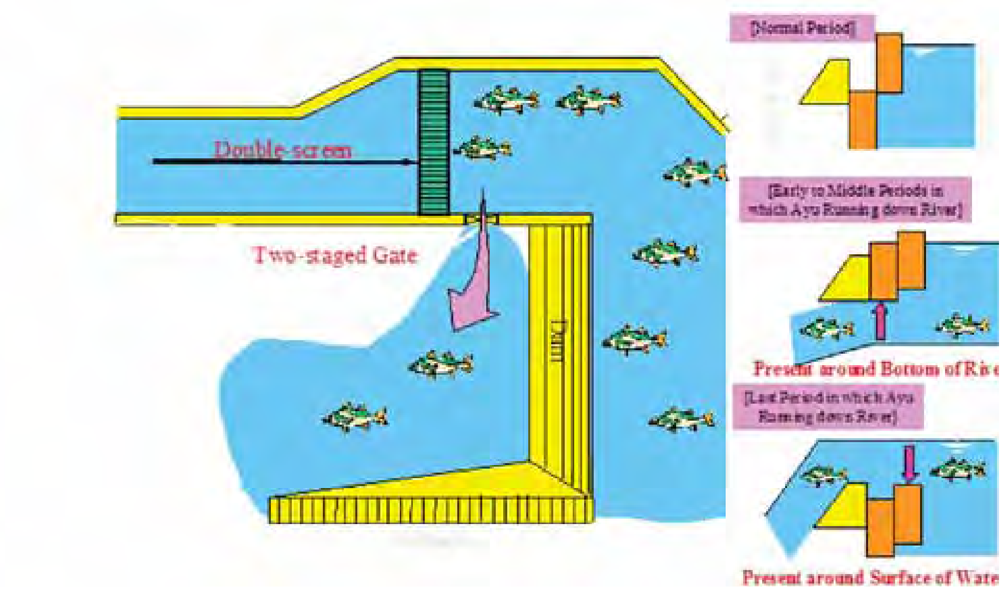
The descending sweetfish entering prevention screen was intended to prevent the descending sweetfish from mistakenly entering the water channel of the power station, and was installed on the water intake opening, and from September 1999 the operation was begun.

The screen is consists of double screens with a bar-pitch of 3cm, width of 6.20m, and height of 4.31m, and prevents descending sweetfish from entering in error. The specifications of the descending sweetfish entering prevention screen are shown in Table 2, and its conceptual diagram is shown in Fig. 2.

Table 2 The specifications of the descending sweetfish entering prevention screen

Design specifications		
Type	Lifting & lowering double screen	
Number of installation	For two spans	
Width of water channel	6.149 m (left) 6.200 m (right)	
Height of the screen	4.310 m	
Design water level difference	0.030 m	
Screen	Screen bar	ϕ 6 mm
	pitch	30 mm
	Effective mesh	24 mm
Lifting height	Sweetfish descending time	4.500 m
	Non sweetfish descending time	10.600 m
Opening and closing speed	2.0 m/min.	
Operation method	Automatic control (timer) and direct operation	

Fig. 2 Conceptual diagram



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

The double screens are lowered from early September when descending sweetfish start to run down stream, to mid-December when sweetfish descending ends. During this period, the effective mesh of the screen bar is narrow at 24mm and debris clogs the screen. Accordingly, the debris is brushed off by repeating lifting and lowering of the upstream screen and downstream screen alternately. The concept of the operation is shown in Fig. 3.

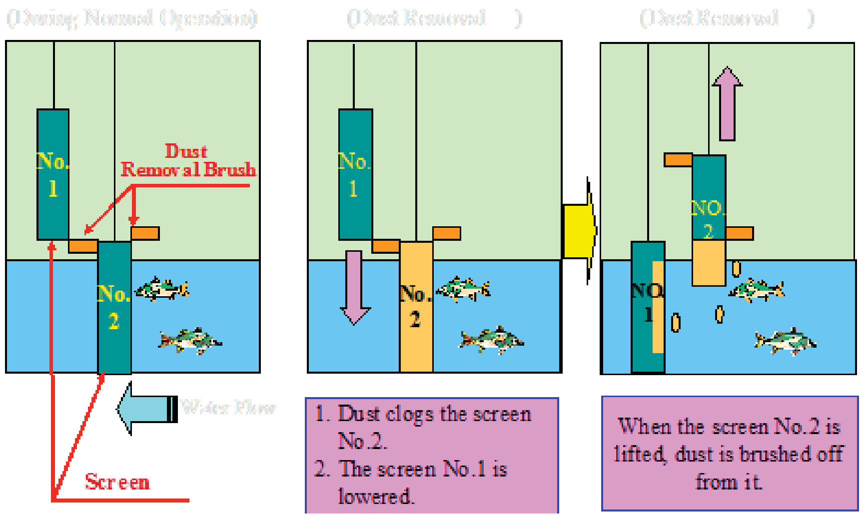


Fig.3 The operation diagram of the descending sweetfish entering prevention screen

In addition, with the descending sweetfish entering prevention screen alone, it was expected that descending sweetfish which become weak in terms of swimming capacity and evading behavior fail to take avoidance behavior so as to return to upstream of the dam, so upstream of the descending sweetfish entering prevention screen, the descending sweetfish discharge system (discharge gate) was installed.

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

Stainless steel was used for screen materials and eliminates the need of the maintenance work such as painting.

3. Feature of the Project

3.1 Best Practice Components

- This project reduce the difficulty of sweetfish migration caused by the construction of the hydropower station, and contributes to the conservation of the biogeocenosis of sweetfish in the river and helps their growth.

- By introducing the mobile type screen specific for sweetfish, it becomes possible that during descending sweetfish season, the screen is lowered in the water channel and operated, and at the time of flooding, the screen is removed from the water channel so as to avoid major debris clogging on screen, and thus, that impact on power generation has been able to be reduced to a minimum.

3.2 Reasons for Success

- As measures for preventing sweetfish from mistakenly entering, there are various ways such as sense of touch stimulation by electricity method, visual sense stimulation by color method and an acoustic sense stimulation by sound. However with these measures, once sweetfish become accustomed, the desired effect is possible to disappear. On the contrary, the double screen adopted in this case prevents sweetfish from entering physically, and its effect is permanent.

4. Points of Application for Future Project

- As for the mobile type screen, when sediment enters, there is possibility that the operation would stop by phenomena such as lifting cable loosening, and so it is necessary to take countermeasures against sediment entering.
- Descending sweetfish remaining in front of the entering prevention screen are weakened in swimming ability and escaping behavior, and so it is expected that they can’t return to the river. Therefore, it is necessary to install the system that returns the fish to the river.

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

- Though monitoring was not conducted after the installation of the descending sweetfish entering prevention screen, so far, there are not any complaints from the fishermen’s unions.
- (reference) Before the installation of the descending sweetfish entering prevention screen, during the sweetfish descending season, sweetfish which entered by mistake into the water channel of the Takatsuo Power Station were measured at fixed point by an automatic ultrasonic monitoring system (fish detector). As a result, a maximum 8,000 – 10,000 fishes per day and daily average about 2,000 fishes were confirmed. (Since this system count how many times fish pass, so from the sweetfish behavior point of view, there was a possibility that the same fish was counted several times.).

6. Further Information

6.1 Reference

- The Shin-Takatsuo Power Station Construction Work Report (1999)

6.2 Inquiries

Kansai Electric Power Company
URL: http://www.kepco.co.jp/

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

Category and Key Points

Main: 1-f) Environmental conservation and improvement

Sub: 1-a) Energy policies if countries & states

1-c) Integrated management of water resources and river systems

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

Project Name:

Sediment sluicing engineering works of the Yamasubaru and Saigo dams in the Mimikawa River System

Name of Country (including State/Prefecture):

Japan, Miyazaki Prefecture

Implementing Agency/Organization:

Kyushu Electric Power Co., Inc.

Implementing Period:

from 2011 to 2016 (plan)

Trigger Causes for Renewal and Upgrade:

(B) Environmental deterioration

(D) Needs for safety improvement

Keywords:

Measure of sediment deposition, Sediment Sluicing, Renovation of dams

Abstract:

In 2005, Typhoon No. 14 brought a record setting rainfall and caused a huge natural disaster on the widespread river basin of the Mimikawa River System by slope failure, flooding and other troubles. For this reason in October, 2011, the "Mimikawa River System general sediment control management plan" was developed so as to totally resolve the various problems such as sediment deposition at the dams, shore erosion and other problems caused by earth and sand in the Mimikawa River System. This was done with cooperation and collaboration between stakeholders of the river basin in which the river administrator (Miyazaki Prefecture) takes a central role. In order to reduce the flood damage caused by sediment deposition, the dam renovation plan, which enables sediment to pass through and recover the original river sediment flow which was prevented by the dams construction, was decided to be implemented through the dam sediment sluicing operation plan with cooperation between the Yamasubaru, Saigo and Oouchibaru dams.

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

The Mimikawa River is an important class B river in Miyazaki Prefecture which flows in the south east area of Kyushu from west to east into the Hyuganada sea. It has a total length of 94.8 km and drains a basin area of 884.1 km². Since the Mimikawa River System has a large water volume and head, from the beginning of the Showa era, construction and development of dams and hydro electric stations has been conducted. Today, Kyushu Electric Power Co. Inc., owns 7 dams and power stations with a total power output of 340,000 kw and an annual total power generation capacity of 900 million kwh in this river basin thus making this area leading hydropower generation zone in Kyushu. Locations of dams and power stations, and their specifications are shown in Fig. 1 and Table 1.

Fig. 1 Location map of water power stations

Table 1 Specifications of power stations

Items		Specifications	
Power Station	name of power station	Yamasubaru power station	Saigo power station
	maximum output	41,000kW	27,100kW
	maximum plant discharge	120m³/s	120m³/s
	effective head	40.79m(No.1, 2 system) 40.35m(No.3 system)	27.27m(No.1 system) 26.16m(No.2 system)
Dam	name of dam	Yamasubaru dam	Saigo dam
	name of river	Mimikawa River System; Mimikawa River	Mimikawa River System; Mimikawa River
	basin area	598.58km²	647.79km²
	type	concrete gravity type	concrete gravity type
	height	29.404m	19.964m
	Length of dam crest	91.140m	84.540m
Reservoir	total storage capacity	$4.194\times10^6m^3$	$2.452\times10^6m^3$
	effective storage capacity	$1.261\times10^6m^3$	$1.222\times10^6m^3$
	effective head depth	3.03m	3.33mm

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)-(a) Environmental degradation – decrease of sediment deposition

In the reservoir of the Yamasubaru dam, sediment deposition had remained constant without much increase or decrease until around 1993. After then, floods frequently occurred and the amount of sediment deposition has increased every year since. Thus, dredging had been tried so as to reduce sediment deposition. But in 2005, Typhoon No. 14 brought a huge quantity of earth and sand which had not ever been seen in past history, resulting in a huge amount of sediment deposition.

Since the inflow and deposition of sediment into the dam reservoirs are expected in the future as well, we decided to conduct a dam sediment sluicing operation and the renovation necessary for each dam's sediment sluicing operation.

(2) Improvement of value (functions)

(D)-(a) Necessity to improve safety - to improve safety

After consultation with the river administrator (Miyazaki Prefecture), dam renovation was planned and conducted with a view to improve the dam structures so as to enable the following functions: to increase the water discharge capacity to more than the existing maximum water flow (Yamasubaru: 4,110m^3/s, Saigo: 4,940m^3/s, the maximum water flow during Typhoon No. 14 in 2005) but also less than the dam design flood water level by construction works to add the sediment sluicing function to the existing dams. On this occasion dam design flood flow (Yamasubaru: 3,387m^3/s, Saigo: 3,572m^3/s) and the design flood water level were not changed.

(3) Necessity in market

(not applicable)

2.2 Process to Identify and Define Renewal and Upgrade Work Measure

December 1929:	Operations of Saigo power station began.
January 1932:	Operations of Yamasubaru power station began.
July 2001:	The basic policy of the river project of Mimikawa River System was adopted. (Miyazaki Prefecture)
June 2004:	The river project plan of the Mimikawa River System was adopted. (development of the downstream site of Mimikawa River) (Miyazaki Prefecture)
September 2005:	The Mimikawa River System was extensively damaged from Typhoon No. 14. (slope failure, flood damage)
2006:	Investigation of a plan for sediment sluicing for the dams and dam renovation works was begun.
March 2009:	The river project plan of the Mimikawa River System was changed (to add an improvement project on the upstream site of the Mimikawa River System) (Miyazaki Prefecture)
July 2009:	Technical research on the "Mimikawa River System general sand control management plan was begun. (Miyazaki Prefecture)
October 2011:	General sediment control management plan on the Mimikawa River System was adopted. (Miyazaki Prefecture)
November 2011:	Construction work on dam renovation was started.
December 2016:	Construction work on dam renovation will be completed.

2.3 Description of Work Undertaken (detail)

1- a) Energy policies of countries & states

This project aims to secure the soundness of existing hydroelectric stations and to maintain electric power generation. Also the policy of this project corresponds with the goal of the nation's energy policy (promotion of hydroelectric power development: The Agency of Natural Resources and Energy) which emphasizes the importance of water energy which is the mainstay of clean domestic energy.

1- c) Integrated management of water resources and river systems

In the river project plan of the Mimikawa River System, for implementation of the river project, "improvement of sand discharge function of power station dam" is emphasized and thus this project has a close relationship with the river system development projects whose basic policy is to promote the general improvement of flood control, water utilization and the environment.

1- f) Environmental conservation and improvement

If original sediment flow of river which was blocked by the dams was restored, it is expected to make the river basin environment, including downstream sites and the coastal area, and the ecological system, sound again by the prevention of river-bed degradation and shore erosion, and the promotion of the cleaning effects on dry riverbeds. Effects on the physical environment of the river area (downstream to ocean) and effects on inhabitants living there which might be caused by the sediment sluicing operation, will be surveyed by an environment monitoring survey in a wide area from the Yamasubaru dam reservoir to the river mouth at the ocean. Based on this information, the status of environment preservation and improvement will be confirmed through consultation with the "Evaluation and improvement committee on the Mimikawa River System general sediment control management" which was established by the river administrator (Miyazaki Prefecture).

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

We have repeated discussion and consideration on the sediment deposition problems of dams which is becoming more serious year by year with national organizations, academic institutions and the various watershed stakeholders such as Miyazaki Prefecture. As a result, with a view to recover the original sediment flow which had been blocked by dams and to balance the safety of the river, water utilization and preservation of river environment, the "Mimikawa River System general sediment control management plan" was adopted which conducts the sediment sluicing operation through the collaboration between the Yamasubaru, Saigo and Oouchibaru dams. The sediment sluicing operation of dams means the operation, which passes sediment which flows into the dam from up stream, by the following actions; when a flood is expected from a typhoon, to lower the water reservoir level in advance so as to close it to original river status, and by that action to pass sediment flowing from up stream through the dam to downstream (Fig. 2).

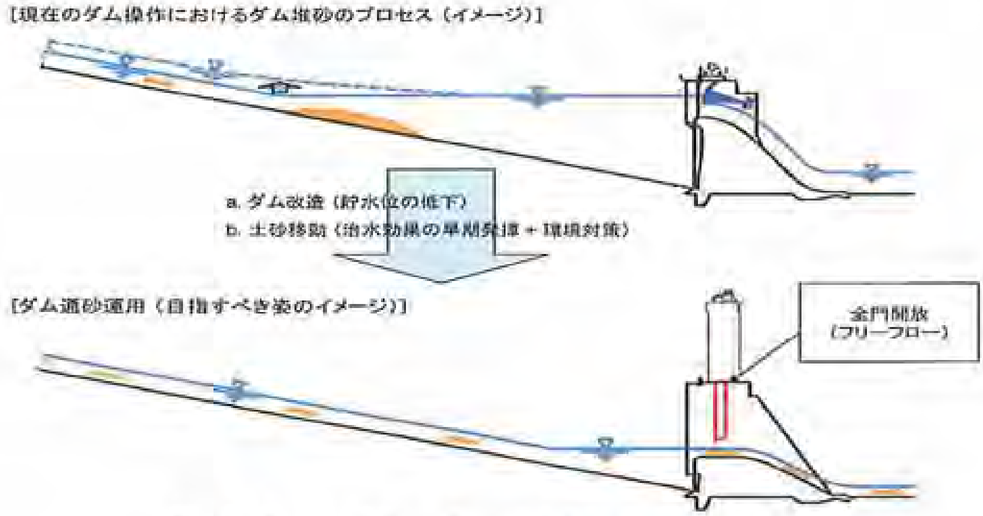


Fig. 2 Image of the sediment sluicing operation of dam

- For the Yamasubaru and Saigo dams it is not possible to lower the water level to the point necessary for the sediment sluicing operation with the existing structure. Therefore, dam renovation will be conducted by reducing the height of the existing dams partially in a range which doesn't negatively affect the dam structure, to add the sediment sluicing function. Such a dam renovation which adds a new sediment sluicing function to the existing dams which have been in use for 80 years is the first trial even in Japan. Incidentally, as for the Oouchibaru dam located at the most downstream site, the height of dam is already low and since it is possible to conduct the sediment sluicing operation with the current structure, dam renovation will not be conducted.

- The shape of the cut down for dam renovation is the most important factor which determines the sediment sluicing effects. Therefore, it is necessary to totally evaluate the cut down shape from the point of view of the safety of the river, environment conservation and effect on power generation. With regard to the Yamasubaru and Saigo dams, in 2005 overflow of the dams occurred due to a huge rainfall from Typhoon No. 14, therefore the shape of the cut down of the dam structures was designed on the condition that existing maximum water flow (Yamasubaru: 4,110m^3/s, Saigo: 4,940m^3/s, the maximum water flow from Typhoon No. 14 in 2005) would pass through within the dams' design flood water level.

- In the design of the shape of cut down for dam renovation, as one part of the total evaluation of the effects on the river safety, environment preservation and power generation index, the sediment control cost shown in the formula (1) is introduced.

$$Cm = (Cd+Cs+Ce+Cp)/V \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad \text{formula (1)}$$

Where: Cm = sediment control cost, Cd = dam administration cost, Cs = expenditure on measures to deal with flood, Ce = environmental cost, Cp = cost of the reduction of generated electricity, and V = volume of sediment which passes through the dam

- As a result of these considerations, it is confirmed that the optimum measure for the Yamasubaru dam is to cut down the height to overflow the top by about 9.3m by removing 2 existing central spillway gates, and the optimum measure for the Saigo dam is to cut down the height to overflow the top by about 4.3m by removing 4 existing central spillway gates. Images of the final dam renovation of Yamasubaru dam and Saigo dam are shown in Fig. 3.

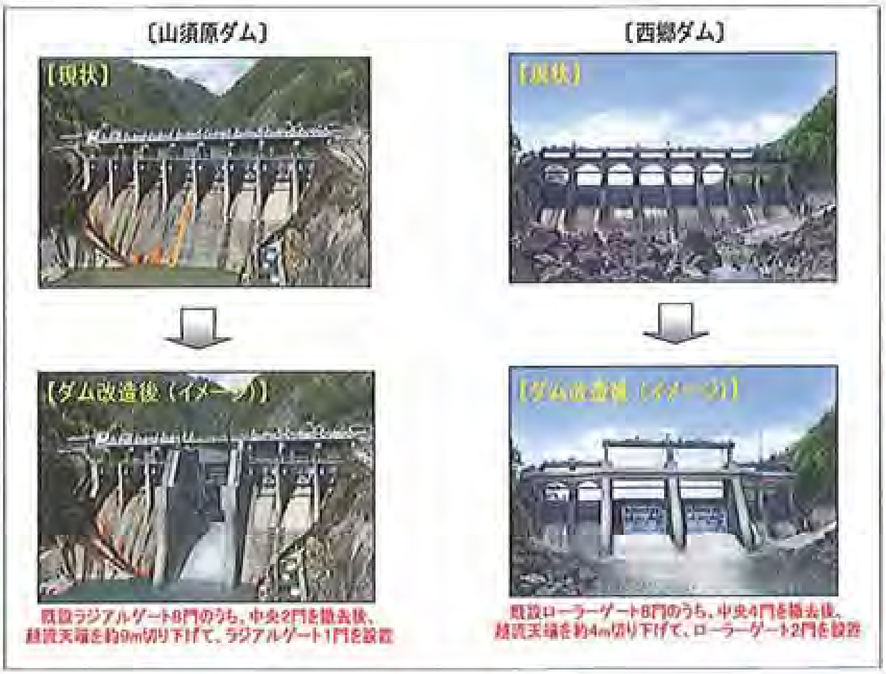


Fig. 3 Images of dam renovation

- Renovation work on the two dams was started in November, 2011, and completion is planned in about 5 years by December, 2016. In principle, renovation work is conducted in the time period from November to May when water isn't discharged through the dam's gates. Renovation work is conducted by installing a temporary cofferdam upstream of the dam, and diverting the flowing water through the headrace to continue generating power. Furthermore, in the main renovation work, even while conducting the renovation, it is necessary to be able to discharge dam water safely when floods occur the same as usual, therefore, it was determined that a makeshift gate (Steel-Rubber Gate) of 4m, which is the first case in Japan, is planned to be installed on the top of the temporary cofferdam (Fig. 4).

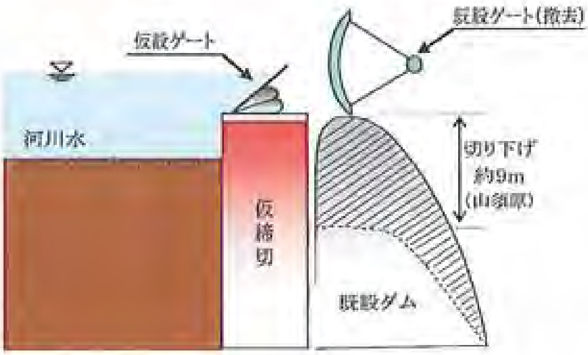


Fig. 4 General concept of temporary cofferdam to be installed upstream by dam renovation work

3. Feature of the Project

3.1 Best Practice Components

- Measures on sediment deposition for dams and rivers

3.2 Reasons for Success

Miyazaki Prefecture, that is, the river administrator, has pursued integrated sediment control management so that sediment flow in the whole basin from the mountain district to the dams, river and shore can be controlled. This is done by recognizing the various problems of the whole basin caused by sediment in the water system from the point of view of the safety of the river, water utilization and river environment preservation, and not focusing only on individual problems.

In implementing these projects, it is important to decide the goal to pursue which needs to be shared and to define the sharing of roles so as to achieve the targeted goal, and so, many stakeholders in the water basin are involved. Therefore, by sharing information on the problems and subjects of sediment which the basin has, through the cooperation and collaboration between basin relevant local sectors, public administration and private sectors by considering solving the total sediment control problems, in October, 2011 the "Mimikawa River System general sediment control management plan" was adopted.

From now on, we plan to pursue and continue the measures which aim to recover the Mimikawa River with the close cooperation of concerned parties of the whole basin while annually evaluating and improving the implementation status and their effects of individual projects based on this project.

4. Points of Application for Future Project

(View point of the river environments)

- Impact on rivers such as the occurrence of turbid water caused by the sediment sluicing operation (drawdown) needs to be small
- Occurrence of scouring of river banks and revetments caused by the sediment sluicing operation (drawdown) needs to be small

(View point of the construction cost increase)

- It is necessary to construct large temporary structural objects such as temporary cofferdams so as to renovate the existing dam installed on rivers
- Construction schedule becomes relatively long because work is conducted only for the time period when water is not discharged.

(View point of the operation)

- Decrease of electricity generated caused by the sediment sluicing operation (drawdown) needs to be planned for.

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

After the sediment sluicing operation started, sand and gravel which wasn't flowing smoothly before began to flow nearly as its original natural flow. In order to evaluate and understand these environmental changes, periodically, in cooperation with Miyazaki Prefecture since November, 2007, we have been conducting environmental monitoring for water quality, conditions of the river bottom, fishes, attached algae and others.

The environmental monitoring is planned to continue to be conducted in the future as well so that their findings will be utilized adaptively on the sediment sluicing operation of the dams, the removal plan of sediment from reservoirs and others.

6. Further Information

6.1 Reference

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2) T. Yamashita, M. Kaku, Y. Yamagami "Verification of adaptability of Reservoir of Oouchibaru Dam for the Dam Sediment Sluicing Operation Plan" *Journal of Electric power Civil Engineering*, volume 353 (2011)

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4) R. Maehata, K. Yamaguchi, and T. Shibata "Renovation Plans of Yamasubaru Dam and Saigo Dam for the Dam Sediment Sluicing Operation Plan in Mimikawa river system" *Journal of Electric power Civil Engineering*, volume 361 (2012)

6.2 Inquiries

Kyushu Electric Power Co

URL: http://www.kyuden.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-f) Environmental conservation and improvement

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

Project Name:

Expansion Project of Surface Water Intake Equipment and Limpid Water Bypass Tunnel at Nishiyoshino No. 1 and 2 Hydropower Stations

Name of Country (including State/Prefecture):

Japan, Nara Prefecture

Implementing Agency/Organization:

Electric Power Development Co., Ltd.

Implementing Period:

from 2007 to 2011

Trigger Causes for Renewal and Upgrade:

(B) Environmental deterioration

Keywords:

Countermeasure for Turbid Water in Reservoir, Surface Water Intake Equipment, Limpid Water Bypass Tunnel

Abstract:

In recent years, due to extensive flooding, the Sarutani Reservoir problem in which turbid water continued for a long period became recognized. Especially in 2004, several typhoons struck the area and caused severe flooding, and from June for about half a year, in the Kinokawa River and its subsidiary stream the Nyukawa River, muddy water flow continued. Consequently it was even discussed as to whether or not to stop the water sharing from the Sarutani Reservoir. For these reasons, we had repeated meetings and consultations with the local governments and related organizations. As a result, it was decided that as a countermeasure to reduce the muddy water from the Kinokawa River which is the main source of long periods of turbid water, surface water intake equipment was installed on the water intake of the Sarutani Reservoir. For the downstream subsiding area of the Kurobuchi Dam in the Nyukawa River, a limpid water bypass tunnel was also to be installed. As the water inlet for this bypass tunnel, the open inlet of the upstream regulating reservoir located at a site above the Nishiyoshino No. 1 Hydropower Station was to be used.

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

The Nishiyoshino No. 1 and 2 Hydropower Stations were constructed as a part of the Totugawa & Kinokawa River Integrated Development Project upstream of the Shinmiyagawa water system by constructing the Sarutani Dam (height: 73.2m, concrete gravity type). This project, as a generation business, has participated in a water sharing project which utilizes the river system for irrigation, water supply and industrial water over the range of Nara, Wakayama Prefecture, by changing the basin into the Kinogawa River system, Nyukawa River with a headrace tunnel (length: 9,613.5m). The Nishiyoshino No. 1 Hydropower Station (maximum output: 33,000kW) and the Nishiyoshino No. 2 Hydropower Station (maximum output: 13,100kW) have a total of 46,100kW maximum output and annually generate electricity of about 163 million kWh. The Nishiyoshino No. 1 Station utilizes a head of 231.3m created by this basin change. The Nishiyoshino No. 2 Station utilizes a head of 77.4m through the headrace tunnel (length: 4,994.4m) which has been created by the construction of the Kurobuchi Dam (height: 13.5m, concrete gravity type) at a point 1.1km apart from the No. 1 station, and by adding Nyukawa River's flow to the water flow (maximum: 16.7m^3/s) from the No. 1 station.

Out of the generation facilities of the Nishiyoshino No. 1 Hydropower Stations, Sarutani Dam, Sarutani Reservoir, Kawarabikawa River subsidiary channel, Sakamoto water intake, and some parts of the headrace, ownership is shared by the Ministry of Land, Infrastructure, Transport and Tourism and Electric Power Development Co., Ltd. Sarutani Dam, Reservoir and Kawarabikawa River subsidiary channel are under the jurisdiction of the Ministry of Land, Infrastructure, Transport and Tourism, and the Sakamoto water intake and some parts of the headrace are under the jurisdiction of Electric Power Development Co., Ltd.

The specifications of the hydropower stations are shown in Table 1. The location map of the hydropower stations, brief diagram of basin and vertical cross-sectional view of rivers are shown in Fig. 1, 2 and 3.

Table 1 Specifications of the power stations

	Nishiyoshino No. 1 Hydropower Stations	Nishiyoshino No. 2 Hydropower Stations
Operation start date	November, 1956	September, 1955
Generation type	Dam waterway type	Dam waterway type
Approved output	33,000kW (16.7m^3/s)	13,100kW (20.0m^3/s)
Name of dam (height)	Sarutani Dam (73.2m)	Kurobuchi Dam (13.5m)
Effective head	231.3m	77.4m
Effective volume	17.3 million m^3	106 thousand m^3

Fig. 1 Location map of the power station

Fig. 2 Brief diagram of the basin

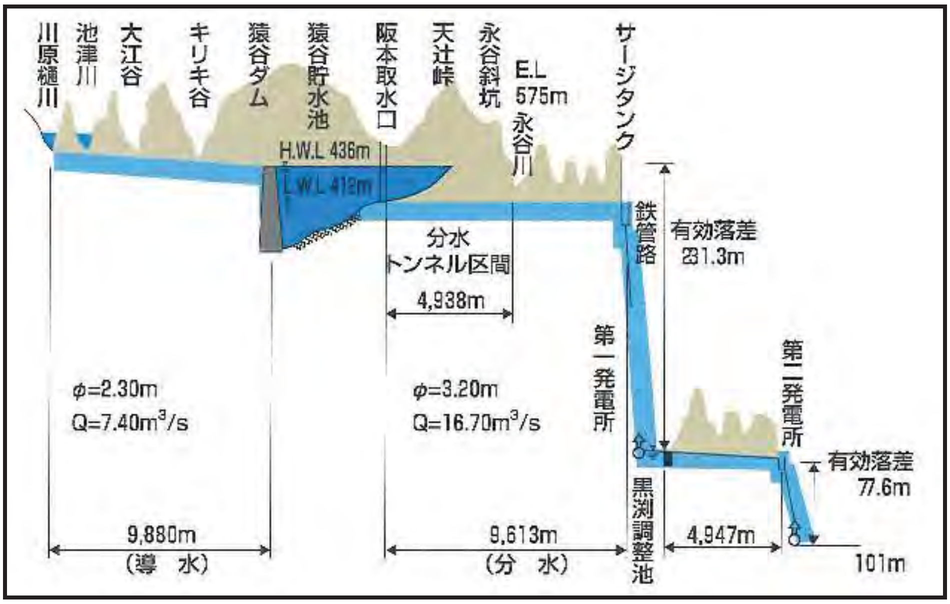


Fig. 3 Vertical cross-sectional view of rivers

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 the river environment

The Sarutani Dam was constructed with the purpose of supplementary feed to the Kinokawa water channel (agricultural water) and the hydropower stations. Water from the Sarutani Reservoir (Totugawa River side) flows through the Nishiyoshino No.1 Hydropower Station to the Kurobuchi regulating reservoir (Nyukawa River) so as to share water. Water holds there for a while and then flows further through the Nishiyoshino No.2 Hydropower Station and then is finally discharged to the Nyukawa River. Thus, if muddy water in the Sarutani Reservoir continues for a long period, the river maintenance flow from the Kurobuchi Dam also becomes muddy for a long period.

Since the extensive flood occurred in 2001 and 2004, muddy water kept flowing for about half a year. Consequently, the river environment of the subsiding area deteriorated, and strong improvement requirements were submitted. For these reasons, we had repeated meetings and consultations with the local governments and the related organizations. As a result, it was decided that as a countermeasure to reduce the muddy water, on the Sakamoto water intake of the Nishiyoshino No. 1 Hydropower Station, surface water intake equipment was installed, and the limpid water bypass tunnel was to be installed by a detour route. The limpid water bypass tunnel was intended to move the clear water, instead of the existing maintenance flow discharge system, to just beneath the Kurobuchi Dam by in-taking water directly from the Nyukawa River (Kurobuchi regulating reservoir inlet) which is located upstream of the outlet of the Nishiyoshino No.1 Hydropower Station from which the shared water from the Sarutani Reservoir is discharged, when muddy water continues to flow for a long period.

The main specifications of the surface water intake equipment are shown in Table 2. The overall view is shown in Fig.4, the main specifications of the limpid water bypass tunnel is in Table 3, the plan view of the tunnel is shown in Fig.5, and the vertical section is shown in Fig.6.

Table 2 Main specifications of the surface water intake equipment

Type	Steel, 3 stage roller gate (with safety gate), one gate
Intake range	HWL436.000 - WL422.000 (surface intake range)
Door body dimension	clear span 5.000m× door height 25.75m
Foundation height	EL405.850m
Opening/closing gear	Automatic wire rope winding type (one for each upper and lower door)
Pump head	At intake time 14.0m、at inspection time: 22.136m
Intake flow	Maximum 16.7m^3/s
Intake depth	3.4m
Design water depth	3.0m、operation water depth 1.0m
Water seal type	Front three side rubber water seal
Accessories	Break equipment

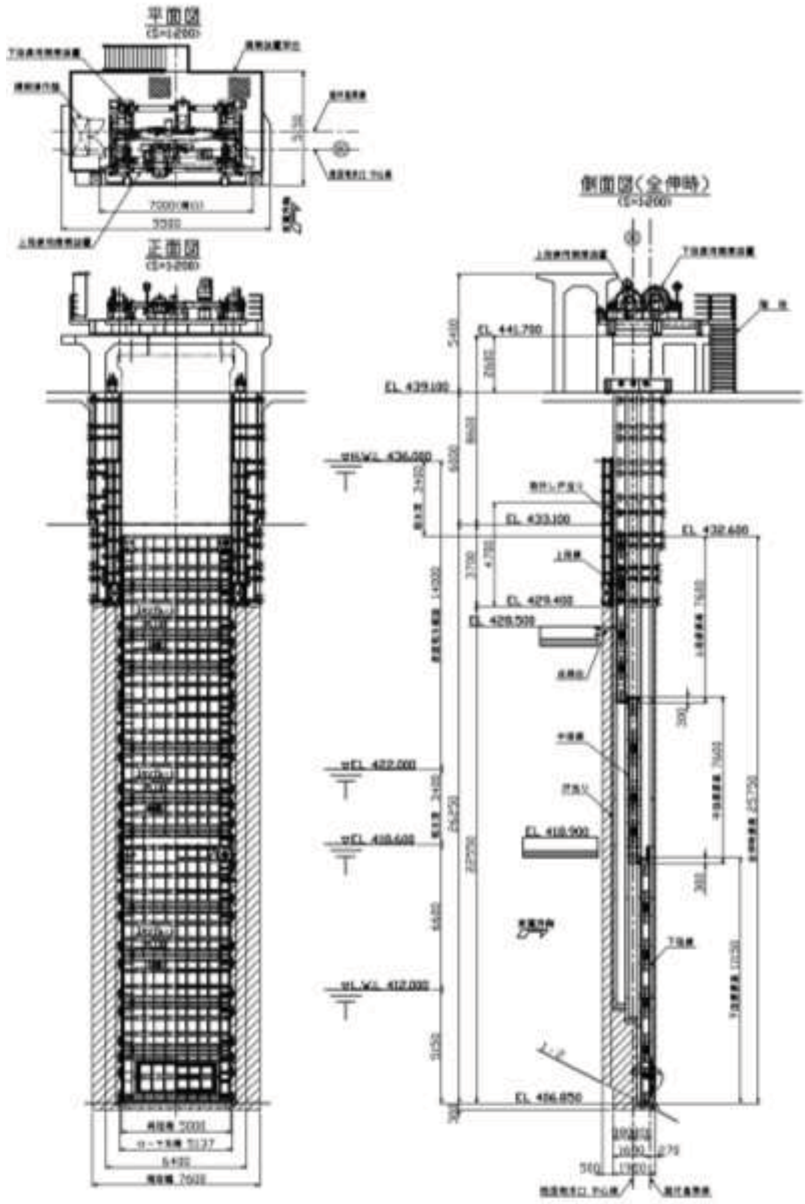


Fig. 4 Three view drawing of the surface water intake equipment

Table 3 Main specifications of the limpid water bypass tunnel

Items	Specifications
Intake method	Run-of-river type
Waterway facilities	Length：about 400m Inner diameter：0.4m Difference of elevation：about 8m Conduit：high-density polyethylene pipe Discharge flow：0.3m^3/sec
Intake facility	Steel gate, one gate
Discharge facility	Steel gate, one gate; slice valve, one valve

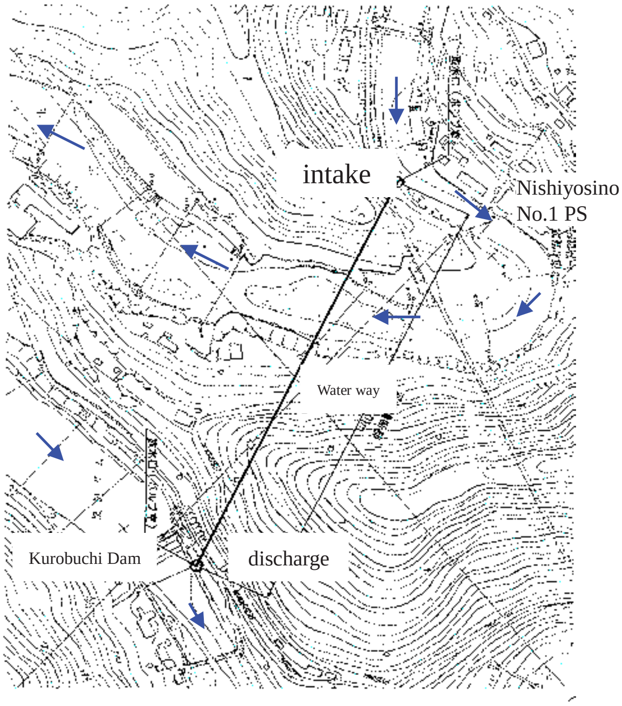


Fig. 5 Plan view of the limpid water bypass tunnel

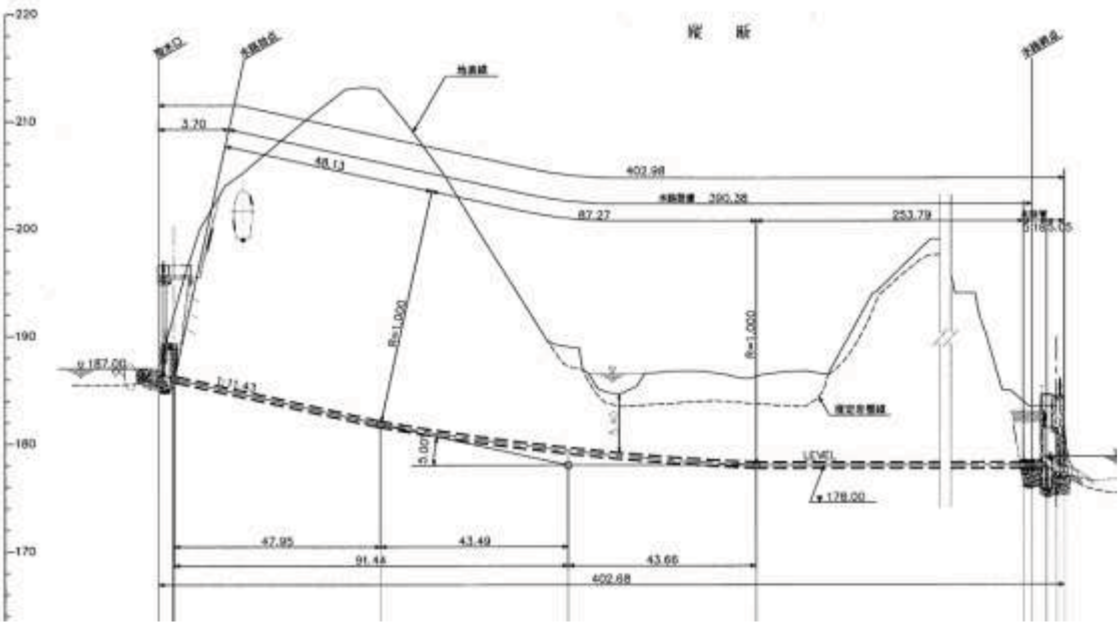


Fig. 6 Vertical section of the limpid water bypass tunnel

(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

September 1955:	The operation of the Nishiyoshino No. 2 P.S. (existing station) began
November 1956:	The operation of the Nishiyoshino No. 1 P.S. (existing station) began
October 2007:	The construction work for the limpid water bypass tunnel began
February 2009:	The installation work on the surface water intake equipment on the Sakamoto intake began
March 2009:	The construction work on the limpid water bypass tunnel was completed.
May 2011:	The installation work on the surface water intake equipment on the Sakamoto intake was completed

2.3 Description of Work Undertaken (detail)

1-f) Environmental conservation and improvement

(1) Surface water intake equipment

Nishiyoshino No. 1 Hydropower Station has to supply agricultural water downstream and needed to reduce muddy water while maintaining a constant amount of water intake from the Sarutani Reservoir. It was judged that adoption of the surface water intake system can reduce by half the time of period for muddy water (turbidity more than 20ppm) continuing from the discharge outlet of the Nishiyoshino No. 1 Hydropower Station, and also reduce more than 70% of the soil particles in the discharging flow. Thus, the surface water intake system can produce a large effect on the problem of muddy water flowing for a long period.

(2) Limpid water bypass tunnel

This limpid water bypass tunnel can intake water from the Nyukawa River, upstream of the Nishiyoshino No. 1 Hydropower Station outlet (Kurobuchi regulating reservoir inlet), from which the shared water from the Sarutani Reservoir is discharged. Therefore, when muddy water in the Sarutani Reservoir continues for a long time, by discharging clear water from upstream of the Nyukawa River directly to a point of just below the Kurobuchi Dam by changing the system from the existing river maintenance flow to this bypass system, the reduction of the problem of long periods of muddy water is intended to be resolved by this water sharing.

By means of the limpid water bypass tunnel, the reduction effect on the problem of muddy water continuing for long periods was surveyed for the past 10 years (from 1999 to 2008). As a result, the time period of muddy water occurrence in which the turbidity is more than 15ppm was able to be reduced by more than 60% of the annual average, and so it was judged to be effective.

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

(1) The surface water intake equipment

Before the installation work on the surface water intake equipment, brief explanation of the existing sill which was necessary to be removed is provided here.

By adjusting to the limited water level of the reservoir, as for the existing sill structure, in the first phase, the crest of EL433.1m - EL420.6 m was divided into 7 parts (left & right banks total =14 blocks), and in the second phase, the part from EL420.6m to the bottom was divided into 6 parts (left bank= total 12 blocks) and the removal work was conducted.

First, the metal part of the existing sill structure was cut by gouging in alignment with the parting line, then furthermore cut by core drilling + wire saw method. This resulted in about 2.0t blocks which were removed by electric hoist. The work capacity of the core boring per day was 9m/ day for a ϕ150mm hole, that is, 4.5m/ day machine (half side) x 2 days. Including wire saw work, one block was removed for about every 5 days. Discharge water created by the core boring works was received by the lower pan, pressure fed to a simple muddy water treatment system by a high-lift pump ($5m^3/h$) where SS treatment and PH treatment were conducted.

The appearance of the work is shown in Photos 1 to 4.

Photo. 1 Core boring

Photo. 2 Hoisting of the cut hole cores

Photo. 3 Wire saw working

Photo. 4 Hoisting of the blocks

(2) The limpid water bypass tunnel

For the construction of the waterway, the arc propulsion method which possibly could shorten the construction schedule versus the other methods was adopted. With regard to the arc propulsion method, the first excavation (pilot excavation) was conducted from the water inlet upstream toward the discharge outlet using pipe diameters of ϕ311mm and ϕ251mm. Afterwards, by a second excavation, the tunnel was widened to the final diameter of ϕ610mm. A brief explanation of the arc propulsion method is shown in Fig. 7, and a brief explanation of the excavation method is shown in Table 4.

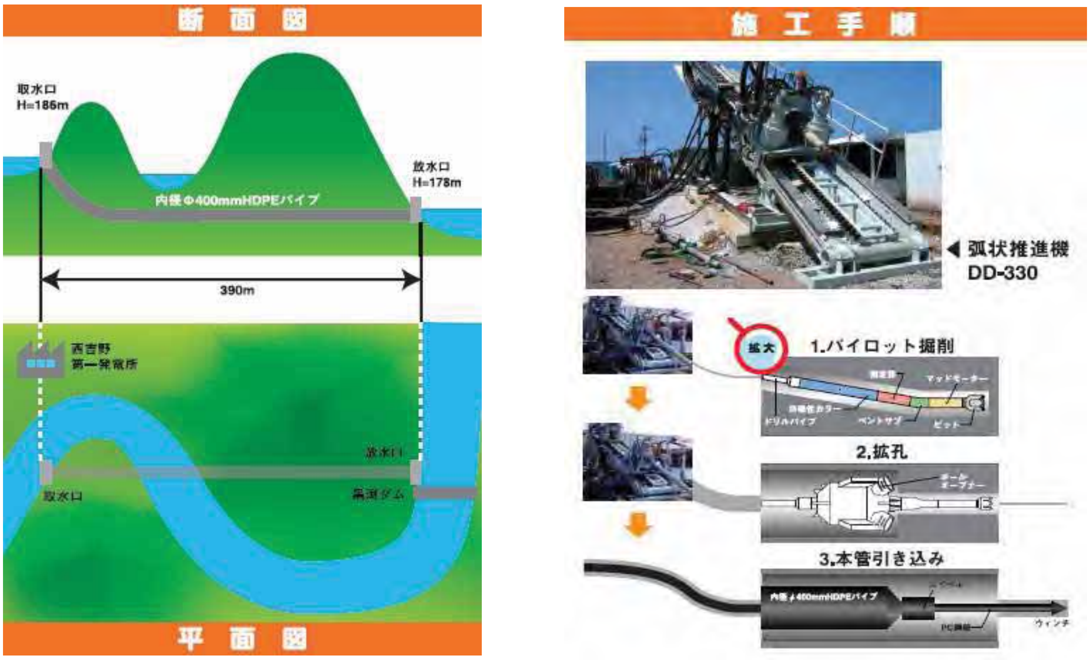


Fig. 7 Brief explanation of the arc propulsion method
(Reprint from the material of Japan Drilling Co., Ltd.)

Table 4 Brief explanation of the excavation method

	Semi-sealed method	Arc propulsion method
Summary	-by semi-sealed tool attached on a top of the pipe, a face excavated is conducted, and a pipe is propelled by a jack attached on the reaction wall. - since there is a reaction wall, a vertical shaft is not necessary - possible to work on hard rock by exchanging bits	- first, horizontal excavator with an excavation position control system excavate a hole of small diameter, after then expanded to the necessary diameter, and then pipe is pulled in. - since an excavator is placed on the ground, so vertical shaft is not necessary - possible to work on hard rock by exchanging bits
Actual performance	- water supply and sewerage systems - diameter 800 - 3000mm	- pipeline (water line, communication cable etc.) - diameter 100 - 350mm for hard rock: 220mm

For the pipe line, from the construction work point of view, flexibility and adequate pull strength is required and at the same time, as a material, abrasion resistance, corrosion resistance and decay resistance is required. Consequently, high-density polyethylene pipe was adopted.

The high-density polyethylene pipes were welded to form one pipe 420m long (10m/one pipe) by butt joint welding on the road shoulder adjacent to the water intake (see Photo 5). The welded pipe line was conveyed to the point of the water intake by a cradle with casters, and there, by the jack placed on the discharge outlet, the steel line which was connected with the pulling device attached on the top of the pipe, was pulled in gradually until all pipe was inserted. The work was completed in one day (about 10 hours).

While pulling the pipe, to reduce the friction between the tunnel wall and pipe and to protect the pipe, the inner surface of the tunnel was filled with mucky water. After the pulling work was completed, the mucky water was removed. In order to inspect the pipe inner for conditions such as distortion, existence of foreign matter, and others, a “pig” (tubular shape form) was forced to pass through the pipe with water pressure from the intake opening to outlet opening and the soundness of the pipe line’s cross-section was confirmed. After insertion work was completed, the space between the bypass pipe and the tunnel’s interior was filled with mortar so as to prevent the pipe from the damage caused by landfall and to prevent the pipe from vibrating.

Photo 5 View of the pipe pulling in the works

3. Feature of the Project

3.1 Best Practice Components

(1) Surface water intake equipment

This project was the reconstruction of the existing facilities, and conducted under restricted conditions such as a tight work schedule, water levels at the reservoir, etc., and also the work was conducted in a confined space, that is, the main work was conducted only in the water intake tower and its periphery. But even so, the construction work was able be completed successfully by the originality and ingenuity for the working methods including temporary facilities.

(2) Limpid water bypass tunnel

The high-density polyethylene pipe, which is rarely used for hydropower station facilities, was adopted for the waterway material.

The construction work of this limpid water bypass tunnel was very difficult work which excavated the tunnel in a horizontal direction and also in an arc with the boring machine with a large diameter, requiring high accuracy for reaching the required position. In the actual construction, though the pilot excavation had difficulty because of sectional geological variations, this limpid water bypass tunnel was able to be completed and since then, has contributed to the improvement of the river environment

3.2 Reasons for Success

In the district where the long-lasting muddy water problem became apparent, the business owner who operates and manages the reservoirs and regulating reservoirs is required to improve these problems for the local communities more than in the past because of the rising of environmental consciousness. In addition, in recent years, huge floods and the severe storms have occurred frequently, and thus the countermeasures for river environment improvement have become one of the big issues for the operators.

This project was the case example to handle a long lasting muddy water problem in reservoirs by installing surface water intake equipment and a limpid water bypass tunnel, and such facility measures by itself was not remarkable.

However, in this project, these facilities had to be constructed after the operation of the power station started, and the construction work had to be conducted under many restrictions such as close affinity with the existing facilities, restricted reservoir water level operation conditions, and so well-considered design and implementation plans were absolutely required. The reason why this project succeeded was that under the condition in which the majority of the existing structural objects were used, various restricted conditions were studied and their consideration was reflected in the actual field construction work. Besides, consultations with the local governments and the related organizations were repeated and their understanding of this project was obtained, making this one reason for success.

4. Points of Application for Future Project

In the period of the installation work of the surface water intake equipment, in order to keep inside of the water intake tower dry, in front of the intake screen, a makeshift closure was installed. The crest height of the makeshift closure was set at EL423.0m (gate height: 14m), the dam water level restriction was set at EL418.5m, and the installation work was conducted. The structure was 9 pieces of steel beam flash board, and the spaces between gates were filled with epoxy resin making it possible to secure the structure without any leakage. However, during the construction work, serious flush incidents occurred twice, and the stored water overflowed the makeshift closure’s crest submerging the inside resulting in a major negative impact on the construction work schedule.

It is obviously very important to make a well-considered plan for the facilities which are directly related with the construction of the main system body which is the object of the work. Besides in addition, making a detail plan for working in the temporary facility is also necessary.

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

(1) Limpid water bypass tunnel

After the installation of the limpid water bypass tunnel, its actual annual operations from 2010 to 2012 (as of October) by year are as follows; in 2010, once, in 2011, 8 times, in 2012, 7 times (as of October). By discharging the clear water at a point just below the Kurobuchi Dam through this limpid water bypass tunnel, the river environment has been improved.

(2) Surface water intake equipment

After the installation of the surface water intake equipment, with a view to verify its effect, as shown in Fig. 8, at 4 sites, that is, the Sakamoto water intake, the discharge outlet of the Nishiyoshino No. 1 Hydropower Station, the discharge outlet of the Nishiyoshino No. 2 Hydropower Station and the Nishiyoshino weir, the turbidity was measured. The change in the turbidity and water temperatures are shown in Fig. 9, and from this, it became apparent that after the operation of the surface water intake equipment, reduction of the turbidity and the increase of the temperature are shown, and it became obvious that the expected effects were achieved.

Fig. 8 Location map of the measurement sites

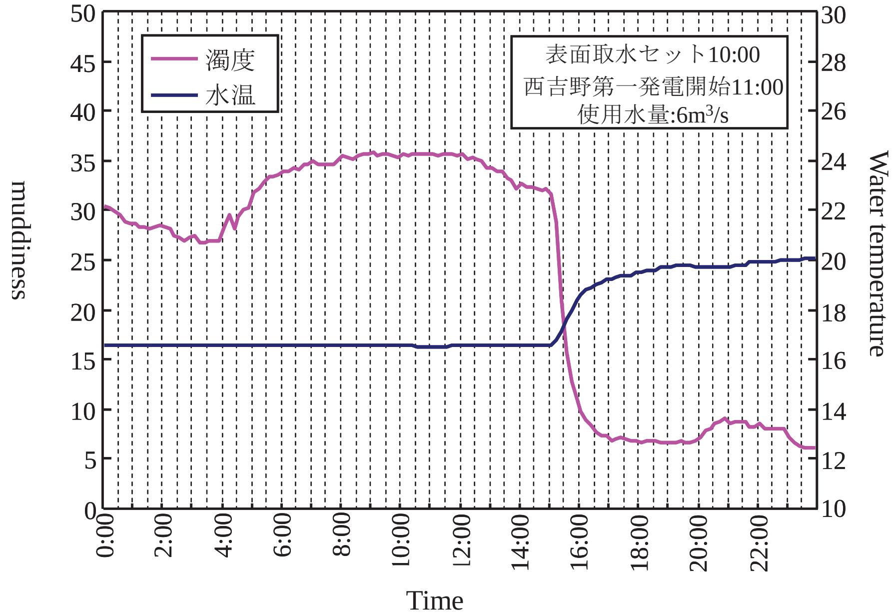


Fig. 9 Change in the turbidity and water temperatures at the discharge outlet of the Nishiyoshino No. 1 Hydropower Station

6. Further Information

6.1 Reference

1) Yamamoto, Nieda, and Wakamatu "The plan, design and construction of the Limpid Water Bypass Tunnel at the Kurobuchi Dam of the Nishiyoshino No. 2 Hydropower Station", *Journal of Electric Power Civil Engineering*, volume 342 (July, 2009)

6.2 Inquiries

Electric Power Development Company

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

ANNEX-11 Renewal and Upgrading of Hydropower Plants

Case History Format for the 2nd Round Data Collection

Category and key points:

Main: 2-a) Technological innovation, deployment expansion for electrical and mechanical equipment

Project name:

Redevelopment of Shin-Nogawa-No.1 hydropower plant

Country and region:

Yamagata, Japan

Implementing organization:

Yamagata Prefectural Public Utilities Bureau

Implementing period:

2004-2010

Reasons for renewal and upgrade:

(C) Needs for higher performance

(E) A necessity for the third party's factor

Keywords:

hybrid servo system, redevelopment

Abstract:

Shin-Nogawa-No.1 hydropower plant has a vertical Deriaz turbine (VD) of 10,000 kW of outputs. On the purpose of laborsaving of maintenance, we adopted a new type of electrically-operator servomotor system (hybrid servo) for the control of movable guide vane and runner vane, which has advantages of an electric servomotor solution over an oil pressure system.

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

Shin-Nogawa-No.1 hydropower plant was built by the Yamagata Prefectural Public Utilities Bureau was built in Nagai-city, Yamagata, with construction of Nagai Dam of the Ministry of Land, Infrastructure, Transport and Tourism (Hereinafter, it is indicated as “MLIT”). According to construction of the Nagai dam, the Kanno dam which the dam of Nogawa-No.1 hydropower plant (former plant) was sunk, so we abolished the former plant and constructed the new plant at the upper stream area of the former plant. See Fig.1 and Table 1 about location and specifications of hydropower plant and dam. Fig.2 is shown comparison of dam scale.

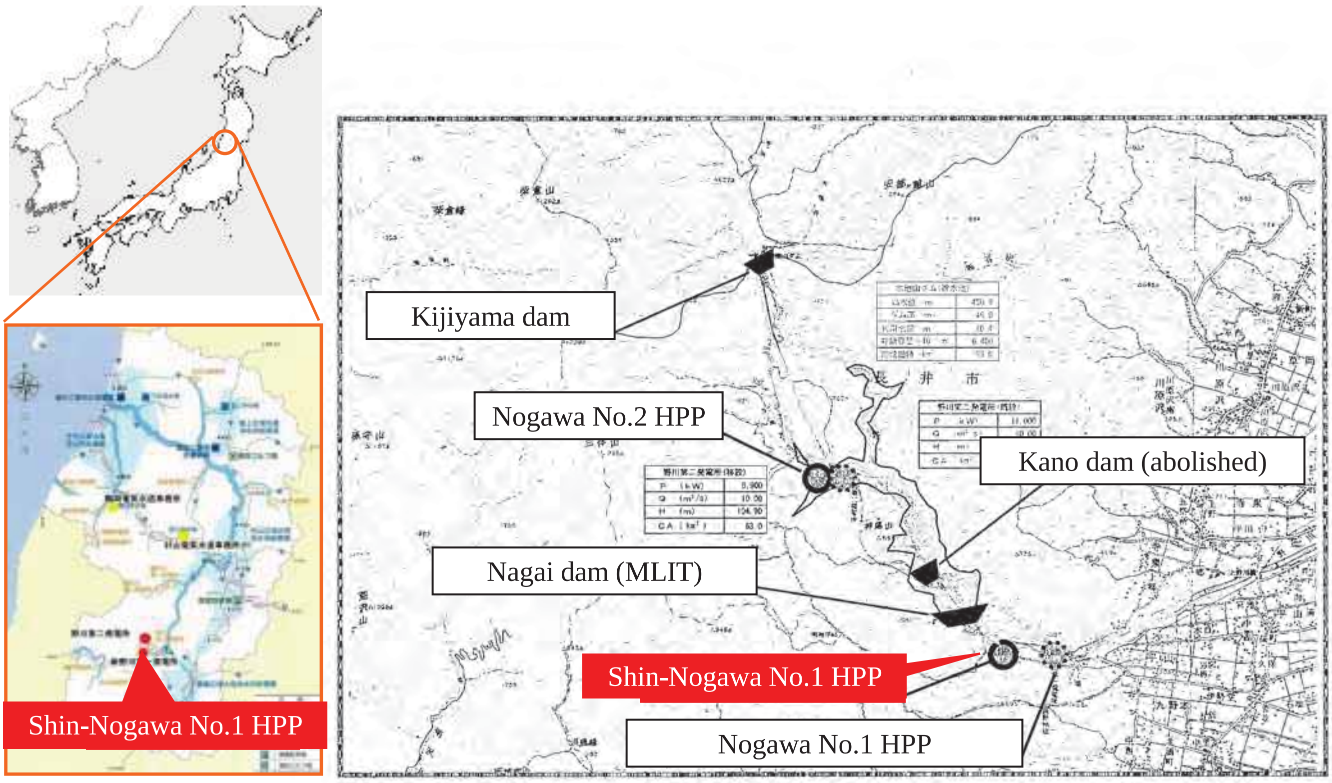


Fig.1 Location of Shin-Nogawa-No.1 hydropower plant

Table 1　Specifications of the hydropower plant and dam

Category	Specification（former plant）	Specification（new plant）
Name of the power plant	Nogawa-No.1 hydropower plant	Shin-Nogawa-No.1 hydropower plant
Maximum output	6,100kW	10,000kW
Maximum dischrage	10m^3/s	12m^3/s
Effective head	73.29m (during a maximum discharge)	99.80m (during a maximum discharge)
Type of plant	Dam and conduit type	ditto
Type of water turbine	Vertical Francis turbine (VF)	Vertical Deriaz turbine (VD)
Scale of runner output	3,360kW×2units	10,500kW×1unit
Scale of generator output	3,500kVA×2units	10,800kVA×1unit
Annual output	37,172MWh	51,773MWh
Date of operation start	1st May1954	2nd June 2010
Name of the dam	Kanno dam	Nagai dam
River name	The Oitama Nogawa river in the Mogami River system	ditto
Type	Gravity type	ditto
Height	44.5m	125.5m
Crest length	81.8m	381.0m
Dam volume	37,141m^3	1,200,000m^3
Gross storage capacity	3,473,000m^3 (at construction)	51,000,000m^3 (at construction)
Active storage capacity	2,045,000m^3 (at construction)	48,000,000m^3 (at construction)
Available depth	12.0m	45.3m

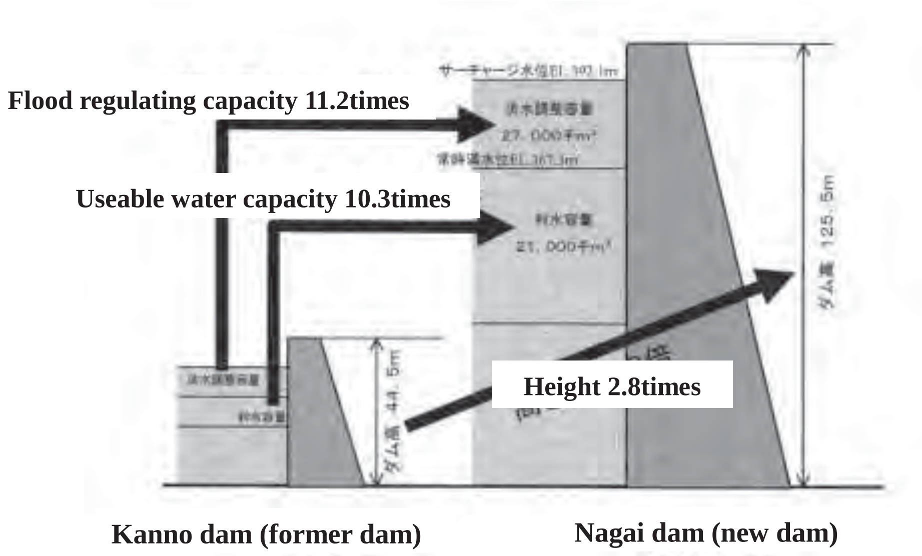


Fig.2　Comparison of dam scale

Comparison of former and new hydropower plant and dam is shown in the Photo 1, a whole plane view and a vertical view is shown in Fig. 3, a plan view is shown in Fig. 4, a vertical view is shown in Fig. 5.

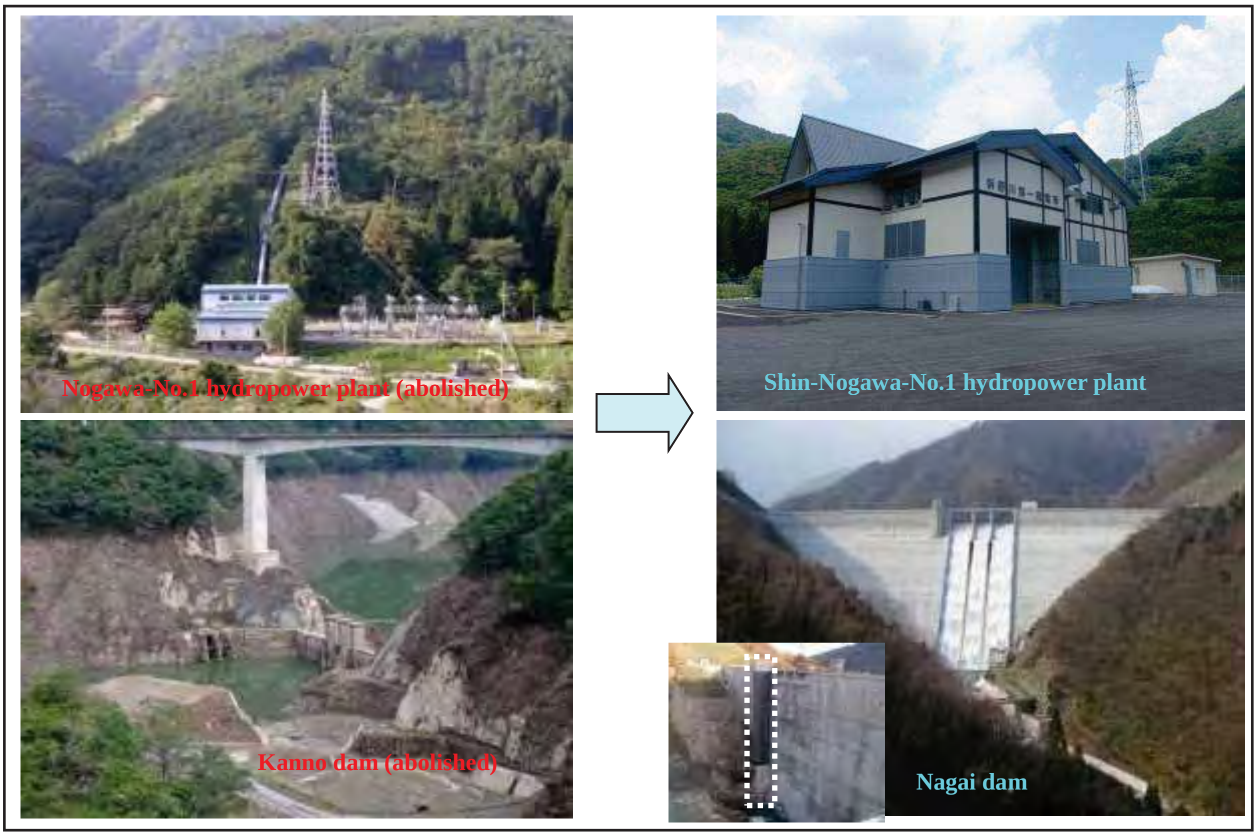


Photo 1　Comparison of former and new hydropower plant and dam

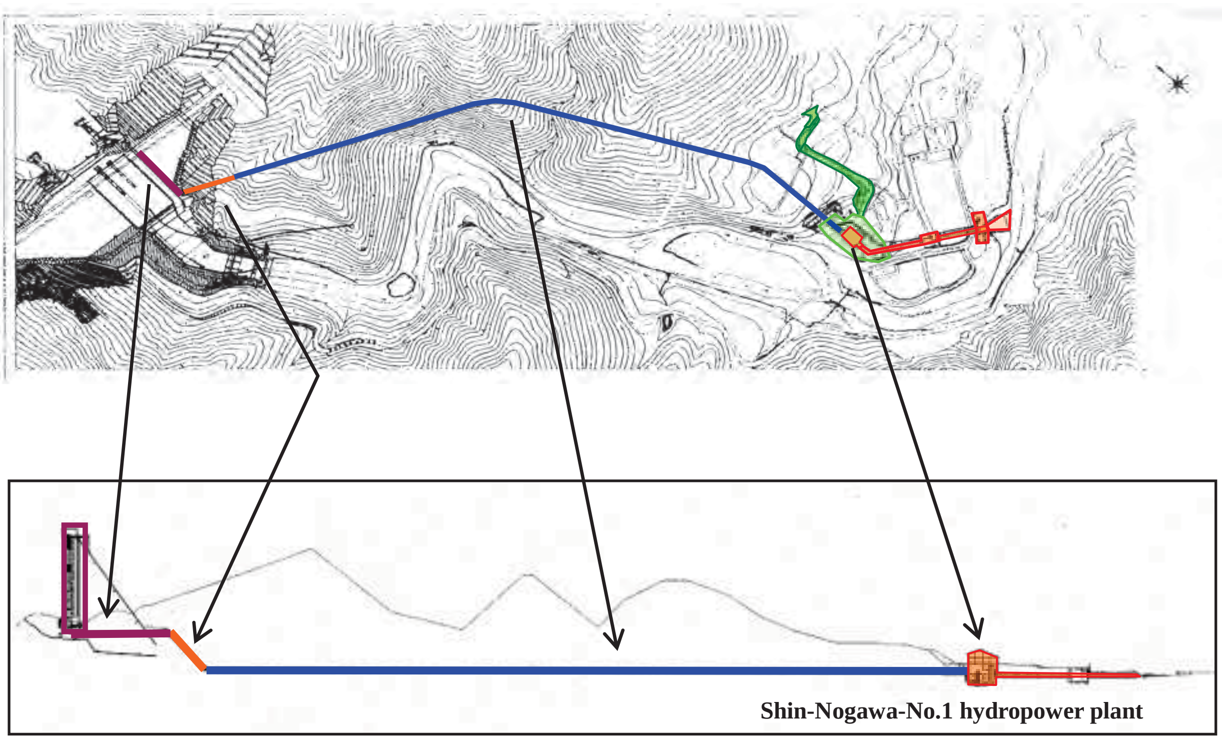


Fig. 3　Whole plane view and a vertical view Shin-Nogawa-No.1 hydropower plant

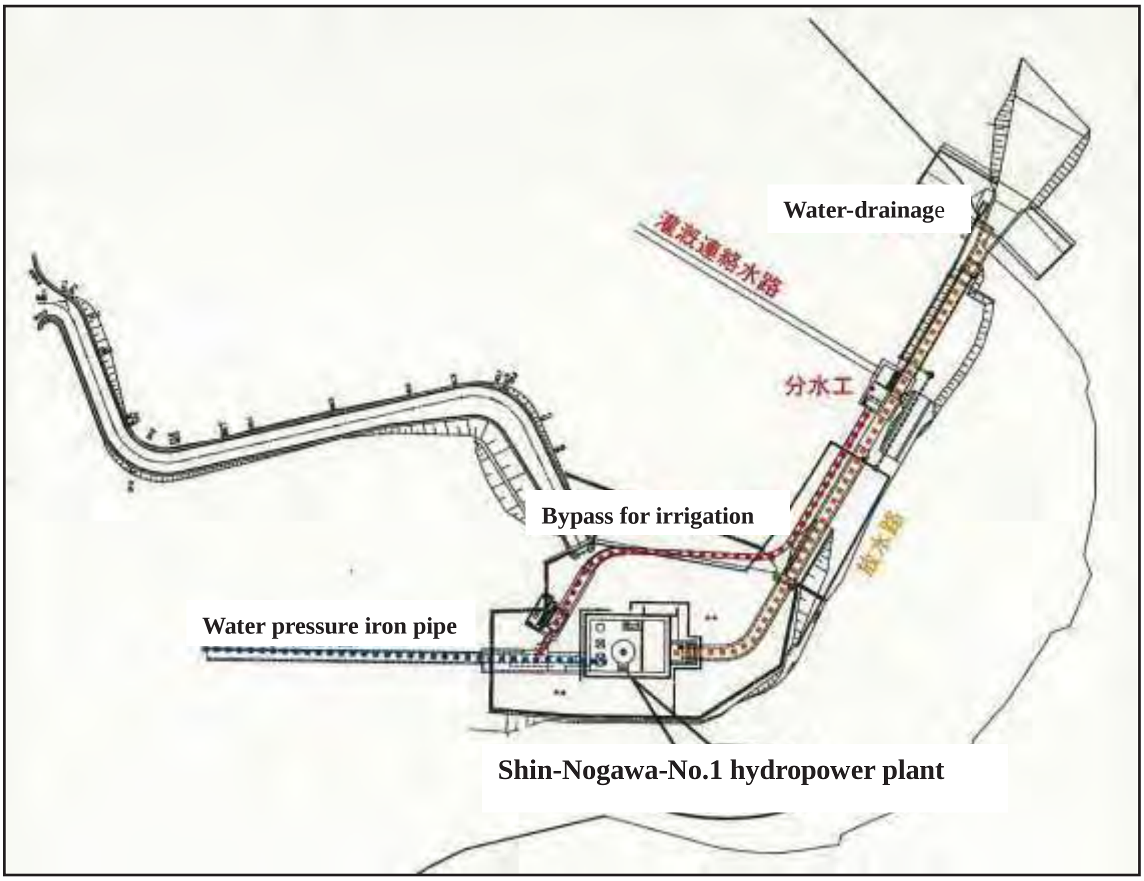


Fig. 4　Plane view Shin-Nogawa-No.1 hydropower plant

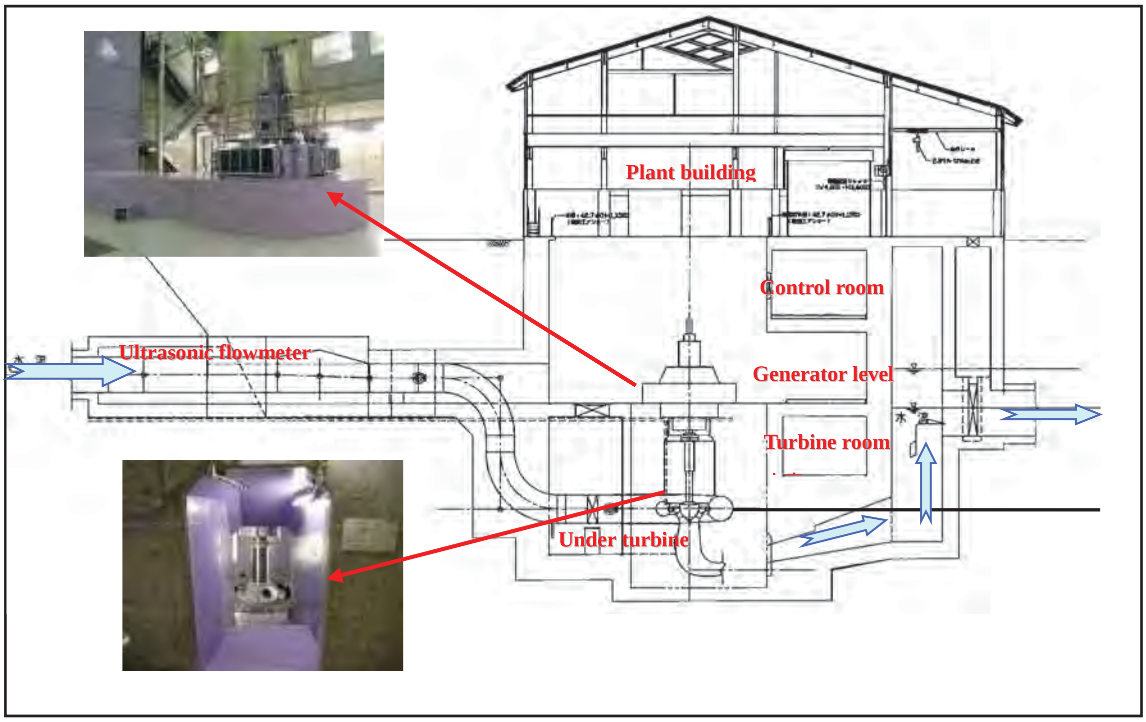


Fig. 5　Vertical view Shin-Nogawa-No.1 hydropower plant

2. Description of the Renewal and Upgrading Project

2.1 Trigger Causes and Drivers for Renewal and Upgrading

(i) Conditions, Performance, and Risk Exposure and Others

(E) Needs due to third party factor

Shin-Nogawa-daiich hydropower plant was redeveloped by construction of Nagai Dam of the MLIT.

(ii) Opportunities to Increase Value

(C) Needs for higher performance

We adopted a new type of electrically-operator servomotor system (hybrid servo) for the control of guide vane and runner vane.

(iii) Market Requirements

(not applicable)

2.2 Process to Identify and Define Renewal and Upgrade Work Measure

Apr. 1954	Start of Nogawa-No.1 hydropower plant generating operation
Dec.1988	Notification of Nagai dam master plan by MLIT (Determination of this project)
Mar.2000	Started constructing major civil engineering works of the Nagai dam
Jun. 2004	Started constructing major civil engineering works of the Shin-Nogawa-No.1 hydropower plant
Sep. 2009	Abolished Nogawa-No.1 hydropower plant
Nov. 2009	Started test flooding in Nagai dam by MLIT (to Sep. 2010)
Jun. 2010	Completion and Start operation

2.3 Description of Work Undertaken (detail)

2-a) Technological innovation, deployment expansion for electrical and mechanical equipment

The Shin-Nogawa No. 1 HPP adopted the Francis turbines as a result of comparison of economic efficiency between the case equipped with two Francis turbines and the case equipped with one movable-vane type diagonal flow water turbine. When adopted, in order to apply to the site in which there is a large head, the system adopted the angle adjusting mechanism for a large movable vane.

The specifications of a water turbine are shown in Table 2. Photo 2 shows a water turbine runner.

Table 2 Specifications of the turbine

Runner hub	Enclosed water	Tap water
	Quality of the material	SCS5
Runner vane	Number of vanes	10
	Quality of the material	SCS6
	Operating angle	5°～27°

Photo 2　Deriaz turbine

For the operation of the power station, the system was planned to operate oil-less using electric servomotors. Then the system equipment manufacturer proposed the use of hybrid servomotors (electric and hydraulic hybrid servomotor) for the control of the guide vanes and runner vanes. We adopted that idea, using these hybrid servomotors, and achieved maintenance labor savings by elimination of pressure equipment.

Hybrid servomotors for runner and guide vanes are shown in photos 3 & 4 and Fig 6.

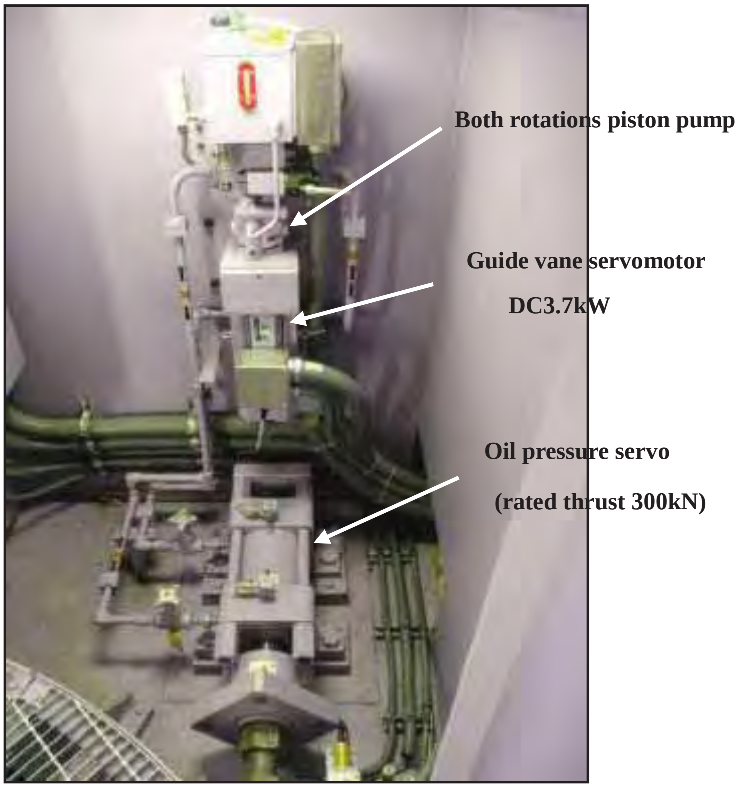


Photo 3　Guide vane servomotor

Photo 4　Runner vane servomotor

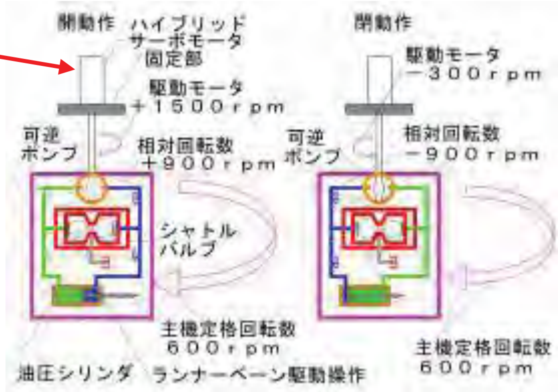


Fig.6　Schematic diagram of Runner vane servomotor system

The water wheel bearing was adopted upper cover cooling system, water supply needlessness was brought about. And phenol resin was adopted as sealing water equipment. Sectional view around turbine is shown in Fig.7

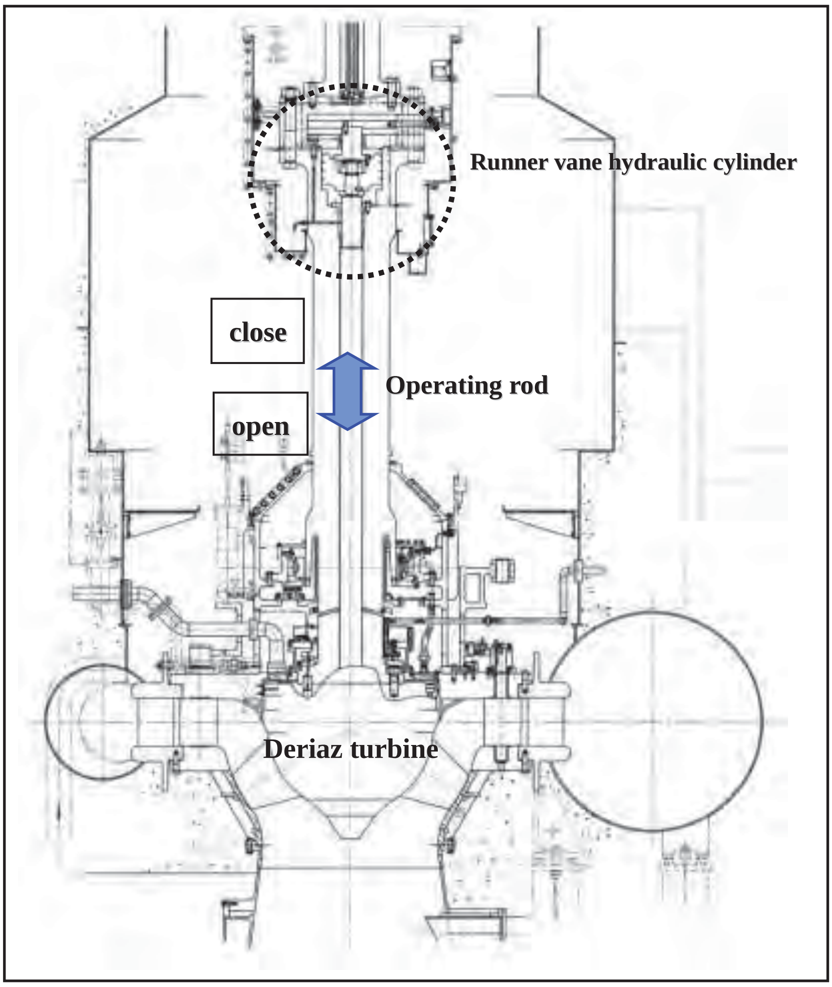


Fig.7　Sectional view around turbine

3. Feature of the Project

3.1 Best Practice Components

The main features of a hybrid servo motor are as follows.

- All the composition apparatus of an actuator is solid construction.
- It is a compact actuator by high oil pressurization.
- Piping work and a complicated installation test are unnecessary at solid construction, and installation is easy.
- An actuator is only exchange of periodical operation oil and is easy to maintain.

3.2 Reason for Success

The Nogawa No. 1 Power Station has been operated for 55 years and has been seriously aging. Then, because the Nagai Dam was constructed, the redevelopment of the Shin-Nogawa No. 1 Power Station became possible.

For the compensation of the existing power station, "Outline of the public compensation standard for public-works projects" (on February 21, 1967, a cabinet decision) has decided to restore the function of the existing public facilities. The appended document of this Outline "Operation rule of this Outline" determines the detail, and for this case, the relocation of the existing power station was not approved from the viewpoint of the physical reason and rationality. Therefore the Shin-Nogawa No. 1 Power Station was constructed by utilizing financing by "The compensation rule for an abolished power station".

Though there are almost no other cases of use, hybrid servo motors were adopted for the 10,000kW vertical shaft diagonal flow water turbine (VD), making it possible to eliminate an oil pressure supply system and reduce the level of maintenance service.

4. Points of Application for Future Project

(not applicable)

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

There is no failure of the hybrid servo since the commencement of operation in June 2010.

6. Further Information

6.1 Reference

(not applicable)

6.2 Inquiries

Company name: Yamagata Prefecture

URL : https://www.pref.yamanashi.jp/kigyo/

ANNEX XI　Renewal & Upgrading of Hydropower Plants

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

Category and Key Points

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

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

Project Name:

The first Renewal of SHIROYAMA Hydroelectric Power Station

Name of Country (including State/Prefecture):

Japan, Kanagawa Prefecture (Asia)

Implementing Agency/Organization:

Kanagawa Bureau of Enterprise

Implementing Period:

From 1996 to 2001, from 2007 to 2010

Trigger Causes for Renewal and Upgrade:

(A) Degradation due to ageing and recurrence of malfunction

Keywords:

Degradation due to aging

Abstract:

The Shiroyama Hydroelectric Power Station is the first reversible recirculating pumped storage power plant which was constructed in Japan.　However, back in those days, the technology of pumped storage generation was not yet developed and at the time of the commencement of operations, there were many adverse conditions such as harsh heat-cycles caused by tough operating conditions including water pumping during Lunch time.　The equipment was placed in the basement where conditions were very extreme such as under high humidity.　For these reasons, equipment was aging seriously since around 1985, causing degradation of efficiency and many failures which led to serious accidents.　On top of that, because of difficulties in obtaining repair parts for maintenance due to system aging, and shortage of maintenance manpower in equipment manufacturers, the operation and maintenance of the system became difficult by partial repair and improvement alone which had been conducted, therefore the renewal plan was considered and implemented.

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

This power station is the first recirculating pumped storage power plant in Japan which is located in Midori-ku, Sagamihara-shi, Kanagawa Prefecture (maximum output 250MW, construction began in April, 1961, operations began in November, 1965). The Shiroyama Dam which is located downstream is a multi-purpose dam with the aim of flood control, city water and industrial water supply. The location map of the power station and dam, and the specifications are shown in Fig. 1, and Table 1.

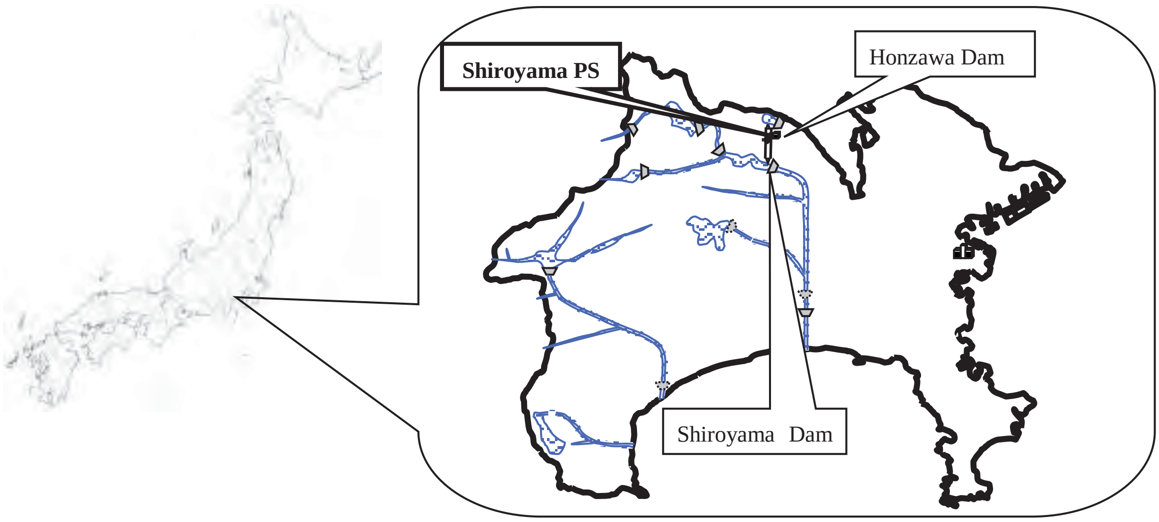


Fig. 1: Location map of the Shiroyama Hydroelectric Power Station

Table 1: Specifications of the Shiroyama Hydroelectric Power Station

Item		Specifications	
Hydroelectric power station	Name of dam	Shiroyama Hydroelectric Power Station	
	Maximum output	250MW（62.5 MW/unit×4units）	
	Maximum plant discharge	192.0 m^3/s	
	Standard effective head	123.9 m	
Dam	Name of dam	Honzawa Dam (upper dam)	Shiroyama Dam (lower dam)
	Name of river	Sakaigawa water system, Sakaigawa river tributary, Honzawa	Sagamigawa water system, Sagamigawa river
	Basin area	0.58km^2	1,323.1km^2
	Type	Rockfill type	Gravity type
	Height	73.0m	75.0m
	Length of dam top	234.0m	260.0m
	Dam volume	1,852,000 m^3	362,000 m^3
Reservoir	Reservoir total pondage	3.927×10^6 m^3 (when constructed)	62.30×10^6 m^3 (when constructed)
	Effective pondage	3.835×10^6 m^3 (when constructed)	54.70×10^6 m^3 (when constructed)
	Used water depth	28.0m	29.0m

2. Description of the Renewal and Upgrading of the Project

2.1 Trigger Causes and Drivers for Renewal and Upgrading

⑴Condition, capability, influence of risk and others

About 30 years since the start of operations, a great deal of trouble had been occurring due to degradation from aging, making stable operation of the pumped storage power station difficult.

(A)－(a)(b) Degradation due to ageing and recurrence of malfunction --- improvement of efficiency, improvement of durability and safety

(1) Pump turbine

Runners were progressively corroded by cavitation, and electrolytic corrosion at the edges of the welded part by stainless overlay welding, and repeated welding repair work having caused heat stresses. In addition, runner efficiency was declining.

(A)－(b) Degradation due to ageing and recurrence of malfunction --- improvement of durability and safety

(1) Inlet valve

A variety of issues have occurred such as: thinning of the flange part of the valve case due to corrosion, cavitation corrosion from water leakage, corrosive wear of the bearing bushing, wear on the sliding surface of the valve body bearing, cavitation corrosion of the water seal external wall, and the amount of water leakage was becoming excessive. Also, a mechanical safety lock-out system was not installed.

(2) Generator motor

The stators of all systems had almost come to the end of their life due to degradation of the coils. In addition the iron cores of No. 3 and 4 systems were rusted and distorted by shortage of heat dissipation capacity.

The rotors were seriously degraded by heat cycling of the insulators. The damper coils and the short circuit plate were distorted and cracked by mechanical and thermal stress because of capacity shortage at the time of pumping operations.

(3) Main cable

The insulating materials for the main cables were butyl rubber and cases of accidents were reported by the mixing of water moisture and insulating material. And in past fire accidents, cable insulators were fire damaged, and then, water gradually intruded into the inside from the fire damage repairs and water remained inside of the anticorrosive layer.

(A)－(b)(d) Degradation due to ageing and recurrence of malfunction --- improvement of durability and safety, Easy maintenance with less labor

(1) Governor

The governors are very complex in their link mechanism and other parts, and there was a fear that in the future, a shortage of maintenance service engineers would occur. Also, since the production of vacuum tubes and magnetic amplifiers for the governor control panel was discontinued, it had become difficult to supply service parts.

(2) Exciter arrangement

The exciter arrangements were less degraded, but maintainability such as with brush exchanges was not good. The automatic voltage regulators are the HTD type for No. 1 and 2, and Amplidine type for No. 3 and 4 and production of their parts were almost completely discontinued. Besides, because of the difficulty of adjustment, it had become difficult even for the manufacturers to maintain them.

(2) Improvement of value (functions)

Not applicable

(3) Necessity in the market

Not applicable

2.2 Process to Identify and Define Renewal and Upgrade Work Measure

November,	1965: Operations began
April, 1991:	Study of the renovation plan was started
April, 1996:	Construction work of the first phase of the renovation project began (mainly, for No. 3, 4 systems)
May, 2001:	The first phase of renovation project was completed
April, 2007:	Construction works of the second phase of renovation project began (for No. 1, 2 systems)
March, 2010:	The second phase of renovation project was completed

2.3 Description of Work Undertaken (detail)

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

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

- When runners of No. 3 and 4 systems were replaced, the water turbine was designed with the aim of reducing cavitation corrosion and corrosion by river water particularly. In addition, the efficiency of the pump water turbine was aimed to be improved by changing the shape of the guide vanes into the thin, low loss type. As a result, pump efficiency has been improved by 1 to 2 % for the entire operation range of head, and water turbine efficiency has been improved by about 3 % for the water turbine output range of 100% to 60% , which is the regular operation range.
- For the inlet valves of No. 1 to 4 systems, the mechanical lock systems were not installed, in addition for the water inlet of the upper regulating reservoir, the regulating gates were not installed. Therefore, for safety during water stoppage inspection of the water turbine equipment, the operation lock-out system was necessary to be installed. On top of that, since it was necessary to repair the worn parts and to repair the water leakage caused by distortion of the center shaft of the valve case and valve body, the entire system was renewed as one complete set from the view point of cost-effectiveness.
- The stator coils of No. 3 and 4 machines were prepared as F type insulation, and as B type equivalent temperature increase conditions so as to achieve quality improvement and long service life. By changing to higher grade silicon sheets from the existing ones to reduce stator steel loss, the total efficiency of the generation motor has been improved by 0.3%.

- The increase of allowable current and reduction of temperature increase was pursued by expanding the cross-section area of the rotor damper coil of No. 3 and 4 machines.
- The excitation method of the generator motor has been changed from the DC (direct-current) energization method to the static excitation method (thyristor excitation system).
- From the maintenance records, it became clear that the control system was quickly degraded probably because the generators were operated in the basement under the conditions of excessive high humidity, and use of direct current control circuit of 200V. For these reasons, the whole control system has been renewed completely as one set.

Table 2: Main construction work

Equipment	Contents of Modification	Date of Work
No. 1 and 2 Main equipment	Replacement of governors, governor control panels and water turbine control panels Inlet valves were replaced with biplane valves	1996 - 2001
	Maintenance of runner of pump water turbines Renewal of guide vanes, and operational mechanical parts were changed to unlubricated type	2007 - 2010
	Renewal of stators and field coil (only for No. 1 machine) Renewal of exciters, automatic voltage regulators, air coolers and bearing push up devices	2007 - 2010
	Replacement of the entire electrical switchboard, use of programmable controllers for automatic control, digitalization of protection relays. Main cables were changed from BN cable to CV type	1996 - 2001
No. 3 and 4 Main equipment	Runners and guide vanes of pump water turbines were replaced, and operation mechanisms were changed to unlubricated type Replacement of governors, governor control panels and water turbine control panels Inlet valves were replaced with biplane valves	1996 - 2001
	Replacement of stator iron core of generator motors, coils and rotors. Exciters were changed to the direct thyristor excitation system	1996 - 2001
	Replacement of the entire electrical switchboard, use of programmable controllers for automatic control, digitalization of protection relays. Main cables were changed from BN cable to CV type	1996 - 2001
Direct-current power supply system	Direct-current power supply system was changed from 200V to 100V (systems are segregated above ground and underground)	1996 - 2001

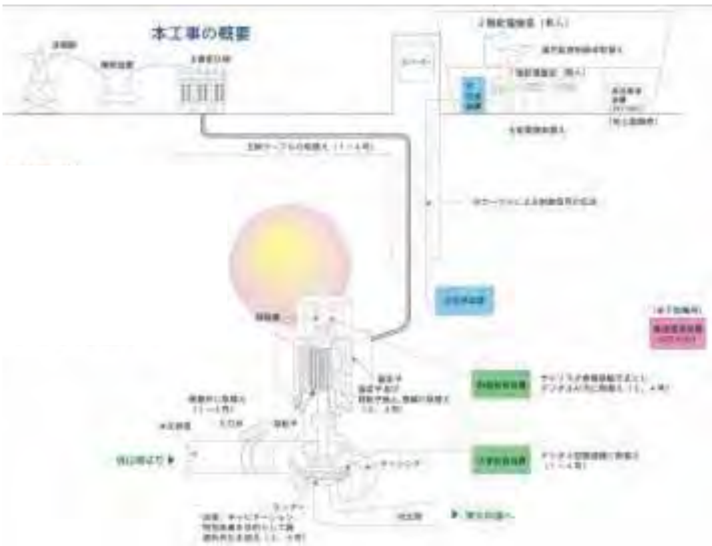


Fig. 2: Work summary

3. Feature of the Project

3.1 Best Practice Components

- At the time when this power station was constructed, polyester resin was used for insulation of the stator coil of No. 1, 3 and 4 machines, but when renewal work was conducted, the stator coils were renewed. No. 2 machine has used epoxy resin for its coils from the beginning to the present day (2013). The reason why resin had been changed was because when No. 2 machine was manufactured, the mass production system for epoxy resin was established.

3.2 Reasons for Success

Renewal work was a kind of large scale overhaul, and its goal was achieved by replacement of machines.

4. Points of Application for Future Project

Not applicable

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

Not applicable

6. Further Information

6.1 Reference

Not applicable

6.2 Inquiries

Company name: Kanagawa Prefecture

URL: http://www.pref.kanagawa.jp/cnt/f27/

ANNEX XI Renewal & Upgrading of Hydropower Plants

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

Category and Key Points

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

Sub: 1-f) Environmental conservation and improvement

Project Name:

Restoration Works on Toyomi Power Station

Name of Country (including State/Prefecture):

Japan, Niigata Prefecture

Implementing Agency/Organization:

Tohoku Electric Power Co., Inc.

Implementing Period:

From 2008 to 2013 (plan)

Trigger Causes for Renewal and Upgrade:

(A) Needs for safety improvement

Keywords:

Degradation due to aging, Change of the number of water turbines, Increase of output, Vertical bulb water turbine

Abstract:

The Toyomi Power Station is a dam type power station which has been in operation for about 80 years. Since commencement of operations, the turbines, the power station structure and the concrete foundation of the power station were degraded seriously, all requiring a large scale restoration.

Thus, without changing the maximum plant discharge, the restoration plan was developed so that 6 sets of water turbines/generators would be integrated into 2 sets. Also the water turbine type would be changed from the Francis turbine to Vertical Bulb water turbine. These restoration works are now under way.

This restoration work aims to increase the maximum output by 5,400 kW from the previous 56,400kW to 61,800 kW. At the same time durability, safety and reliability, and maintainability of the power station would be improved by reducing the number of water turbines/generators.

In addition, adopting the Vertical Bulb type water turbine and reducing the number of water turbines/generators aims to reduce restoration work costs by reducing the machine installation area and main building area.

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

In the Aganogawa water system which was classified as a first-class river, since early times, electrical power development had been conducted relying on an abundance of water volume. In that water system, 16 power stations are built on 11 dams constructed in a staircase pattern from the Tadamigawa River to the Aganogawa River, generating about 40 % of the total energy created by our waterway stations, thus becoming a large generating district.

Among these stations of the Tadanogawa/Aganogawa river system, the Toyomi Power Station, located in Niigata Prefecture, Higashi Kanbara-gun, Aga-machi, a midstream site of the Aganogawa River in the Aganogawa water system, is the second oldest power station. Its operation was started in 1929 with a maximum plant discharge of 270m^3/s and maximum output of 56,400kW as a dam type power station. This power station has been operated continuously for about 80 years and the water turbines, the main power station building and the foundation concrete of the power station have degraded seriously. The location map of the power station system is shown in Fig. 1 and the specifications of the power stations before restoration are shown in Table 1.

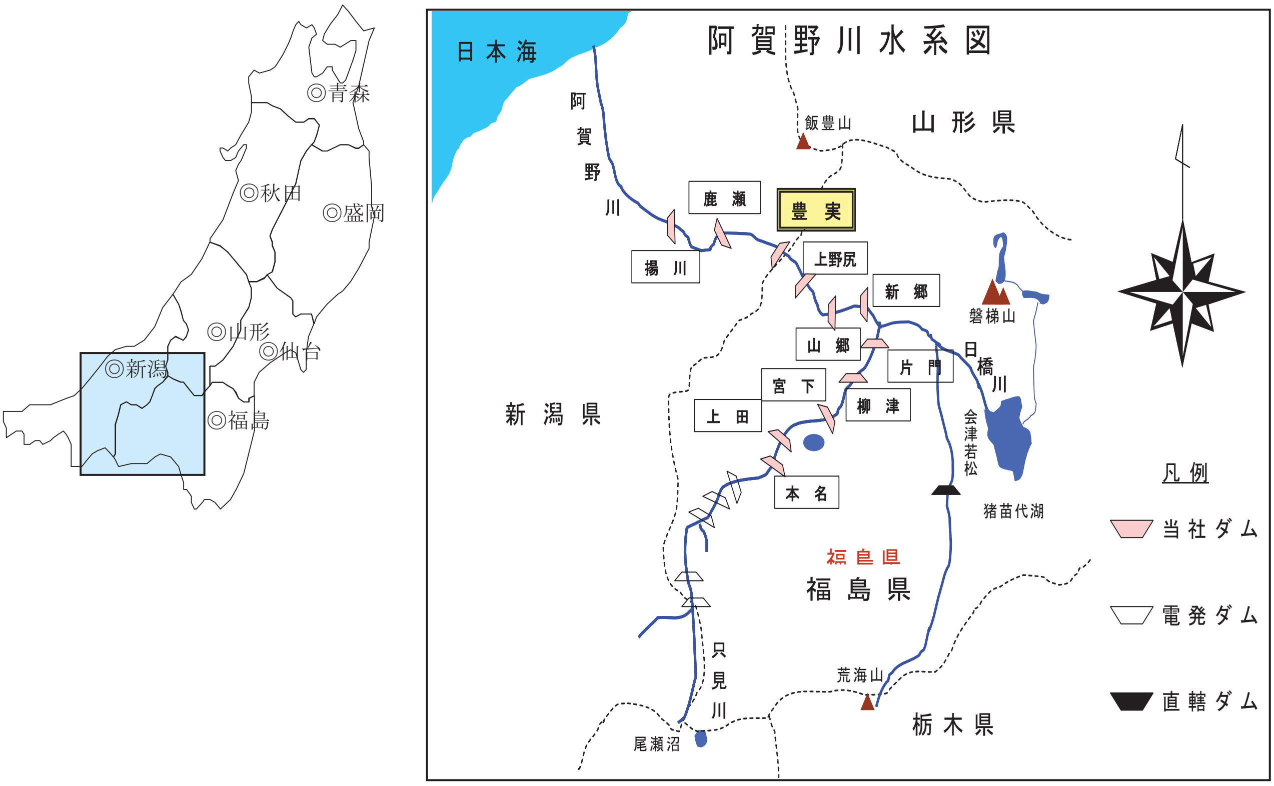


Fig. 1: Location map of the power stations

Table 1: Specifications of the Toyomi Power Station

Item		Specifications
Specifications	Name of power station	Toyomi Power Station
	Maximum output	56,400 kW
	Maximum plant discharge	270.0 m^3/s
	Effective head	25.55 m (when the maximum plant discharge was used)
Dam	Name of dam	Toyomi Dam
	Name of river	Aganogawa water system, Aganogawa River
	Basin area	6,048 km^2
	Type	Concrete gravity dam
	Dimension	Height 34.242 m, Length of dam top 223.200 m
Intake	Type	Natural inlet type, Reinforced concrete
	Dimension	Inlet width 27.300 m (4.550×6 gates), total 13.940 m
Steel Penstock	Structure	Soft steel riveted joint
	Number of lines	6 lines
	Dimension	Inside diameter 3.962 m - 3.505 m, total 26.090 m
Power station	Water turbine type	Vertical Francis turbine
	Numbers of water turbine and generators	6 machines
Tailrace	Structure	Reinforced concrete
	Number of lines	6 lines
	Dimension and shape	horseshoe shape, width 6.060 m, height 4.850 m, total 66.290 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

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

Since the commencement of operations, about 80 years has passed and it was hard to expect a large increase of output by only a partial replacement of water turbines and generators. However, by conducting a fundamental restoration including the change of number and type of water turbines, it was expected to increase electrical energy output.

(a) Water turbine

The reduction of strength of casings and stay vanes which were underground, by progressive damage was found, and so it was determined to carry out an immediate restoration. Especially, with an evaluation of the life expectancy of the stay vanes of each system, it was judged that in the shortest case, the necessary safe life of 10 years, was not assured.

(b) Generators

For the generators, serious aging had progressed and defects and corrosion were found throughout. In addition, deformation of the stator frame and corrugation of the iron core was detected, and so it was feared that without repairs or replacement, the generators would begin to vibrate destructively.

(c) Auxiliary machinery

The auxiliary machinery, various control panels and governors including the generators' operating panels, were seriously degraded due to aging, and since service parts were not obtainable because their manufacture was discontinued, it was necessary to renovate the whole system at one time.

(d) Foundation of the power station

As for the concrete of the foundation, much damage such as shifting, cracks and water leaks were found, and Carbonation was progressing centering around these deteriorated areas.

Much of this deterioration was found on the structure such as support beams for the generators, slabs, support columns and underground side walls. Some of these parts (main support beams for generators, underground support beams, bracing strut beams, and slabs of each floor, etc.) were subjected to stresses exceeding their allowable limits during normal operations, therefore immediate restoration was required.

(e) Building

Since there were problems in earthquake protection, it was necessary to conduct a well-planned restoration.

(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 1929:	Operation of the Toyomi Power Station (existing station) began
2001:	A full-scale study of restoration of the Toyomi Power Station began
August 2008:	The restoration work of the Toyomi Power Station was started
November 2008:	Full-scale restoration work of the Toyomi Power Station began (demolish work began)
July 2013:	Test operations will be started (scheduled)
September 2013:	Full power station operation will be started (scheduled)

2.3 Description of Work Undertaken (detail)

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

a) Restoration plan

When the restoration plan was studied, three cases of restoration methods and scale were investigated:

(1) without changing the maximum plant discharge, a renovation could be conducted retaining the existing system composition of 6 vertical Francis turbines,

(2) without changing the maximum plant discharge, a renovation could be conducted by integrating the water turbine/generator system into 2 Vertical Bulb water turbines, or

(3) changing (increasing) the maximum plant discharge, a renovation could be conducted by integrating the water turbine/generator system into 2 Vertical Bulb water turbines.

As a result of study, the conclusion was reached that option (2) was the best plan for mechanical and economic efficiency. The specifications of the restoration plan are shown in Table 2, and the restoration scheme drawing is shown in Fig. 2 and 3.

Table 2: Specifications of the restoration plan of the Toyomi Power Station

Item		Current specification	**Restoration plan**
Specifications	Name of power station	Toyomi Power Station (no change)	
	Maximum output	56,400 kW	**61,800 kW**
	Maximum plant discharge	270.0 m^3/s (no change)	
	Effective head	25.55 m (when the maximum plant discharge was used)	**25.48 m**(when the maximum plant discharge was used)
Dam		Concrete gravity dam (no change)	
Inlet		Natural inlet type, Reinforced concrete (no change)	
Penstock	Structure, line numbers	Soft steel riveted joint 6 lines	**none**
Powerhouse	Water turbine type	Vertical Francis turbine	**Vertical Bulb water turbine**
	Numbers of water turbine/ generators	6 sets	**2 sets**
Tailrace	Structure	Reinforced concrete	Reinforced concrete
	Number of lines	6 lines	**2 lines**
	Dimensions, shapes	horseshoe shape, width 6.060m, height 4.850m, total 66.290m	**Circular form 8.000m to rectangular width 8.000m - 13.400m, No. 1 system: total 55,566m, No. 2 55.483m**

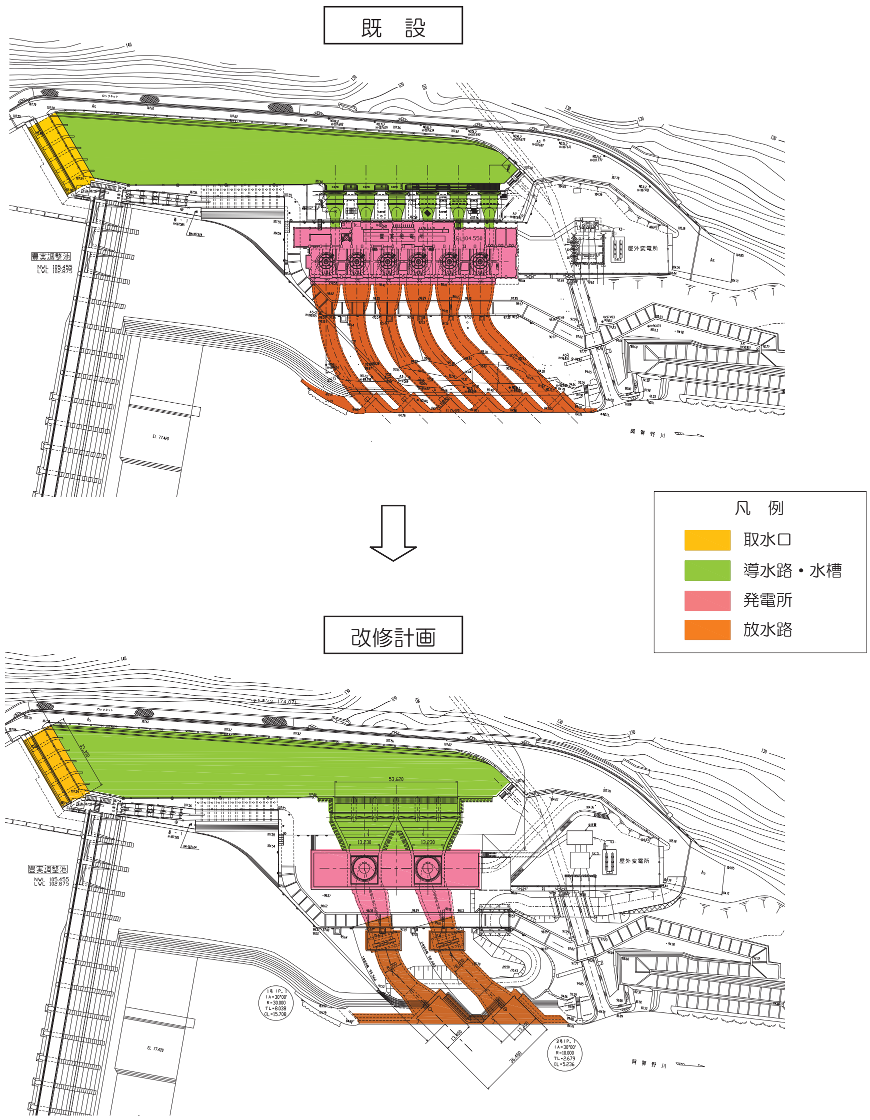


Fig. 2: Plan view before and after restoration

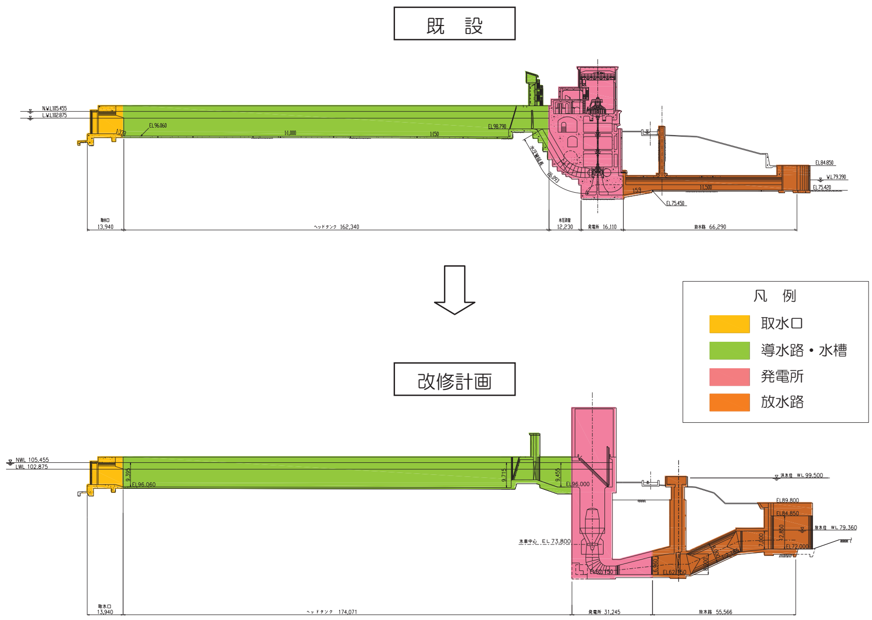


Fig. 3: Longitudinal profile before and after restoration

b) Engineering innovation and application expansion of electromechanical systems

The Vertical Bulb water turbine adopts the latest design technologies and has the following characteristics: The Toyomi Power Station is the second case of this type of the power station since the operation of our No. 2 Kaminojiri Power Station (maximum output of 13,500kW) was started in 2002. The schematic view of the water turbine generator using the Vertical Bulb water turbine is shown in Fig. 4.

○ Casings, water turbines and generators are installed vertically, thus it is possible to reduce the installation area for a power station, making it possible to install the power plant in a small area therefore, the cost of the civil engineering and construction can be reduced. Besides, the degree of freedom for designing the whole layout of the power station is greater than with other water turbine types.

○ Regardless of the direction of the intake channel, the direction of the draft tube and tailrace are able to be selected freely in the range of 360 degrees centering on the water turbines/generators, therefore reducing the space restriction for the power station.

○ Since a curved draft tube was used with a small head, losses increase slightly, but the water way length upstream from the intake channel to the casing is able to be shortened, therefore loss caused by water intake is reduced.

○ In a conventional vertical system, runners are located at the lowest point, so it is necessary to dismantle runners last in the disassembly/reassembly process of the water turbines/generators. Therefore, after overhaul, it was necessary to assemble the runners first in the process. However, in this system, since the dismantling of the runner is possible from the side, it reduces the time necessary for the installation process and overhaul.

On top of that, this power station adopts the following advanced technologies.

○ Valve support structure

The Vertical Bulb water turbine is subjected to a much larger vertical load, including its own weight, than a horizontal bulb system, and has to be supported with the bracket of the bulb water turbine. Any deflection of the bulb bracket has an impact on the water turbine performance and the gap of guide vanes and others which are located downstream from it. Consequently, we conducted an analysis of stress and deformation by an analysis model and have adopted the most appropriate bulb bracket structure.

○ Cooling technology for generators

For the Vertical Bulb water turbine, the generators are located inside of the bulb situated in the water way which is an advantage for the generator’s cooling, and various cooling technologies were developed and adopted with the aim of simplifying of the auxiliary machinery.

In this power station, various cooling methods are adopted such as: 1) the method which disperses the heat developed by the stator iron core directly into the flowing water outside of the bulb by installing the stator iron core directly on the inside wall of the cylinder hollow, 2) for the heat caused at the coil end of the rotor and stator coil, heat is circulated by a self-ventilation fan fixed on the rotors and dispersed into the flowing water outside of the bulb through the fins attached on the upper area of bulb.

○ Adoption of the oil-less type water turbine

Inside of the runner hub in which the operating mechanism for the movable blades of the water turbine is installed, oil-less bearings which don't require lubricant oil are used. For the water turbine, bearings made of phenol resin were adopted so as to improve maintenance and to prevent oil from leaking into the river.

○ The measure to prevent an air-sucking vortex

Since the Vertical Bulb water turbine takes in water directly from the intake channel through the vertical shaft, when the water intake level is low and the water depth at the upper end of the vertical shaft is shallow, an air-sucking vortex occurs. In order to prevent this vortex from developing, numerical analysis and experiments using model test equipment similar to the hydraulic profile around the intake channel were conducted. Based on the obtained results, flow-straightening inclined plates are installed in the upper part of the vertical shaft.

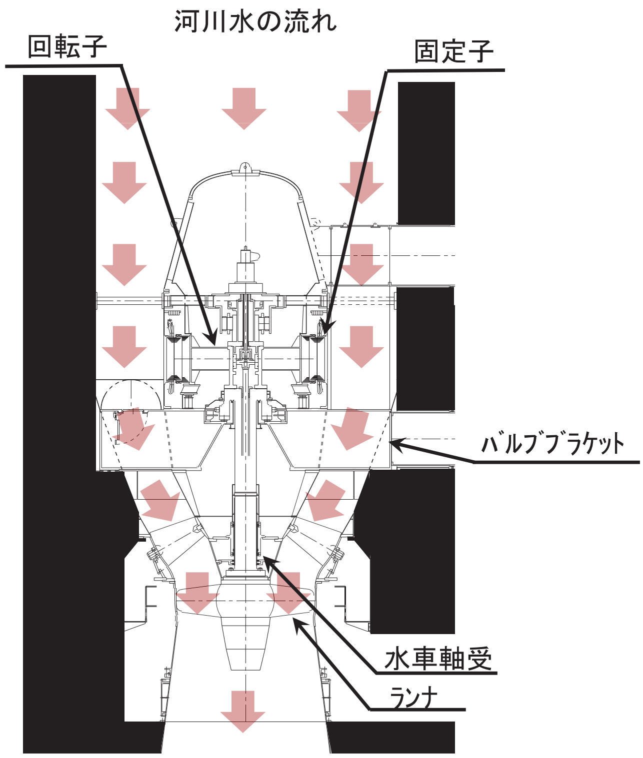


Fig. 4: Schematic view of the water turbine generator

1-f) Environmental conservation and improvement

Around 20,000 m^3 generated by the construction work, which is equivalent to 80% of the entire demolished concrete, was reused as recycled concrete to give due considerations on the environment.

The recycled concrete was used to fill the hollow portion of the power plant foundation created when removing the existing water turbines. This project is highly evaluated in terms of its contribution to reducing industrial waste.

3. Feature of the Project

3.1 Best Practice Components

In accord with a full-scale restoration due to aging, by adopting the Vertical Bulb water turbine which is highly efficient in terms of mechanical performance and economic efficiency, various other goals were set such as: to increase output, improve durability, safety and reliability, and also to improve maintainability by decreasing the number of water turbine/generators.

3.2 Reasons for Success

Since the water turbine generators and the foundation of the power station are degrading due to aging, the restoration plan was made, and then a detailed comparison study was conducted considering the maximum plant discharge, the numbers and types of the water turbines/generators, and an optimum plan was established. This project is currently in progress.

4. Points of Application for Future Project

- ○ Since it is necessary to support a load which is applied vertically on the water turbine generator, it is necessary to consider its rigidity.
- ○ It is necessary to take countermeasures to prevent an air-sucking vortex which is influenced by the shape of the intake channel and intake water level.

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

(not applicable)

6. Further Information

6.1 Reference

1) Murasato, Kobayashi, Kumagaya, "The hydraulic analysis associated with the adoption of the Vertical Bulb water turbine" *Journal of Electric power Civil Engineering*, volume 333 (2007.7)

2) Sasaki, Murasato, Kobayashi, "Outline of the restoration plan of the Toyomi power station" *Journal of Electric power Civil Engineering*, volume 339 (2009.1)

3) Yui, Murasato, Shimizu, "Design and construction of the makeshift cofferdam for the outlet of the Toyomi Power Station" *Journal of Electric power Civil Engineering*, volume 343 (2009.9)

4) Sasaki, Kobayashi, Nagai, "Outline of the removal work portion of the restoration work of the Toyomi Power Station" *Journal of Electric power Civil Engineering*, volume 347 (2010.5)

5) Sasaki, Nagai, "Construction of the tailrace tunnel of the Toyomi Power Station" *Journal of Electric power Civil Engineering*, volume 352 (2011.3)

6) New Energy Foundation, Hydroelectric power division, "The restoration plan of the Toyomi Power Station", *Text for the 7th workshop for the small and medium-sized hydroelectric power station*, October, 2009

7) Waratani, Tada, Takahashi, "Effective utilization of the dismantled concrete of the restoration work of the Toyomi Power Station", *Journal of Electric power Civil Engineering*, volume 356 (2011.11)

6.2 Inquiries

Tohoku Electric Power Company

URL: http://www.tohoku-epco.co.jp/

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

Category and Key Points

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

Sub: not applicable

Project Name:

New construction work of the Tsuchimurokawa Power Station using unused head of the existing dam.

Name of Country (including State/Prefecture):

Japan, Yamanashi Prefecture

Implementing Agency/Organization:

Tokyo Electric Power Co., Inc.

Implementing Period:

from 1996 to 1999

Trigger Causes for Renewal and Upgrade:

(C) Needs for higher performance

Keywords:

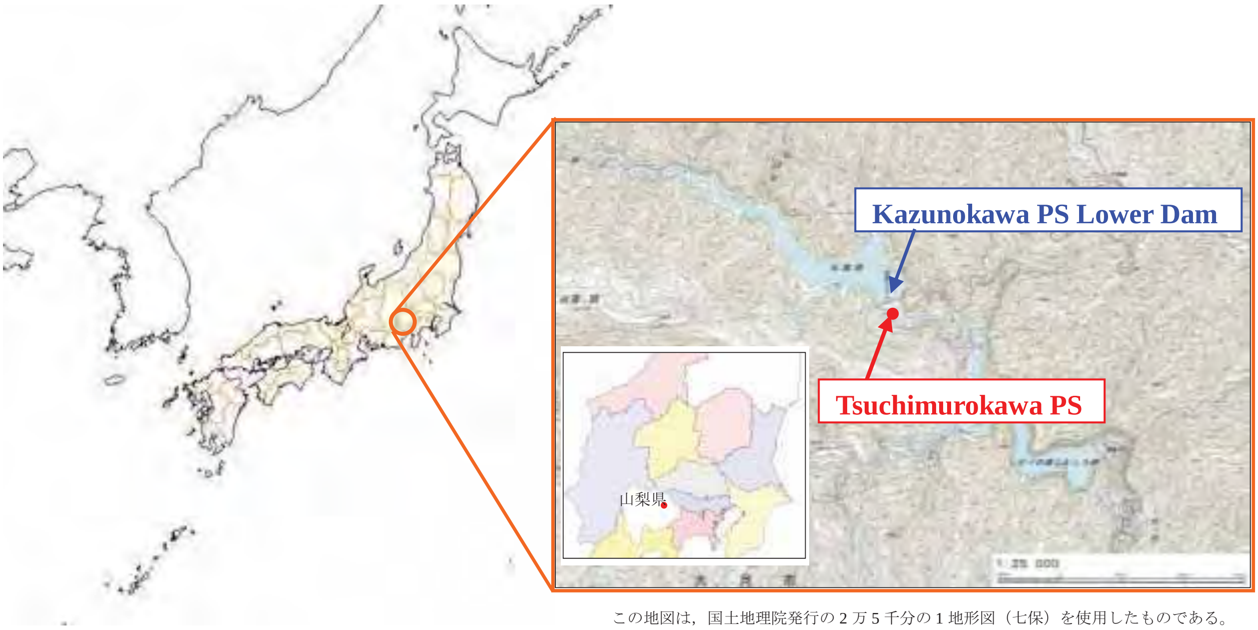
Utilizing discharge from a dam, Take advantage of unused head

Abstract:

The Tsuchimurokawa Power Station uses natural discharge from a dam from the surface selective intake facility installed downstream of the Kazunogawa dam. When the construction was conducted, it was pursued to reduce the construction cost by measures such as expansion of the application range of the Pelton turbine, careful selection and simplification of the necessary functions for the construction of the hydroelectric power station and synchronization with the Kazunogawa Power Station which was under construction at the time.

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

The location map of the powerhouse and dam, and specifications of the power station are shown in Fig. 1 and Table 1.



この地図は，国土地理院発行の２万５千分の１地形図（七保）を使用したものである。

Fig. 1: Location map of the Tsuchimurokawa Power Station

Photo 1: Photos of the Tsuchimurokawa Power Station

Table 1: Specifications of the Tsuchimurokawa Power Station

Name of power station	Tsuchimurokawa Power Station
Location	Yamanashi Prefecture, Ootsuki-shi, Nanaho-machi
Name of river system and river	Sagamigawa water system, Tsuchimurokawa River
Type of generation	Dam type, Run-of-river power plant
Maximum output	350kW
Maximum plant discharge	0.50m^3/s
Effective head	89.94m
Possible generated energy (Planned value)	1,225MWh

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) Needs for higher performance

Since hydroelectric power generation has less environmental burden and has high supply stability for purely domestic energy, the energy policy promoting hydropower development was proposed after discussions such as with the "New century hydropower plan development committee" (Meeting with the Public Utilities Department manager of the Resources and Energy Agency) held in 1993, and from the "Interim report of Demand and Supply Department of the Electricity Utility Industry Council" in 1994. Responding to this national policy, this power station was developed from the investigation of the effective utilization of the natural final effluent from a pump-up dam, and utilization of the maintenance effluent flow from the existing dam, which was the study to consider the new site development.

(3) Necessity in market

(Not applicable)

2.2 Process to Identify and Define Renewal and Upgrade Work Measure

March, 1996: The project plan was approved.
April, 1998: Construction began
August, 1999: The installation of the water turbine generator began
December, 1999: Operations of the Tsuchimurokawa Power Station began

2.3 Description of Work Undertaken (detail)

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

The Tsuchimurokawa Power Station was planned to generate electric power by utilizing the natural final effluent discharged from the Kazunokawa Dam which is a downstream dam of the Kazunokawa Power Station (pure pump-up type, output of 1.6 million kW) which was under construction at that time.

When the generation plan was made, simplification of the facilities and labor savings were considered so as to improve economic efficiency which was the most important goal for this small scale hydroelectric power station. As one concrete example, in the selection of the waterway route, the effluent pipe installed on the body of the downstream dam was to be used as a shared facility with this power station, and at the middle of the line, a steel pipe was to be branched and used to feed the power station. The location of branching was studied and designed to shorten the length of the pipe so as to save on civil engineering work costs.

According to the “Selection Guide of the Water Turbine Type”, four types (horizontal Pelton turbine, Turgo impulse turbine, cross flow turbine, and horizontal Francis turbine) were applicable for this power station. Also, the conditions at this power station needed to be considered as follows; 1) the low volume water flow lasts for an extended period of time, and 2) there is a fluctuation of the dam water level caused by the operation of the Kazunokawa Power Sstation. As a result, the Pelton turbine was chosen because it is better in terms of Variable Water Volume and Variable Head Characteristics than other types.

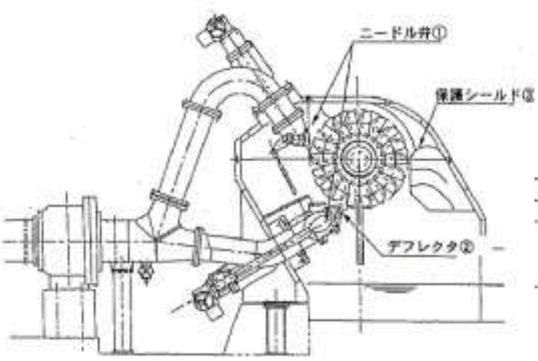
(1) Development of the horizontal shaft three-jet Pelton turbine

A Pelton turbine has an advantage of high partial load efficiency, but it is also higher in cost, so we carried out collaborative research with the system manufacturer to achieve low cost while retaining the Pelton turbine’s advantages.

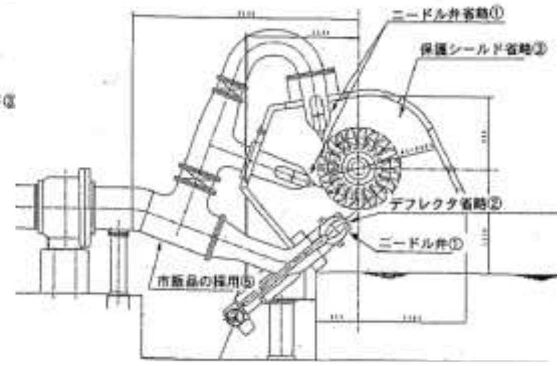
In this study, we have investigated increasing the nozzles for the horizontal Pelton turbine and conducted verification tests using models. We were able to achieve the 3 nozzle Pelton turbine. This development improves the flow characteristic for head and expands the applicable range into low head and large water volume, making it possible to downsize the water turbine and simplify the facility.

(2) Application to the Tsuchimurokawa Power Station

The developed horizontal shaft three-jet Pelton turbine was tested and confirmed in its application performance by a test using effluent from the downstream dam, and the results obtained were reflected in its machinery design. As a result, it was determined that only No. 1 nozzle needs to adopt the conventional needle operation system, and the other two nozzles utilize electric motor operated shut-off valves. For actual application, it was confirmed that a fluctuation of flow volume caused by nozzle switching was acceptable and there was no impact on the bearing by the unevenness of water flow volume from each nozzle. This design enabled simplifying the operating mechanism to adjust discharged water volume, and achieve the desired cost savings. (Fig. 2)



Toraditional Pelton (two jet type)



Simplify Pelton (three-jet type)

Fig. 2: Comparison between the conventional Pelton turbine (2-jet type) and the simplified Pelton turbine (3-jet type)

The water flow volume regulation of this power station is conducted as part of the dam water discharge control, and basically, targeted water discharge is determined from the civil engineering view point. As for the water turbine, water volume is totally controlled by the combination of opening level control of the needle and nozzle switching, and for the outlet gate, by the gate opening degree control.

On top of that, simplification of the facilities and cost savings was pursued by the elimination of the deflector by eliminating speed restraints, elimination of the flow straightening plate in the housing, and adoption of a commercial T pipe for the nozzle branch pipe, and others.

(3) Other cost saving

For the generators, by adopting induction machines, exciters and governors were able to be eliminated and thus save cost. Besides, the control protection system was studied to find the best suited system for the supervised control for this power station, and it was found that the general integrated electric switchboard can be used. By adopting this switchboard the numbers of control panels can be reduced and costs can be saved.

3. Feature of the Project

3.1 Best Practice Components

(1) Construction was conducted concurrently with the Kazunokawa Power Station

Since the construction was able to be conducted concurrently with the work of the Kazunokawa Power Station, civil engineering work cost was able to be reduced.

(2) Expansion of the applicable range of the horizontal shaft three-jet Pelton turbine

Expansion of the applicable range enables simplification and labor saving on the equipment and makes it possible to save costs.

(3) Simplification of the facilities

Since the facilities were able to be constructed with the minimum necessary functions, the construction cost was able to be saved.

3.2 Reasons for Success

This project was successful for the following reasons: 1) the applicable range was able to be expanded with the development of the horizontal shaft three-jet Pelton turbine, 2) necessary functions for this power station were fully studied and reflected in the design, and 3) design and construction of the waterway and the power station layout were able to be conducted concurrently with the Kazunokawa Power Station. These things enabled constructing the power station economically and efficiently.

4. Points of Application for Future Project

Since it is hard to obtain the advantage of scale in the development of a small scale hydroelectric power station, it is important to reduce the construction cost while retaining the essential functions as a power station. In this project, construction cost was able to be reduced by the development of the horizontal shaft three-jet Pelton turbine, and designing the facility configuration which kept the minimum necessary function as a power station

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

Since the operation was started, there have been no major troubles and the station has remained running with the planned electricity being generated.

6. Further Information

6.1 Reference

“Design and construction of the environmental flow discharge power station” (Inekoki Power Station and Tsuchimurokawa Power Station)

- *Tsuchimurokawa Power Station utilizing natural final effluent from the newly constructed recirculating pumped storage power station*. (Hara, Yohei, et.al., practice workshop about small-medium hydroelectric power station, July, 1999)

6.2 Inquiries

Company name: Tokyo Electric Power Company, Incorporated

URL: http://www.tepco.co.jp/index-j.html

ANNEX XI　Renewal & Upgrading of Hydropower Plants

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

Category and Key Points

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

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

Project Name:

The Restoration work of the Nishikinugawa Hydroelectric Power Station

Name of Country (including State/Prefecture):

Japan, Tochigi Prefecture

Implementing Agency/Organization:

Tokyo Electric Power Co., Inc.

Implementing Period:

From 1997 to 1999

Trigger Causes for Renewal and Upgrade:

(A) Degradation due to ageing and recurrence of malfunction

Keywords:

Restoration cost, Reduction of maintenance and inspection cost, Increase of the annual power generation

Abstract:

Since the turbine generators and the power station building were seriously aging, this restoration work had to be conducted.　The work was carried out so as to be the most economically efficient by studying how to reduce the restoration costs, maintenance and inspection cost, yet how to increase the annual power generation.

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

The Nishikinugawa Hydroelectric Power Station owned by Tokyo Electric Power Co., Inc. is located in Utsunomiya-shi, Tochigi Prefecture at a midstream site of the Kinugawa River in the Tonegawa water system. Its operation was started in May, 1928 with a maximum plant discharge of 12.22m^3/s and maximum output of 1,000kW using an effective head of 11.21m as a waterway type power station. Some of the intake water is discharge water from the Kazami Power Station owned by Tochigi Prefecture which is located 4km upstream.

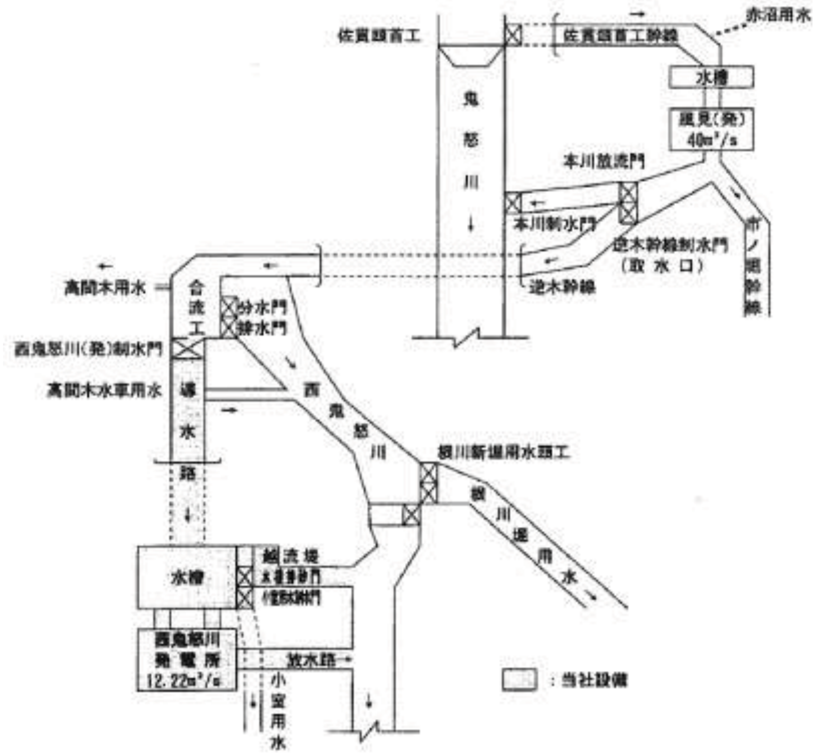


Fig. 1: Outline of the site around the Nishikinugawa Hydroelectric Power Station

Table1: Specifications of the Nishikinugawa Hydroelectric Power Station before restoration

Item		Specification
Output		1,000（kW）
Annual energy production		6,813（MWh）
Type of power station		Waterway type
Plant discharge		12.22 (m^3/s)
Effective head		11.21 (m)
Turbine	Type	HF-2ROW 2 machines
	Output	580kW
	Rotating speed	428 rpm
Generator	Type	Horizontal revolving-field type three-phase alternating current synchronous generator; 2 machines
	Output	680 kVA
Power station building		made of wood and plaster
Head tank regulating gate		Steel slide gate: 2 gates

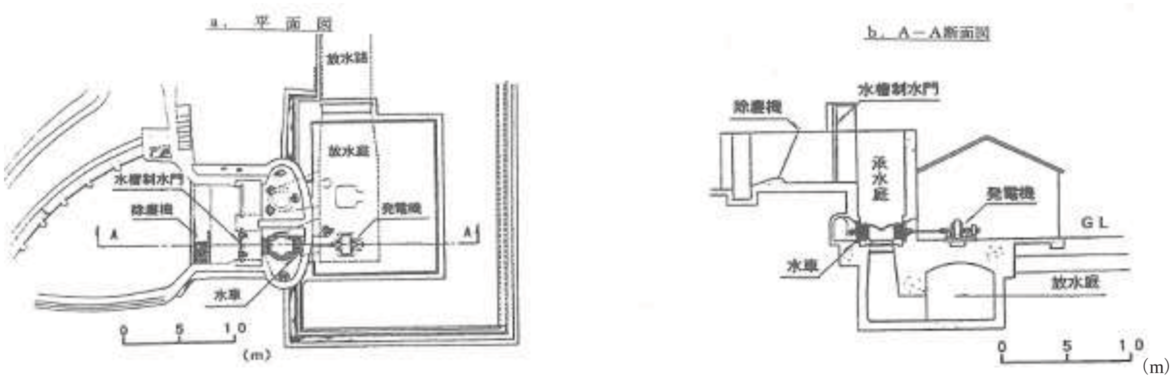


Fig. 2: Plan view and cross section view of the power station before restoration

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) Degradation due to ageing and recurrence of malfunction

a. Turbine

The previous turbines were an inside type turbine whose guide vane operation mechanism was submerged so sliding surfaces tended to freeze up and to degrade the foundation concrete of the catch basin. This in turn resulted in the machines moving out of level which led to trouble closing the guide vanes. Therefore, before restoration, movement tests of full opening and full closing were conducted periodically every day. In addition, once a year an overhaul was conducted. Since the turbines were a double wheel, single jet type, a large adverse change of the level of the installation occurred in the one place where the draft bend pipe was attached, and two places where the headrace frame guide vane was attached (3 places total), making it extremely difficult to assemble and adjust parts after overhaul.

Besides, progressive defects were found where the turbine shaft side runner was attached and on the key groove, and the shaft diameter was reduced by wear, resulting in a decrease of the fatigue strength allowance for the turbine shaft.

b. Power station main building

The main building was made of wood and plaster, and the foundation, beams and columns were corroded and generally aging seriously and so provided little earthquake protection.

c. Catch basin

For the catch basin which functioned as a casing (vertical shaft after restoration), some portion of the concrete inside of the catch basin was peeled and cracks occurred. From these cracks and construction joints water leaked into the generator room.

d. Head tank regulating gate

The head tank regulating gate was seriously aging due to rust development on the gate body and vibration of the hoisting winch occurred due to the gears rusting.

As described above, the turbines, the power station building and some parts of the waterway facilities were generally damaged, and since it was judged that it is difficult to maintain the necessary function with only a partial repair, it was determined to implement a complete restoration.

(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 Nishikinugawa Hydroelectric Power Station had been operated for 70 years since commencement in 1928, and seriously aged. The resulting failures and trouble with the turbines, the power station building and some parts of the waterway facilities made it difficult to maintain the functions with only a partial repair, so it was judged necessary to conduct a complete restoration.

1928:	Operation of the Nishikinugawa Hydroelectric Power Station (existing) began
1964:	The Kazami Power Station (owned by the Prefecture) was newly built upstream, and modification work was conducted so that the water inlet of the Nishikinugawa Power Station was connected to the outlet of the Kazami Power Station.
September 1997:	The restoration work of the Nishikinugawa Hydroelectric Power Station began
January 1999:	The restoration work of the Nishikinugawa Hydroelectric Power Station was completed.

2.3 Description of Work Undertaken (detail)

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

This power station had been operated for 70 years since commencement in 1928, and seriously aged. The resulting failures and trouble with the turbines, the power station building and some parts of the waterway facilities made it difficult to maintain the functions with a partial repair, so it was judged necessary to conduct a complete restoration.

The restoration plan was developed to convert the existing facilities fully and the turbine type was selected so as to be the most beneficial in terms of annual energy production and economic efficiency of the restoration work cost based on the current flow conditions and head.

As a result, it was determined that two turbines were to be replaced with one new turbine, and S-type tubular turbines were adopted because it was the most economically beneficial. This turbine type enables minimizing the expansion of the foundation of the power station and tailrace due to turbine location, and is able to increase the maximum output by an increase of turbine efficiency, further increasing annual energy production.

Table 2: Specifications of the Nishikinugawa Hydroelectric Power Station after restoration

Item		Specification
Output		1,200 (kW)
Annual energy production		8,026 (MWh)
Type of power station		Waterway type
Plant discharge		12.22 (m^3/s)
Effective head		11.01 (m)
Turbine	Type	HK-1RTS 1 machine
	Output	1,220kW
	Rotating speed	300 rpm
Generator	Type	Horizontal revolving-field type three-phase alternating current synchronous generator; 1 machine
	Output	1,160kVA
Powerhouse		made of wood and plaster
Head tank regulating gate		Sliding steel gate: 2 gates

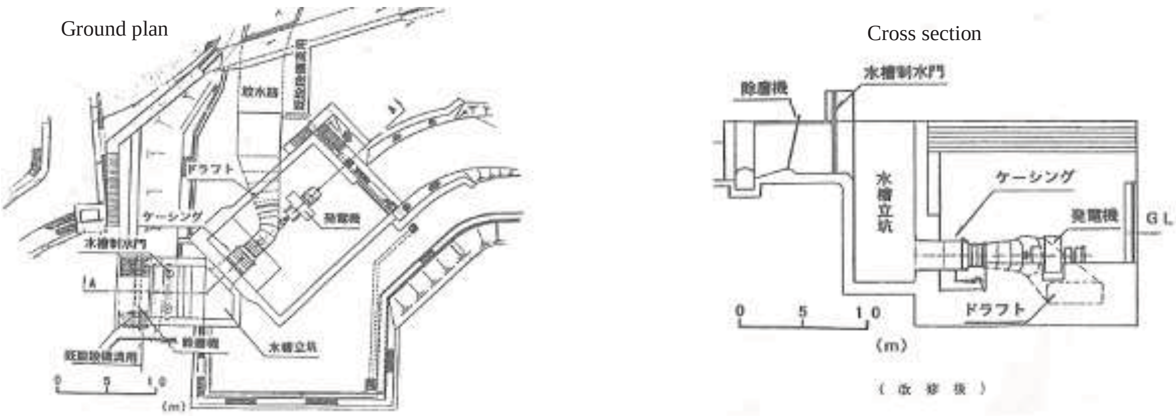


Fig. 3: Plan view and cross section view of the power station after restoration

(1) Turbine and generator

For the turbine, the two previous horizontal Francis turbines were replaced with one horizontal S-type tubular turbine with movable blades because it has economic advantages such as an increase of annual power generation by high efficient operation, smaller foundation space for the turbine generator where restoration was required, availability of the existing tailrace, and fit for low building overhead clearance.

For generators, a runaway speed regulator was adopted in order to reduce generator weight decreasing flywheel effects. In addition, by downsizing of a crane, the construction cost was reduced.

On top of that, the number of the main machines was reduced from 2 to 1, to save maintenance cost.

(2) New installation of the head tank shaft and some parts of the tailrace

On the premise that for the head tank, casing joint area, drafts and tailrace, the existing facilities were retained as much as possible. The layout for the existing power station site was studied, and a head tank shaft and some parts of the tailrace were newly constructed.

The planar shape of the head tank shaft is asymmetrical versus the casing shaft of the S-type tubular turbines, and from the left-hand corner, a large swirl flow occurs developing a vortex, therefore it is supposed that air-sucking tends to be easily created.

Furthermore, since the cover depth for the corresponding diameter of the vertical shaft is small, there was a fear that air-sucking would be induced. Therefore, for the shape of the vertical shaft, it was designed so that the downward flow rate would be less than 1m/s.

As shown in Fig. 4, in the head tank vertical shaft, vortex prevention measures was taken by adopting a 45°tilted plate on the upper wall surface to mask about 2/3 of the free water surface, so as to prevent the occurrence of a second swirl flow and an air-sucking vortex.

In actual operation, no vortex occurred accompanied with air-sucking at the inlet into the vertical shaft, and there was no vibration, therefore it became clear that this restraint measure works well.

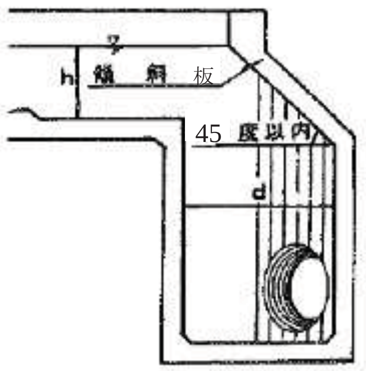


Fig. 4: Setting of the tilted plate

In the design of the materials of the head tank vertical shaft, the existing catch basin whose wall thickness was 2.0m and GL-2.00m, was sunk into the bedrock, and furthermore connected to the tailrace tunnel whose wall thickness was 76cm, making an integrated structure.

The new vertical shaft of the head tank was designed to be located at the GL-3.00m floor inside of the existing catch basin. On the other hand, the largest load in vertical shaft designs is applied on the lower side wall of the vertical shaft where the maximum water pressure occurs.

From these facts, the vertical shaft materials were able to be reduced by increasing the strain effect of the new constructed vertical shaft side wall while retaining the foundation of the catch basin as much as possible.

The study model of the head tank vertical shaft is shown in Fig. 5.

By retaining some of the catch basin, when compared with the case in which the entire catch basin was demolished, it became possible to reduce the thickness of the concrete material of the newly constructed vertical shaft and to reduce the amount of demolished concrete to be removed by 20%.

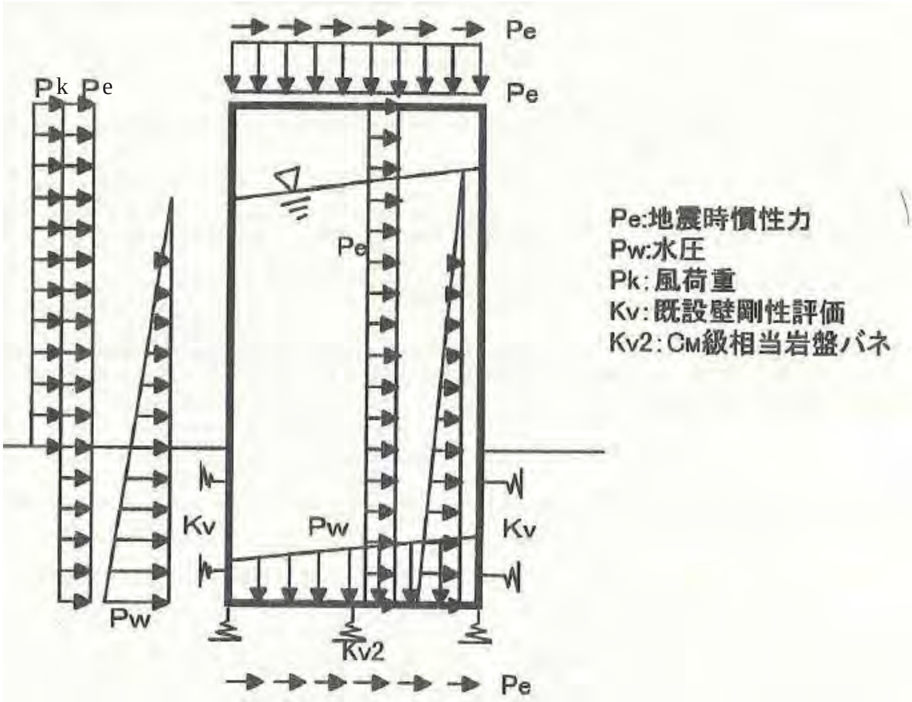


Fig. 5: Study model of the head tank vertical shaft

(3) Electric servomotor

Electric servomotors were adopted for the control mechanism of the guide vanes and runner vanes, eliminating the ancillary facility such as for hydraulic oil pressure supply systems and cooling equipment, thus the facilities were able to be simplified saving maintenance costs. In addition, by eliminating the hydraulic oil systems, it reduced the risk of oil leaking into the river.

(4) Thrust bearing

For the thrust bearings, an air cooling method was adopted simplifying the facilities further reducing maintenance costs.

(5) Head tank regulating gate and inlet valve

The head tank regulating gates were changed from two gates to one in accordance with the number of turbines, and by installing an automatic lowering function on the regulating gate, the turbine inlet valve was eliminated.

As a result, when compared to the case in which inlet valve is installed, the depth of the power station building was able to be reduced by about 3m, enabling a reduction in construction costs.

As for the opening and closing apparatus of the regulating gate which has the automatic lowering function, a wire rope type and a rack type were compared in terms of economic efficiency. As a result, the rack type is able to use more commercially available parts for its hoisting device than the wire rope type and so is more economical. Also, the necessary inspection period is able to be much longer than that of the wire rope type and better in terms of maintenance, so the rack type was adopted as the opening and closing apparatus.

3. Feature of the Project

3.1 Best Practice Components

(1) Adoption of the horizontal S-type tubular turbines

- able to increase maximum output and annual energy production
- able to reduce the restoration cost by reusing the existing tailrace and by downsizing the restoration area of the turbine foundation.

(2) Integration of the main machines and elimination of the ancillary equipment such a hydraulic oil supply system and cooling equipment.

- able to downsize the facilities and reduce the future maintenance and inspection costs.

(3) Adoption of electric servomotors and runaway speed regulators for the generators.

- able to reduce the restoration cost by downsizing of the hoist, and to reduce the risk of an oil leak by adopting the oilless system.

(4) Prevention countermeasure of air-sucking and vortex occurrence at the head tank vertical shaft

- able to successfully control this by the design of the shape of the vertical shaft and by setting of the tilted plate.

(5) Utilization of the foundation of the existing catch basin

- by keeping the foundation of the existing catch basin, the concrete material thickness of the head tank shaft was able to be reduced.

3.2 Reasons for Success

In order to reduce the restoration cost and increase an annual energy production, the turbine type, the shape of the head tank vertical shaft and machinery layout were properly designed, allowing the restoration work to be completed economically. Also, by integrating the main equipment and by downsizing the facilities such as the ancillary equipment, it became possible to reduce maintenance and inspection costs.

For the design of the head tank vertical shaft, by implementing the vortex prevention measure by the setting of the tilted plate, abnormal vibration on the turbine was eliminated, and since the commencement of the operation, there have been no major problems.

4. Points of Application for Future Project

For this restoration work, in order to make the power station economical, it was important to develop a restoration plan so as to minimize the restoration work costs and the future maintenance cost per generated energy. In this restoration project, from such a view point, the S-type tubular turbine was adopted, and the main machinery was selected (integrated from two machines to one machine), the existing facilities were reused as much as possible, machinery layout was developed appropriately, and some ancillary equipment was eliminated.

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

This restoration work was started in September, 1997, and completed in January, 1999 when operation began. Since then, until today, this power station has been operated successfully without any major problems occurring.

6. Further Information

6.1 Reference

New Energy Foundation, "The Plan, Design and Construction of the Restoration Project of the Nishikinugawa Hydroelectric Power Station", *Text for the workshop for the small and medium-sized hydroelectric power station*, November, 1999

6.2 Inquiries

Company name: Tokyo Electric Power Company, Incorporated

URL: http://www.tepco.co.jp/index-j.html

ANNEX XI Renewal & Upgrading of Hydropower Plants

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

Category and Key Points

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

Sub: 1-f) Environmental conservation and improvement

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

Project Name:

The restoration work of the Minakata Hydroelectric Power Station

Name of Country (including State/Prefecture):

Japan, Nagano Prefecture

Implementing Agency/Organization:

Chubu Electric Power Co., Inc.

Implementing Period:

from 1998 to 2000

Trigger Causes for Renewal and Upgrade:

(A) Degradation due to ageing and recurrence of malfunction

(B) Environmental deterioration

Keywords:

Metal & Plastic Spraying, Low frequency vibration, Consolidation of intake gates

Abstract:

The Minakata Hydroelectric Power Station has been operated for about 70 years since the commencement of operations, and the turbine generators, intake facilities and spillway gates were progressively aging. Therefore, so as to extend its life and improve maintainability, almost all of the facilities were fully restored. In addition, in this restoration work, countermeasures were implemented against low frequency vibration which occurred in the operation of the turbine generators.

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

The Minakata Hydroelectric Power Station, owned by the Chubu Electric Power Co., Inc. is a channel type power station with a maximum output of 24,100kW (26,700kW: after restoration) which is located in Nakagawa-mura, Kamiina-gun, Nagano Prefecture, at a point mid-stream of the Tenryugawa water system (see Table 1 and Fig. 1).

Table 1: Specification of the power station

Power station	Minakata Hydroelectric Power Station
Water system, River	Tenryugawa river system, Tenryugawa River
Maximum output	24,100kW(26,700kW after restoration)
Maximum plant discharge	$37.70m^3/s$
Effective head	79.35m
Commencement of operation	April, 1929

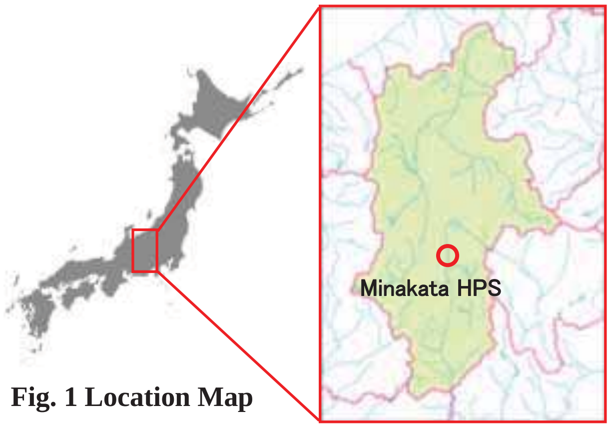


Fig. 1 Location Map

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 frequent failures - Improvement of durability and safety

(Spillway gate)

Four rolling gates, each with a length of about 26m and a diameter of about 2.9m, are installed on the concrete gravity dam whose height is about 7.6m, length is about 123.6m, and since construction, about 70 years has passed.

Throughout this time, periodic inspections and painting have been conducted so as to control the degradation due to aging. However 70 years has passed and the corrosion of skin plates was progressing.

(Water intake facilities)

Six steel sluice gates were installed as intake regulating gates, and in front of them, six screens were placed. But due to aging, degradation of the concrete structures and corrosive degradation of the steel sluice gates and screens was identified.

(Turbine generators)

Two vertical Francis turbines and two vertical three phase AC generators were operated for about 70 years since the commencement of operations, and the corrosive degradation of the turbine casings and decrease of the insulation resistance of the stator coil of the generators was progressing.

(A)－(d) Degradation due to aging and frequent failures --- Easy maintainability with less labor

(Water intake facilities)

Previously, trash which was trapped on the screens had to be removed manually.

(B)－(c)　Environmental degradation - Others

(Draft tube)

Draft tubes progressively corroded and some steel cladding was peeled off from the concrete body, thus, it was difficult to maintain a good condition by only a partial repair.

Besides, from residents living in the vicinity of the power station, there have come complaints about low frequency vibration caused by the operation of the turbine generator (partial load range).

(2) Improvement of value (functions)

Not applicable

(3) Necessity in the market

Not applicable

2.2 Process to Identify and Define Renewal and Upgrade Work Measure

April 1929:	Operation of the Minakata Hydroelectric Power Station began
1967:	Stress test of the spillway gate of the Power Station was conducted.
1987:	Thickness survey of the plates of the spillway gate of the Power Station was conducted.
1990:	Drilling survey of the lining of the headrace of the Power Station was conducted.
1994:	Geological survey of the cross section of the headrace of the Power Station was conducted.
August 1998:	The restoration work of the facilities of the Power Station began
June 2000:	The restoration work of the facilities of the Minakata Hydroelectric Power Station was completed.

2.3 Description of Work Undertaken (detail)

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

(Turbine generator)

From the view point of head and discharge, this power station's turbine range of 100～200m-kW is within the typical vertical Francis turbine's range, therefore vertical Francis turbines were adopted the same as the existing facilities.　The power station building and hydraulic steel pipes were reused. For the number of the main machines, the two machine scheme was retained because of good economic efficiency as was revealed by investigation.

With the aim of downsizing the turbine generator, the rotation speed was increased from 300rpm to 327rpm. (See Table 2)

Table 2: Specifications of the turbine generator

Item		Before restoration	After restoration
Turbine	Type	Vertical shaft, single runner, single discharge, spiral Francis turbine	
	Output	16,412/15,666kW×2 machines	13,800kW×2 machines
	Frequency	60/50Hz	60Hz
	Rated rotation speed	300rpm	327rpm
	Cooling method for bearing	Water cooling type	Water less type (air cooling)
Generator	Type	Three phase synchronous vertical revolving-field type	
	Capacity	15,000kVA×2 machines	14,100kVA×2 machines
	Rated rotation speed	300rpm	327rpm

1-f) Environmental conservation and improvement

(Draft tube)

To control the low frequency vibration, the countermeasures shown in Table 3 were implemented.

Table 3: Actual countermeasures and their expected effects

Countermeasure items	Contents	Expected effects
Installation of triangular fin	Fin was installed in the conical region of the draft	- Reduction of the water pressure pulsation - Control of whirl by the straightening effect
Structure modification of the draft outlet	Elimination of the resonance space	- Prevention of resonance
	Modification of the pier	- straightening effect - Control of vortex flow
Change of the draft shape	Expansion of the draft outlet area	- Straightening effect - Reduction of water surface , Fluctuation and pulsation
	Elongation of the draft length(3m)	- Elimination of the resonance space - Straightening effect

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

(Spillway gate)

As a result of the survey of this gate, it became clear that there was no problem in terms of stress by virtue of cylinder geometry, but skin plates and beam materials were seriously corroded. Therefore, construction methods which prevent the progress of the degradation were adopted.

Adopted construction methods were a blast process to remove the degraded steel membrane, and metal and plastic spraying.

The metal spraying is a process to create a metal membrane on skin plates and beam materials by spraying an alloy of zinc (95%) and aluminum (5%), which are melted and misted by compressed, high-temperature air

Since the sprayed metal membrane is composed of overlapping metal micro-particles, the coated layer is porous. By impregnating the metal membrane with plastic resin which is melted and misted by heated, compressed air into the porous voids to seal them off, it was intended to improve the rust prevention effect for the coated metal surface by preventing the penetration of moisture. (See Fig. 2)

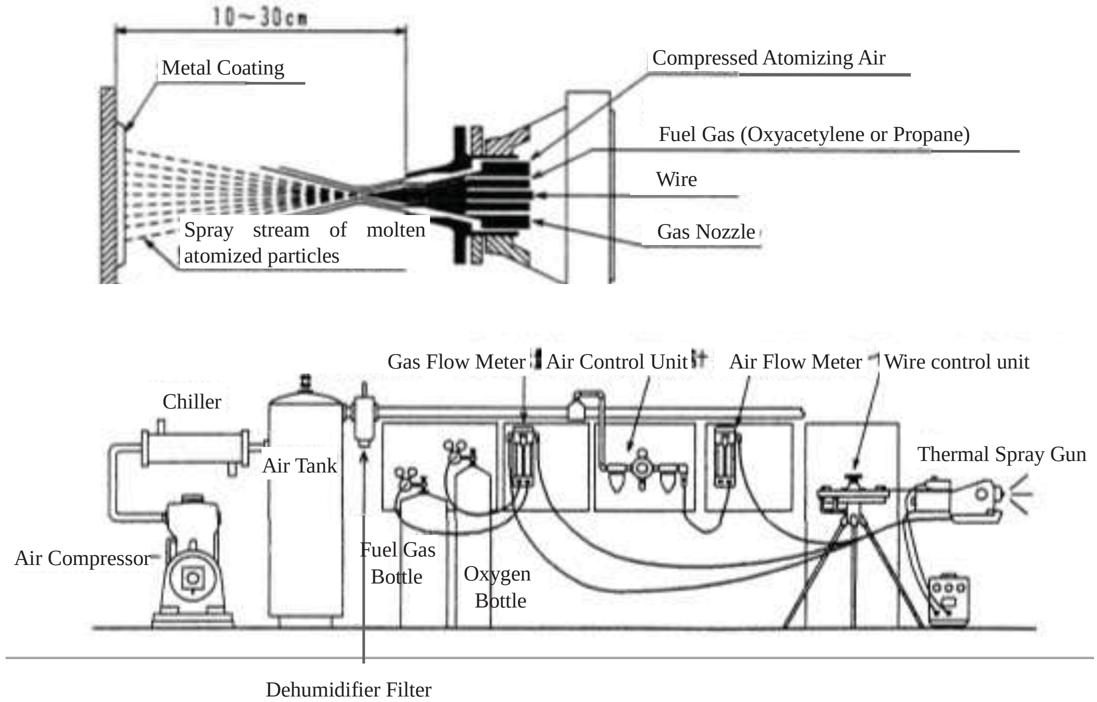


Fig. 2: Schematic Diagram of Metal Spraying Process

Metal spraying is a process to utilize the sacrificial anticorrosive effect, and when compared with the other anticorrosive methods (i.e., heavy-duty coating, zinc plating (include paint application)), 1.5 to 1.8 times of the initial investment is required. However, since more than 2 times the life limit is expected, life cycle costs became advantageous.

In addition, the metal spraying process can be used at the construction site, so the application range is larger than others. Further, when compared with heavy-duty coating methods which also can be used at construction sites, the metal spraying process doesn't require curing even when multiple spraying processes are conducted simultaneously, so, generally the term of work is shorter.

(Water intake facilities)

There were six intake regulating gates and six screens. Control of the gates was complicated and inspections and maintenance were cumbersome. Therefore, the water intake concrete structures were demolished and two new screens were installed. In addition, the location of the intake regulating gate was changed to the inlet of the headrace, and the gates were consolidated into one steel roller gate. By these actions, the control, inspection and maintenance process was simplified.

On top of that, by installing two trash collectors which were placed at the front of the screens and are operated automatically, labor saving was achieved. (See Table 4 and Photo 1)

Table 4: Specifications of the intake regulating gate and screen

Item		Before restoration	After restoration
Intake regulating gate	Type	Steel sliding gate	Steel roller gate
	Number of gates	6 gates	1 gate
	dimension	Width 2.995m×height 3.745m	Width 6.000m×height 5.560m
Screen	Number of gates	6 gates	2 gates

Photo 1: Intake before and after restoration works

3. Feature of the Project

3.1 Best Practice Components

- Metal spraying process and plastic spraying process were adopted so as to extend the service life of the steel roller gates
- Maintainability has been improved by consolidating the intake regulating gates into one gate.
- Rotation speed was increased so as to downsize the turbine generator.
- In order to prevent low frequency vibration, the outlet of the draft tube was expanded, and a triangular fin was attached on the conical region of draft.

3.2 Reasons for Success

By utilizing the existing facilities as much as possible, by introducing the latest technologies, and with minimum necessary restoration work, an extension of the working lifetime was achieved.

4. Points of Application for Future Project

- When the old power station is small in scale and there are many facilities used therein, is it possible or not to make them larger and to consolidate them (intake gates, screens and dust collectors, etc.)?
- When the turbine generators and draft tubes are replaced extensively, it is very important to study the structural strength of the power station building, probable retained life of the old facilities, and reinforcing work methods.

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

(None)

6. Further Information

6.1 Reference

T. Hashizume, H. Iida, T. Murakami, “Construction Report of the Restoration Work of the facilities of the Minakata Hydroelectric Power Station ” Electric Power Civil Engineering Association *: Journal of Electric power Civil Engineerin*g, (2000.7)

6.2 Inquiries

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

Project Name:

The application of guide vanes which have a shape for reducing sand abrasion for Himekawa No.2 Hydroelectric Power Station

Name of Country (including State/Prefecture):

Japan, Nagano Prefecture

Implementing Agency/Organization:

Chubu Electric Power Co., Inc.

Implementing Period:

From 2005 to 2010

Trigger Causes for Renewal and Upgrade:

(A) Degradation due to aging and frequent failures

Keywords:

Guide-vanes, Sand abrasion, Interval of Repair work

Abstract:

In the Himekawa No. 2 Hydroelectric Power Station, the turbine parts were being seriously abraded by sand contained in the flow water, and it was necessary to repair the damaged parts in a shorter interval than usual for other power stations.　Consequently, by changing the shape of the guide vane which is a part of the turbine, sand abrasion was intended to be reduced.

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

The Himekawa No. 2 Hydroelectric Power Station owned by the Chubu Electric Power Co., Inc. is a waterway type hydropower with a maximum output of 14,400kW, located in Kotani-mura, Kitaazumi-gun, Nagano Prefecture, upstream of the Himekawa water system (See Table 1 and Fig. 1)

Table 1: Specifications of the Himekawa No. 2 Hydroelectric Power Station

Power station	Himekawa No. 2 Hydroelectric Power Station
Water system, River	Himekawa water system, Himekawa River, Kusugawa River, Matsuzawa River, Oyasawakawa River, Kurosawagawa River
Maximum output	14,400 kW
Maximum plant discharge	10.30 m^3/s
Effective head	164.55 m
Commencement of operation	October 1935

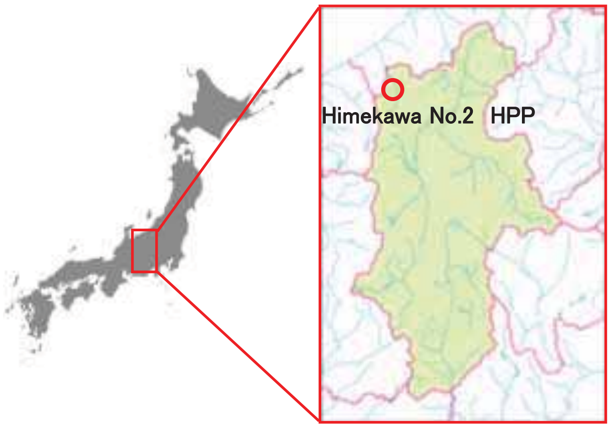


Fig. 1: Location map

The runners and guide vanes (flow regulating devices) of the turbine of the hydroelectric power station, and other parts are abraded by sand contained in the water flow. Thus, periodically they are restored to their original shape by buildup welding and other repairs.

Fig. 2 shows the status of the sand abrasion around the guide vane of the turbine. Generally, in normal power stations, depending on the level of degradation, repairs are conducted at an interval of every 15 years on average. But in this power station, since sand abrasion is much more extensive, repairs have been conducted in shorter, 4 to 6 year intervals so countermeasures to reduce sand abrasion were required.

Consequently, by analyzing the water flow movement containing sand in the turbines using flow analysis (CFD：Computational Fluid Dynamics), a guide vane shape which enables the reduction of the sand abrasion effect (See Fig. 3) was developed, and it was applied to the Himekawa No. 2 Hydroelectric Power Station.

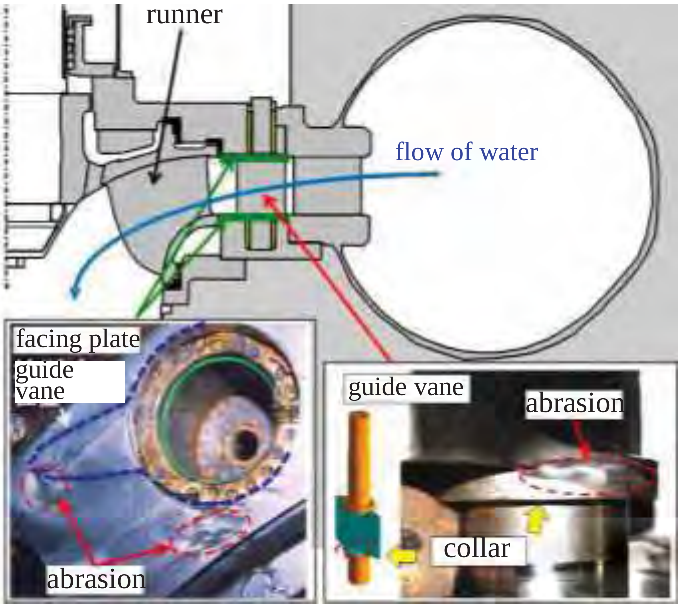


Fig. 2: Sand abrasion of the guide vane of the turbine

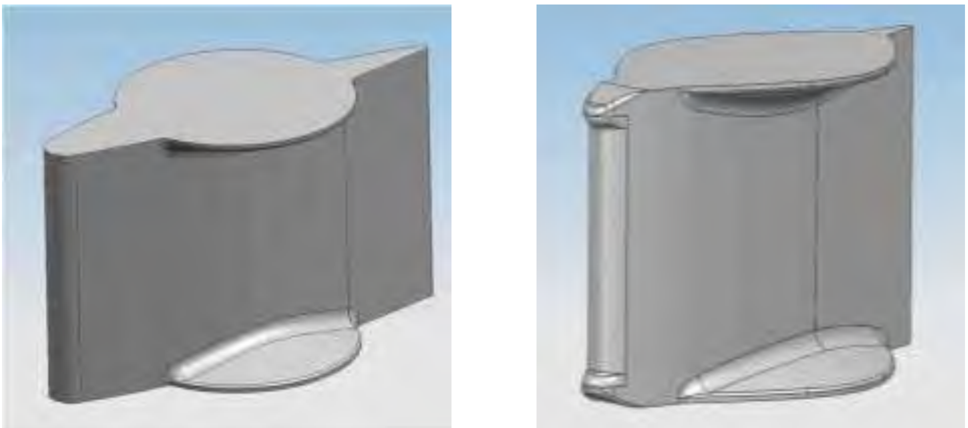


Fig. 3: Shape of a guide vane

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 frequent failures - improvement of durability and safety

For the turbine of the hydroelectric power station, runners and guide vanes (flow regulating devices) and other parts are abraded by sand contained in the water flow.　By this effect, the performance of the turbines decreased, the repair interval became short, repair costs increased and overflow power got larger.

(2) Improvement of value (functions)

Not applicable

(3) Necessity in the market

Not applicable

2.2 Process to Identify and Define Renewal and Upgrade Work Measure

October 1935: Operation of the Himekawa No.2 Hydroelectric Power Station began.

April 2005 to March 2006: Basic study of the analysis technology was conducted.

April 2006 to March 2008: The design of the guide vane shape for preventing sand abrasion was conducted by flow analysis.

December 2007 to March 2010: The field test and evaluation was conducted at the Himekawa No.2 Hydroelectric Power Station

2.3 Description of Work Undertaken (detail)

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

(1) Development of the evaluation method for the sand abrasion

For the development of turbine performance, flow analysis has been utilized, and by optimizing the shape of runners and guide vanes, performance has been improved. However, since the conventional flow analysis was mainly aimed to optimize the shape of the flow channel so as to reduce the flow loss in the turbine, in this case the flow analysis method has been developed to be suitable for evaluation of sand abrasion.

(Development contents)

- mesh generation method of the site of sand abrasion (complicated shape) (See Fig. 4)
- flow analysis method suitable for sand abrasion and evaluation method

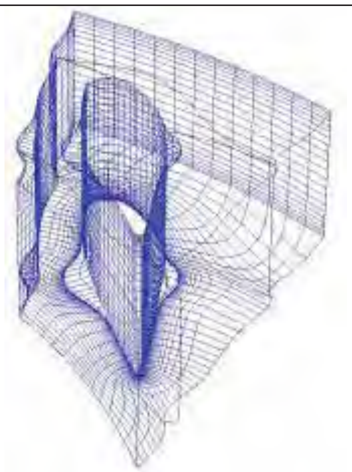
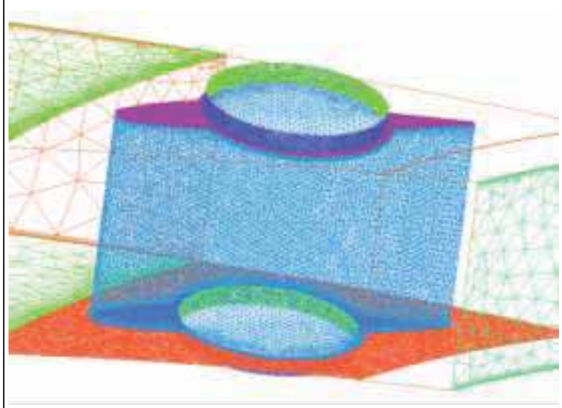
Hexa mesh	Tetra + prism mesh
	
Conventional flow analysis method	Capable to simulate complex shape

Fig. 4: Comparison of the flow analysis methods.

(2) Evaluation of the flow analysis accuracy

The flow analysis was conducted for the standard shape guide vane and clarified the abrasion development mechanism. Comparisons were conducted between the abrasion conditions developed on the actual guide vane and the sheet liner adjacent to the guide vane to confirm the accuracy of the analysis. (See Fig. 5).

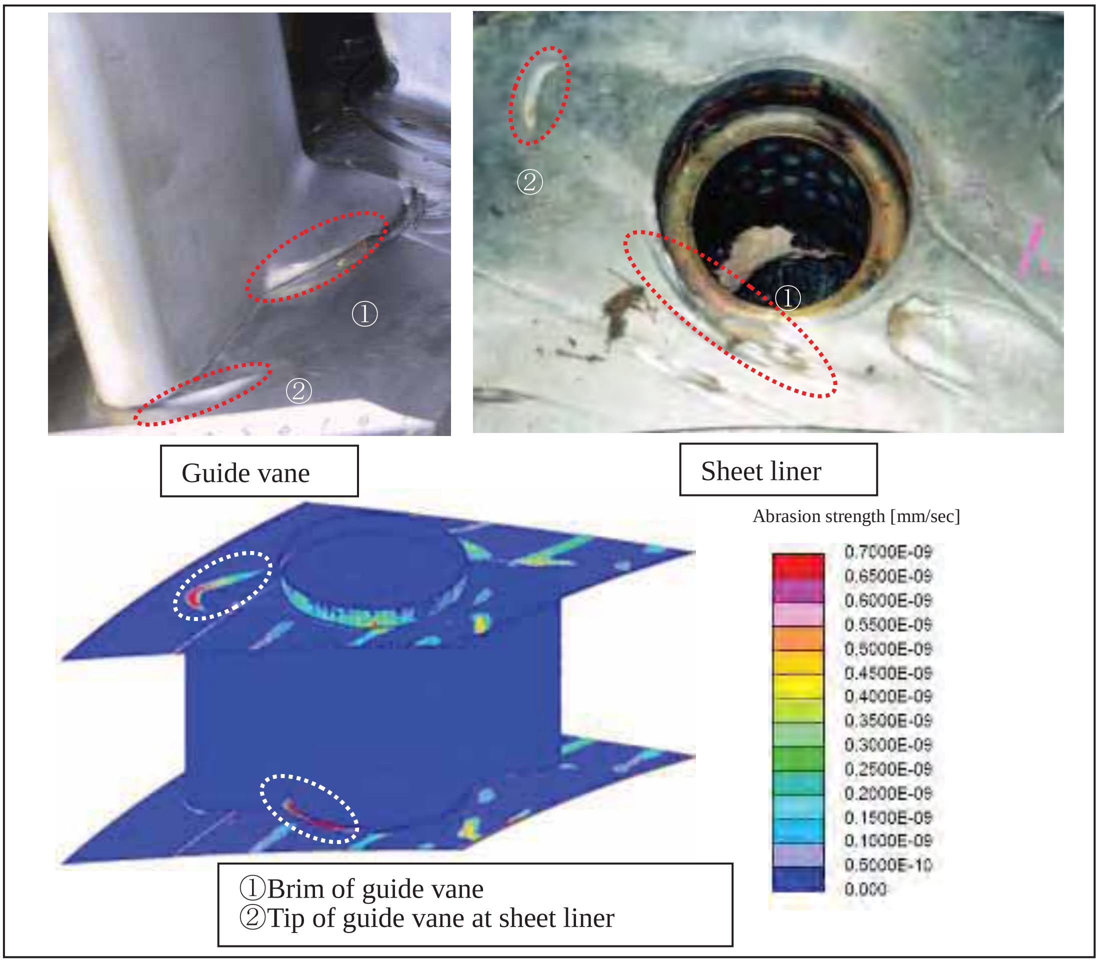
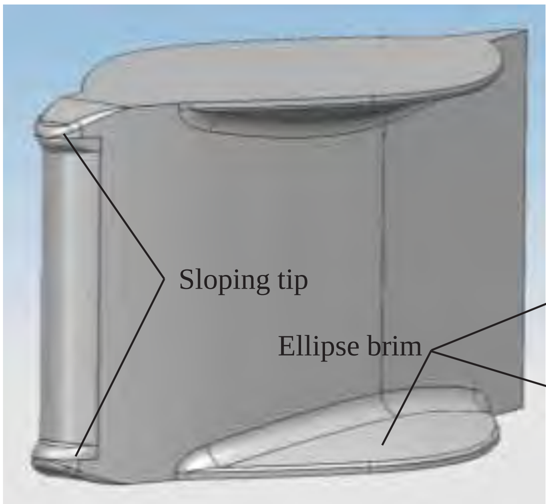


Fig. 5: Results of the sand abrasion strength analysis

(3) Countermeasure for reducing sand abrasion by changing the shape of the existing guide vanes

To prepare the shape which enabled the reduction of abrasion, buildup welding was conducted on the existing guide vane so that the top part of the guide vane inclined and the collar area of the guide vane was modified into an elliptical shape. This change had the effect of reducing the impact angle between sand contained in the flow water and guide vanes and sheet liners (See Fig. 6). As a result, by this shape modification, repair intervals of the guide vane collars became 1.2 times previous, and those of the sheet liners became 3.3 times previous.



New shape by CFD
(Shape modification by buildup welding)

New shape of the actual guide vane
(Shape modification by buildup welding)

Fig. 6: Sand abrasion reducing shape (Shape modification by buildup welding)

(4) Development of the sand abrasion reducing shape of the guide vane for new production

When guide vanes were newly manufactured, the shape which enabled the reduction of abrasion inside the collar area was produced by making the collar area smaller where it was exposed to high speed flow by tilting the guide vane axis to the inside (See Fig. 7). As a result, by the shape modification at guide vane manufacturing, it is expected that the life of the guide vane collar became 2.4 times previous, and that of the sheet liner increased by 10 times. Also the repair interval increased from the current 6 years to 12 years; two times previous experience. (See Table 2).

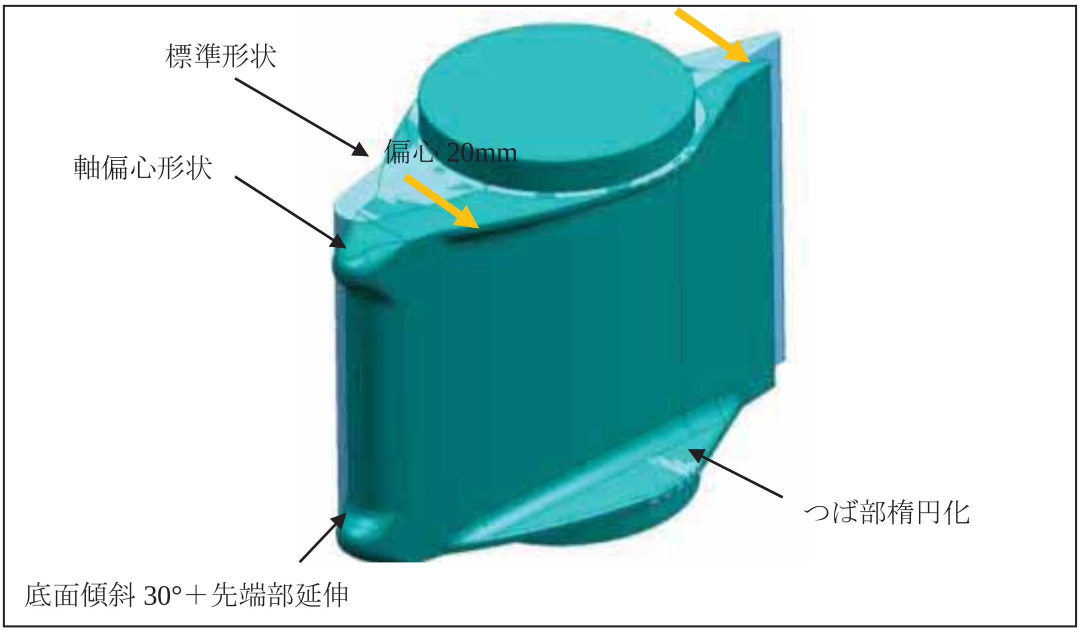


Fig. 7: Sand abrasion reducing shape; new manufacture

Table 2: Evaluation of the shape modification of the guide vane (Flow analysis result)

Item	Modification by buildup welding		Modification as newly manufactured	
Evaluated abraded site	Collar area of guide vane	Sheet liner area	Collar area of guide vane	Sheet liner area
Reduction rate of sand abrasion	△17.0%	△69.5%	△58.5%	△90.3%
Expected extended life length	1.2 times	3.3 times	2.4 times	10 times

3. Feature of the Project

3.1 Best Practice Components

- Improvement of analysis technologies for the water flow containing sand
- Development of the guide vane shape which enables the reduction of sand abrasion

3.2 Reasons for Success

As prevention countermeasures for sand abrasion, coating treatment by thermal spraying, changing into materials with a high abrasion resistance and the optimum design such as shape modification are adopted. When sand abrasion occurs, repairs by buildup welding are conducted. In this case, out of these countermeasures, we focused on the optimum design of the shape, and developed a new flow analysis method. Comparing the analysis accuracy with the results on the actual devices, we conducted field tests and pursued the optimum shape which enables the reduction of sand abrasion. By these actions, it became possible to increase the service life.

4. Points of Application for Future Project

When the repair interval becomes short because of serious sand abrasion of turbine parts, it is necessary to confirm the changes of the flow conditions in that terrain and the sand conditions which are contained in the flow water, affected parts shape, etc., in advance, and to determine the appropriate repair method in terms of running costs.

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

With the view to compare the abrasion level between the modified sand abrasion reducing type shape (modified shape by buildup welding) and the standard type guide vane, field tests were conducted utilizing the actual machine by attaching concurrently both the reducing type and the standard type. The tests were conducted for 2 years. The tested system had 20 guide vanes total; 6 of them were the abrasion reducing type and 14 vanes were the standard shape as shown in Fig. 8.

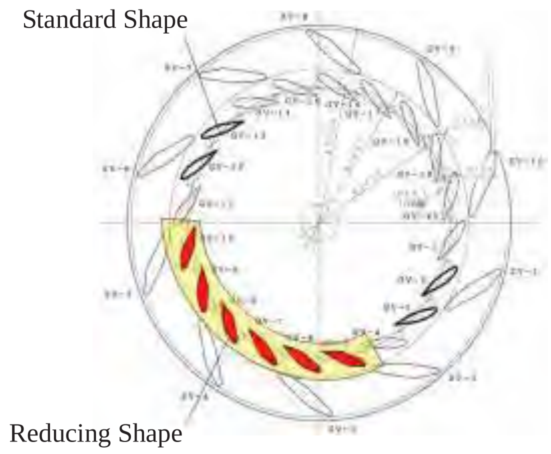
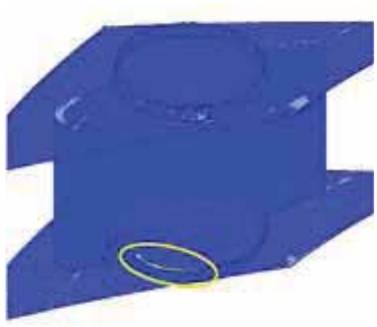


Fig. 8: layout of the guide vanes for the field test

As the result of the field tests, in general, there was not large, distinctive sand abrasion for either the standard type or reducing type, but there were differences in trace damage (dents) by the impact of sand at the area of the collar of the guide vanes. Table 3 shows the results of the field tests. For the standard guide vanes, dents were found in high density mainly on the root of the guide vane, whereas as for the abrasion reducing type, dents were found widely dispersed over the whole collar area. The locations of the dents were similar to the location where strong abrasion was identified from the flow analysis. From these results, it was able to be confirmed that the abrasion reducing type guide vane has a long life in terms of abrasion.

Table 3: The test result of the field tests by the change of the guide vane shape.

	Result of the flow analysis	Result of the field test
Standard guide vane		 Dents are found on the root of the guide vane in high density.
Reducing type guide vane		 Dents are found widely dispersed on the whole collar area

6. Further Information

6.1 Reference

Author, Title, Name of literature, date

Mizutani, Susumu., "Development of the shape of the turbine guide vane which enables the reduction of sand abrasion" *Chubu Electric Power Co., Inc. Technical Development News No.141* (2011.1)

New Energy Foundation, "Countermeasures for reducing sand abrasion of the turbines of hydroelectric power station", *Text for the workshop for the small and medium-sized hydroelectric power station*, February, 2012

6.2 Inquiries

Company name: Chubu Electric Power Co.,Inc.

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

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

Category and Key Points

Main: 2-a) Technical innovation and deployment expansion of electro-mechanical equipment

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

1-f) Environmental Conservation and Improvement

2-c) Technological Innovation, Deployment Expansion and New Materials Used for Civil and Building Works

Project Name:

Renewal of the Oguchi Power Station

Name of Country (including State/Prefecture):

Ishikawa Prefecture, Japan

Implementing Agency/Organization:

Hokuriku Electric Power Company

Implementing Period:

August.2009-March.2011

Trigger Causes for Renewal and Upgrading:

(A) Degradation due to ageing and recurrence of malfunction

(B) Environmental deterioration

Keywords:

Hybrid servo, Adopting a gateless design

Abstract

Around 70 years after commencing operation in December 1938, the Oguchi power station began showing signs of age-related deterioration at the spillway gates, water turbine, generator, etc. associated with the Conduit 1. Hokuriku Electric Power Company conducted repair work in response.

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

The Oguchi Power Station, located in Ozo, Hakusan City, Ishikawa Prefecture, is a conduit-type hydropower station (operation launched in 1938), drawing up to 11.52 cubic meters of water per second from the Ozo River (Conduit 1: Up to 8.85 cubic meters per second) and the Metsukedani River (Conduit 2: Up to 2.67 cubic meters per second) in the Class A river system called Tedori River. Both Conduit 1 and Conduit 2 are equipped with power generation facilities, capable of a maximum output of 17,600kW when Conduit 1 (up to 11,500kW) and Conduit 2 (up to 6,100kW) are combined. (See Table 1 for facility specifications.)

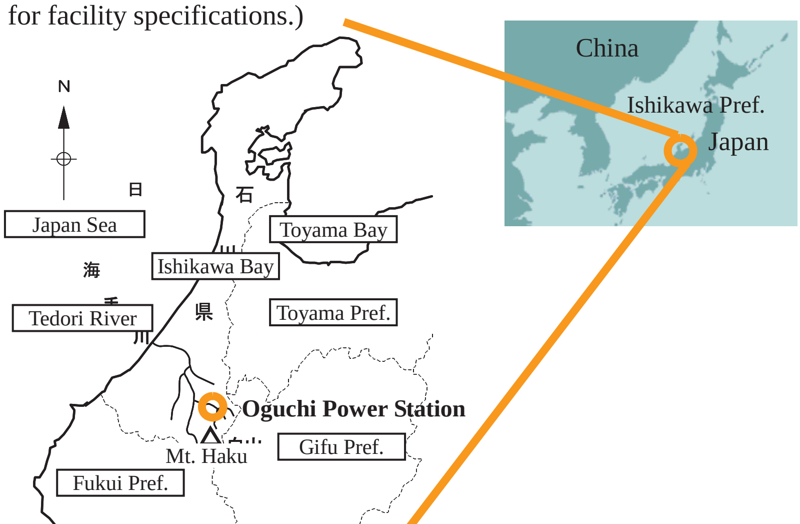


Fig.1 Location of the project site (Oguchi Power Station)

Table 1 Specifications of the Oguchi Power Station (Conduit 1) before and after the renewal

Category		Before the renewal	After the renewal
Power Station	Number of main units	2	2
	Maximum output	11,500kW	12,000kW
	Effective head	159.44m	158.50m
	Water volume used	$8.85m^3/s$	$8.85m^3/s$
Water turbine	Type	Horizontal shaft multi-discharge Francis turbine	Horizontal shaft single-runner single-discharge Francis turbine
	Turbine output	6,900kW	6,260kW
	Flow volume	$5.31m^3/s$	$4.43m^3/s$
Generator	Generator output	7,125kVA	6,280kVA
	Generator voltage	6.6kV	6.6kV
	Number of revolutions	$720min^{-1}$	$600min^{-1}$

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.

(A) - (d) Degradation due to ageing and recurrence of malfunction - Improvement of serviceability

(B) - (a) Environmental deterioration - Improvement of river environment

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

(2) Improvement of the value (function)

(Not applicable)

(3) Necessity in the market

(Not applicable)

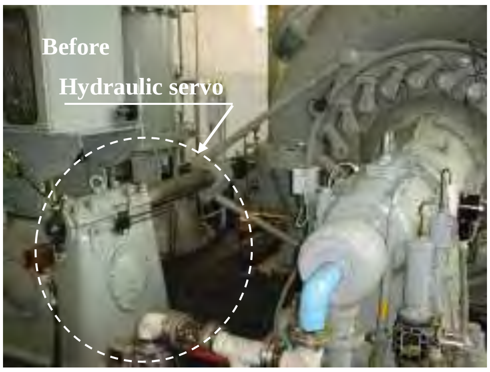
(1) Oguchi No.1 Dam

This dam is located at 550 meters above sea level, in the area that sees one of Ishikawa Prefecture's heaviest snowfalls, surrounded by mountains of around 1,500 meters. The access road to the dam is closed from December to May due to snowfall. Dam workers during this period had to walk one hour through a winter tunnel to reach the site making the work severe.

This dam is an intake basin with no available depth. Even a small amount of rainfall makes it necessary to discharge the water through the gates. This form of discharge occurs as many as 200 days a year. Due to its mountainous location, the dam experiences rapid inundation from localized torrential rains and rainstorms, making it necessary to make a swift discharge call based on accurate inundation prediction. It has been a difficult dam to manage even for experienced workers.

(2) Turbine and Generator

The turbines (two horizontal shaft multi-discharge Francis turbines) and generators (two three-phase AC synchronous generators) at the Oguchi Power Station were over 70 years old, showing signs of deterioration, e.g. wear and cracks in turbine parts and insulation performance degradation of the generators. Renewal work (See Table 1 for facility specifications) was carried out, as it was difficult to restore their full functionality through repair work. The renewal work involved the use of the HD Servo, jointly developed with Hokuriku Electric Co., Ltd., to eliminate the use of pressure oil in turbine guide vane control so as to improve serviceability and environmental performance.



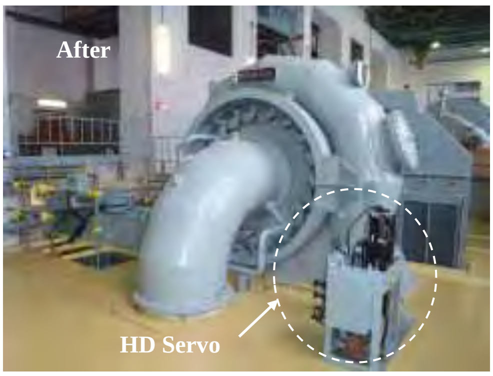


Fig.2 Pressure oil servo before the renewal and HD servo after the renewal

2.2 Process to Identify and Define Renewal and Upgrading Work Measure

1938: Oguchi Power Station's operation launched

2009: Unit 1 and Unit 2 renewal work commenced

2011: Unit 1 and Unit 2 renewal work completed

2.3 Description of Work Undertaken (detail)

1-f) Environmental Conservation and Improvement

-Setting the construction period

The construction period has been determined in consideration for its impact on golden eagles (their breeding season in particular), a type of threatened raptors that live in the area around the dam.

Consultations with the Ministry of the Environment and Ishikawa Prefecture found that construction work should be avoided from December, when golden eagles build nests, up to the time when young eagles mature in early May. It was understood that the impact of the construction work would diminish from early May, when the removal of snow from forest roads around the dam resumes the traffic of general motor vehicles. As a result, the construction period was set from early May to the end of November in principle.

-Landscape considerations

Since this dam is located in Class II Special Zone with the Hakusan National Park, the design incorporated landscape considerations such as painting the newly-laid concrete surface (black) and simulating rock appearance on the concrete surface (except for the dam's overflow sections).

-Effective use of concrete debris

The concrete debris generated in the repair work (approx. 3,000m^3) was crushed at the site as much as possible for on-site recycling to reduce environmental strain, rather being transported off-site as industrial waste.

-Others

In addition, efforts were made to minimize forest felling and change of landform in planning the construction. With regard to the post-project restoration of the site, the seedless re-vegetation approach was used to minimize impact on local vegetation.

2-a) Technological Innovation & Deployment Expansion of Electro-Mechanical (E/M) Equipment

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

Hydraulic servomotor or electric servomotor is generally used for controlling guide vanes at a hydropower station. More recently however, small and medium-sized hydropower stations have started to use a hybrid servo that combines hydraulic pump and hydraulic cylinder, capable of operating in the forward and reverse direction to an electric system.

Hokuriku Electric Power Company has worked in partnership with Hokuriku Electric Co., Ltd. to improve the hybrid servo for general industrial use to develop an affordable hybrid servo (hereinafter 'HD Servo') that can be applied to a hydropower station. It is being phased in to the company's small and medium-sized hydropower stations.

The HD Servo has been used in the renewal of waterwheel and generator at the Oguchi Power Station.

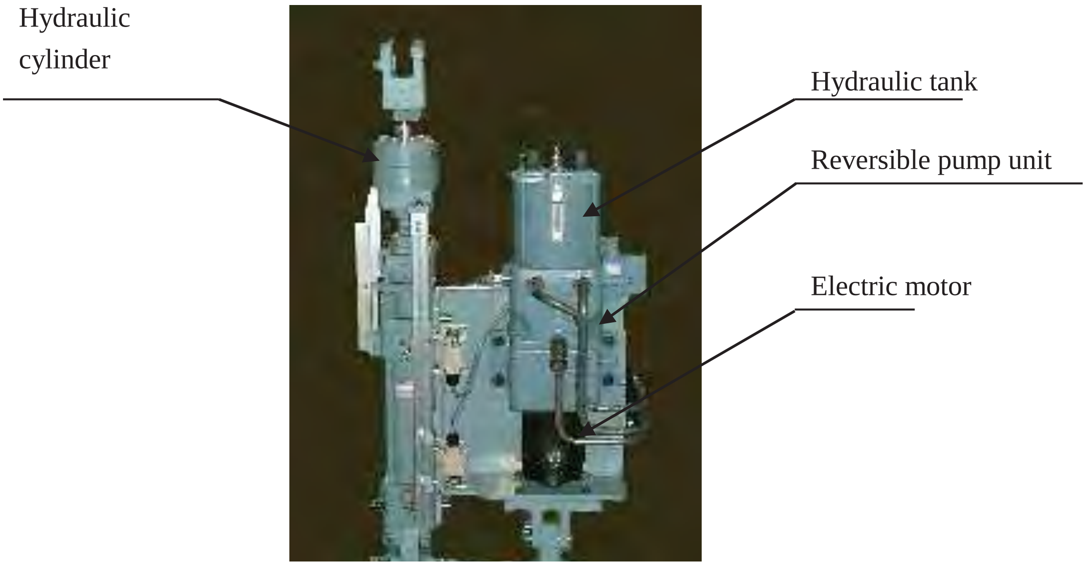


Fig.3 Main body of the HD Servo

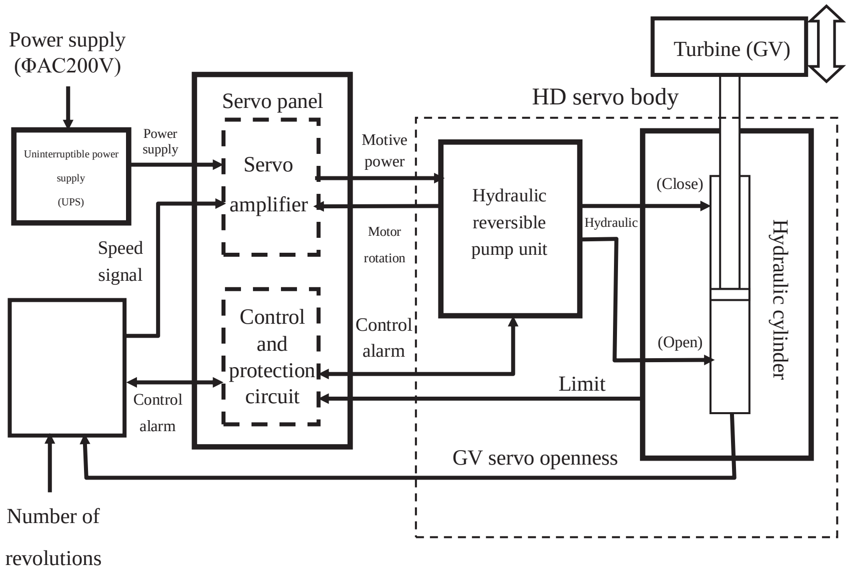


Fig.4 System configuration

Main improvements are:

- -Adding an uninterruptible power supply (UPS) so that the turbine can be safely brought to a controlled shutdown even in the loss of operating power (See Fig.5)
- -Adding a hydraulic bypass circuit so that the guide vanes (or needles) may be 'fully opened' with the self-closing function even when the HD Servo fails (See Fig.6)
- -Changing hydraulic cylinder's packing material to extend its service life
- -Adopting the structure that allows the hydraulic cylinder and reversible pump unit to be installed separately in view of potential space constraints

The HD Servo also has the following features:

- -Using hydraulic cylinder and reversible pump unit for general industrial use
- -Using a generic AC power drive system for the electric motor

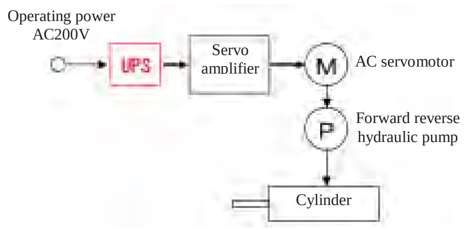


Fig.5 Adding UPS

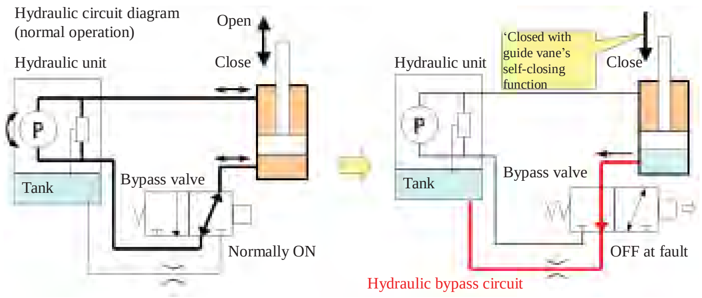


Fig.6 Adding a hydraulic bypass circuit

2-c) Technological Innovation, Deployment Expansion and New Materials Used for Civil and Building Works

Due to the aging of the spillway gates (around 70 years old), the power utility examined the cost advantage and dam management method for (1) adopting a gateless design, (2) replacing the spillway gates and (3) establishing direct connection with the upstream power station (Mitsumata Daiichi Power Station). The gateless option to remove the spillway gates and turning the dam into an unmanned site waseventually chosen, as it was most economical and safest in terms of discharge.

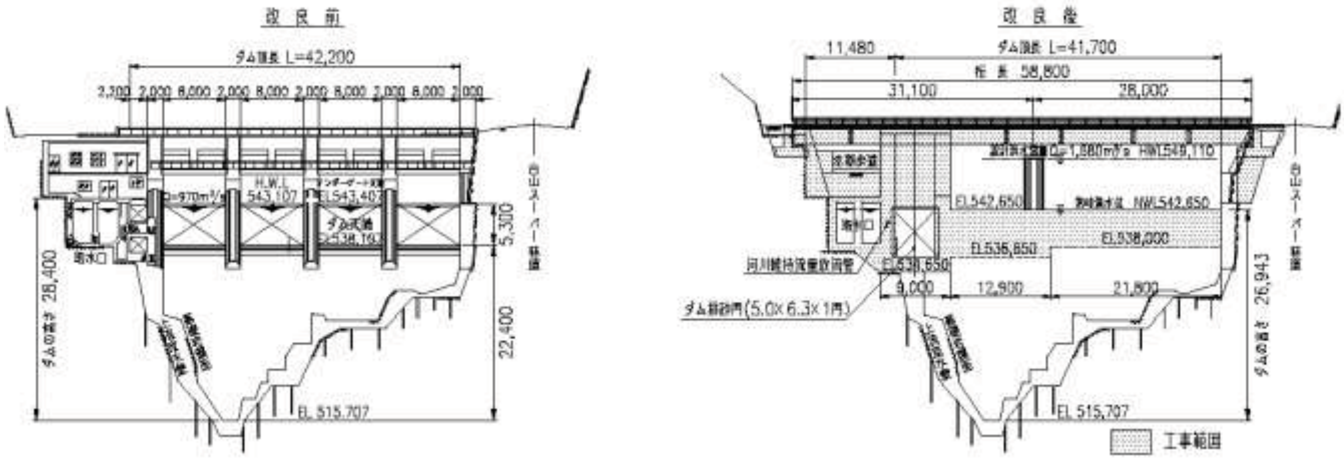


Fig.7 Front view of the Oguchi No.1 Dam after the repair work

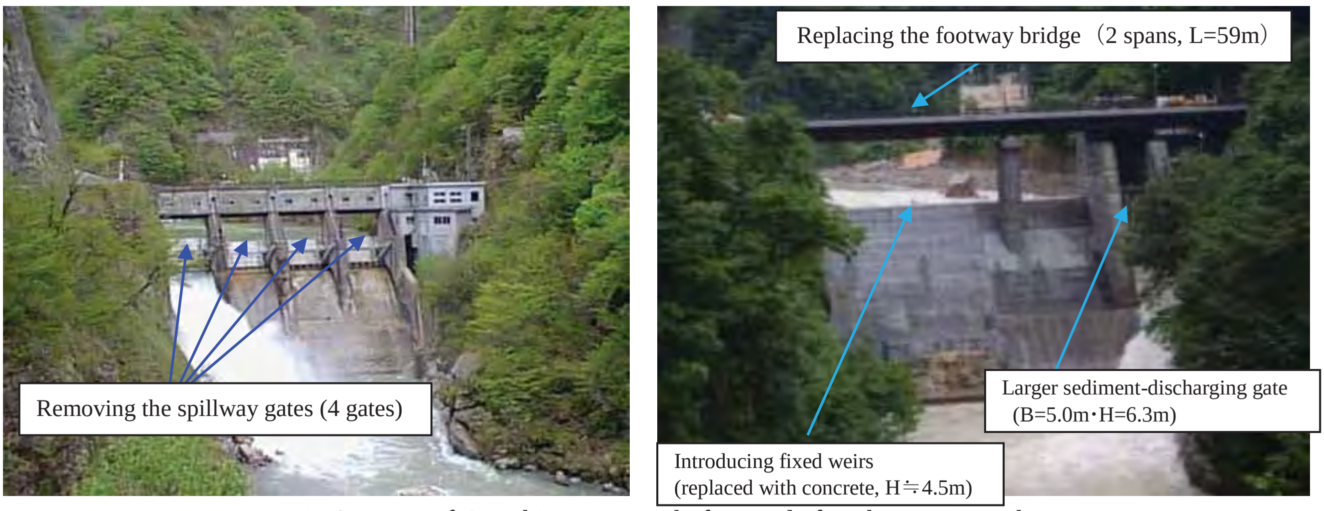


Fig.8 Image of Oguchi No.1 Dam before and after the repair work

Table 2 Oguchi No.1 Dam specifications

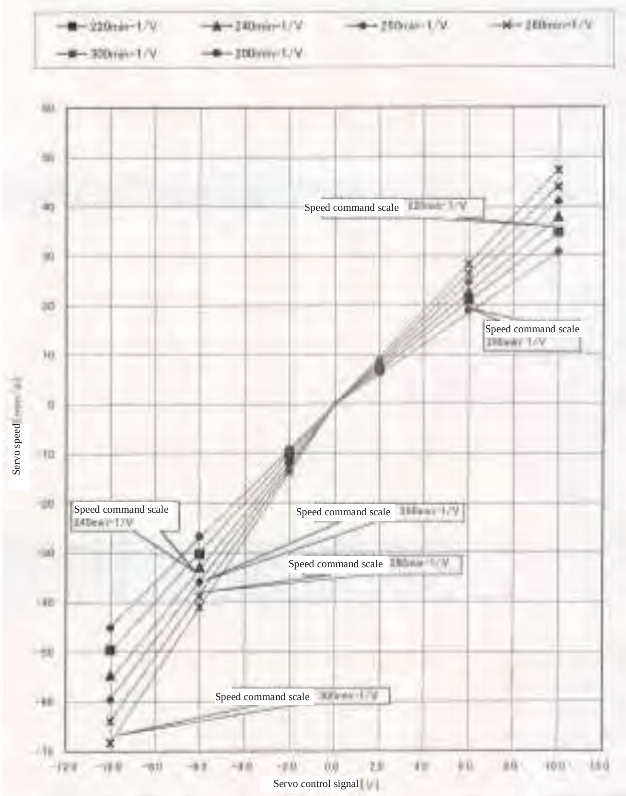
Category	Before	After
Catchment area	101.21km^2	
Water intake volume	8.85m^3/s	
Dam reservoir capacity	-	
Floodwater processing capacity	970m^3/s	1,680m^3/s
High water level	HWL.543.107	HWL 549.110
Normal water level	NWL.543.107	NWL.542.650
Spillway	4 radial gates, H5.0m×B8.0m	Dam overflow system, B=41.0m
Sediment-discharging gate	B2.20m×H2.53m	B5.0m×H6.30m
Dam height	28.40m	26.943m
Dam crest length	42.2m	41.7m
Dam volume	9,000m^3	10,700m^3
Overflow width	32.0m	34.7m
Passage bridge	L42.2m×B3.0m 4 spans	L59.3m×B3.5m 2 spans

3. Feature of the Project

3.1 Best Practice Components (focuses)

The project reduced costs by around 20% compared to the electric servo type while meeting the specifications required by Hokuriku Electric Power Company (See Table 3 for the results of main performance tests), seeking better serviceability and environmental performance than the existing hydraulic servo system.

Table 3 Results of main performance tests

<table>
<tr><th>Performance check categories</th><th>Check results</th><th>Judging criteria</th><th>Result</th></tr>
<tr><td>Guide vane opening – closing speed</td><td>
</td><td>- The servo movement speed should be linear against the input command voltage.
- It must be possible to adjust the opening / closing speed to a specified value.</td><td>OK</td></tr>
<tr><td>Dead time</td><td>0.11 seconds</td><td>No more than 0.3 seconds</td><td>OK</td></tr>
</table>

3.2 Reasons for Success

Table 3 compares the HD Servo with servos in other systems. The HD Servo has fewer components than the hydraulic servo and uses hardly any oil, thereby achieving improved serviceability and environmental performance. Due to the use of a hybrid servomotor for general industrial use, the HD Servo has around 20% less costs than the electric servo system.

Table 4 Comparison between the HD Servo and servos of other systems

	HD Servo [used this time]	Hydraulic servo [existing]	Reference: Electric servo
Structure	- Servo amplifier - Hydraulic unit - Hydraulic cylinder	- Pressure oil tank, pressure oil collection tank, pressure oil pump - Distributing valve, electromagnetic valve, pressure oil pipe - Hydraulic cylinder	- Servomotor, amplifier - Power cylinder
System	- Servomotor and reverse pump set directly driving the hydraulic cylinder	- Distribution valve and electromagnetic valve controlling pressure oil to drive the hydraulic cylinder	- Servomotor's revolving movement converted into linear movement of the power cylinder via the reducer and ball screw
Serviceability	- Periodic exchange of operation oil	- Too many components and cumbersome maintenance	- Grease top-up for ball screws
Environmental performance	- Very small amount of oil used as operation oil	- Using a large amount of oil	- Oil-less
Economic performance	Approx. 80%	-	100%

4. Points of Application for Future Project

The HD Servo's scope of application covers Francis turbines, propeller-type turbines and Pelton turbines with an output of no more than 10,000kW.

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

Table 5 shows the past introduction cases of the HD Servo. A total of 11 units have been introduced so far. No particular issue has been reported over the last 6 years since the first introduction.

Table 5 HD Servo's introduction cases

Year of introduction	Power station	Turbine output (kW)	Turbine type
2006	Fukuoka Daiichi Power Station Unit 4	1,680	Vertical shaft Francis
2008	Oritate Power Station Unit 2	2,120	Horizontal shaft Pelton
2010	Kamidaki Power Station Unit 3	4,160	Horizontal shaft Francis
2010	Oritate Power Station Unit 1	2,120	Horizontal shaft Pelton
2011	Oguchi Power Station Units 1 and 2	6,260×2 units	Horizontal shaft Francis
2011	Higashikadohara Power Plant	2,970	Vertical shaft Francis
2011	Fusegawa Power Station	650	Vertical shaft Francis
2012	Kutani Power Station Units 1 and 2	1,045×2 units	Horizontal shaft Pelton
2012	Oritate (expanded) Power Station	4,100	Horizontal shaft Francis

6. Further Information

6.1 Reference

Electrical Review January 2006 issue

6.2 Inquiries

Company name: Hokuriku Electric Power Company

URL: http://www.rikuden.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-a) Technological innovation & deployment expansion of electro-mechanical (E/M) equipment

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

Project Name:

Renewal of the Doi Hydro-Power Station

Name of Country (including State/Prefecture):

Japan, Hiroshima Prefecture (Asia)

Implementing Agency/Organization:

Chugoku Electric Power Co., Inc.

Implementing Period:

From 2001 to 2010

Trigger Causes for Renewal and Upgrade:

(A) Degradation due to ageing and recurrence of malfunction

Keywords:

Degradation due to aging, Change of the number of turbines; Horizontal shaft, Two runner Single discharge, Double, Spiral case Francis turbine

Abstract:

This power station started its operation 70 years ago in November, 1938. Since then until today, regular and detailed inspections were conducted, and repairs and partial replacement of parts were conducted to continue the operation by maintaining the facilities properly while trying to extend its service life. However, the turbine and generator facilities were seriously degraded such as with serious degradation of the insulation of the generator stators and rotors and the fact that the turbine casings were no longer able to be repaired. Therefore, renewal work was conducted.

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

The Doi Hydro-Power Station is a dam waterway type hydropower which is located in Ota-machi, Aki, Yamagata-gun, northern part of Hiroshima Prefecture. (See Fig. 1).

This power station is a hydro-power station with a maximum output of 8,000kW and an effective head of 129.60m which receives intake water from our Masudamari Dam (dam height 19.2m, effective pondage 215km^3) through a 4.6km headrace. (Main specifications of this power station (before and after renewal) are shown in Table 1).

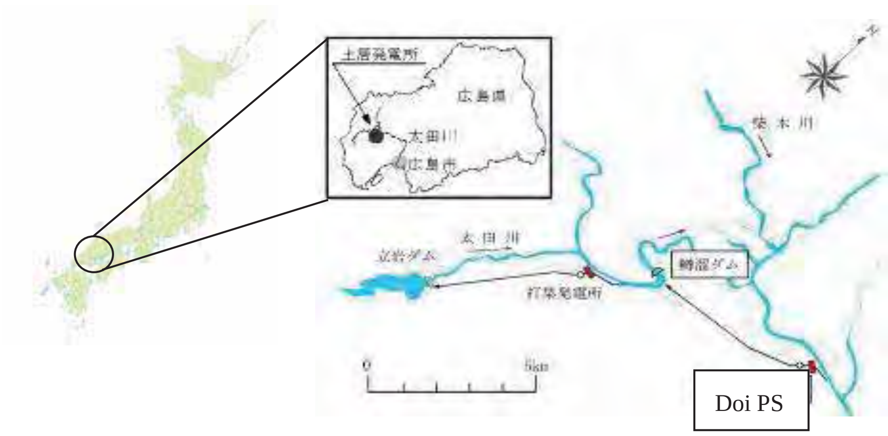


Fig. 1: Location map of the Doi Hydro-power Station

Table 1: Specifications of the Doi Hydroelectric Power Station (before and after renewal)

Item		Unit	Before Renewal	After Renewal
Maximum output		kW	8,000	8,200
Maximum plant discharge		m^3/s	7.6	No change
Effective head		m	129.60	No change
Dam (Masudamari Dam)	Type	—	Concrete gravity dam	No change
	Length of dam	m	98.0	No change
	Height	m	19.2	No change
Hydraulic steel pipe	Number of line	line	2	no change
	Line length	m	No.1 : 205.867 No.2 : 205.810	No.1 : 205.523 No.2 : 205.466
	Inside diameter	m	2.0 - 1.0	No change
Turbine	Number of machines	machine	2	1
	Output	kW	5,000	8,470
Generator	Number of machines	machine	2	1
	Output	kVA	5,000	8,450

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) Degradation due to aging and frequent failures

(a) Improvement of efficiency, (b) Improvement of durability and Safety,

(c) Cost reduction, (d) Easy maintenance with less labor

The Doi Hydro-Power Station has been in continuous operation for 70 years. Consequently, there is a fear that the operation would have major troubles because of many issues such as the decrease of the insulation for the generator stators and the rotors, the turbine casings reaching the end of their service life, and so forth.

(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 2001:	The working group for the renewal plan was started
March 2005:	The renewal plan was determined (medium-term management plan)
May 2008:	The project was approved based on the Water Utilization Rule (Ministry of Land, Infrastructure, Transport and Tourism)
May 2008:	Application of the construction work plan (Article 48, paragraph (1) of the Electricity Business Act) (Ministry of Economy, Trade and Industry)
July 2008:	The construction work began
March 2010:	The Water Utilization Rule was updated (Ministry of Land, Infrastructure, Transport and Tourism)
May 2010:	The change was approved based on Water Utilization Rule (Ministry of Land, Infrastructure, Transport and Tourism)
May 2010:	The change of the work plan was applied (construction schedule) (Ministry of Economy, Trade and Industry)
June 2010:	The work completion inspection was conducted (Ministry of Land, Infrastructure, Transport and Tourism)
June 2010:	The operation began
July 2010:	Safety control review prior to operation was conducted (Ministry of Economy, Trade and Industry)

2.3 Description of Work Undertaken (detail)

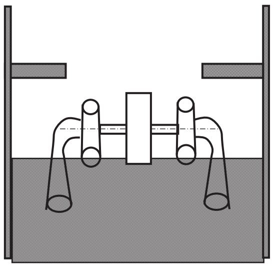
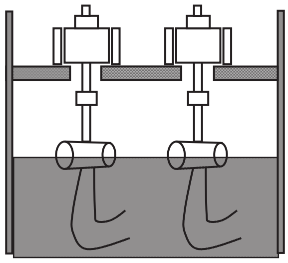
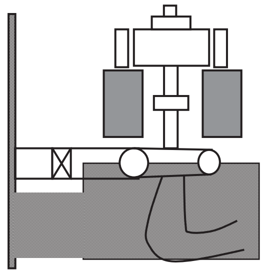
2-a) Technological innovation & deployment expansion of electro-mechanical (E/M) equipment

(1)-1 Selection of the turbine type

At the moment, the utilized capacity of the facilities of the Doi Hydro-Power Station exceeds 70%, and from the view point of the current facilities' water handling ability, it is not expected that plant discharge will increase. Therefore, leaving the plant discharge of 7.6m^3/s as it is, 3 cases using 3 different types of turbines which were supposed to be suitable for this power station were compared and reviewed. As a result, case 1: "Horizontal shaft, Two runner Single discharge, Double, Spiral case Francis turbine" which is the most advantageous in economic efficiency and maintainability was adopted for the first time in our company. (Summary of the comparison review is shown in Table 2).

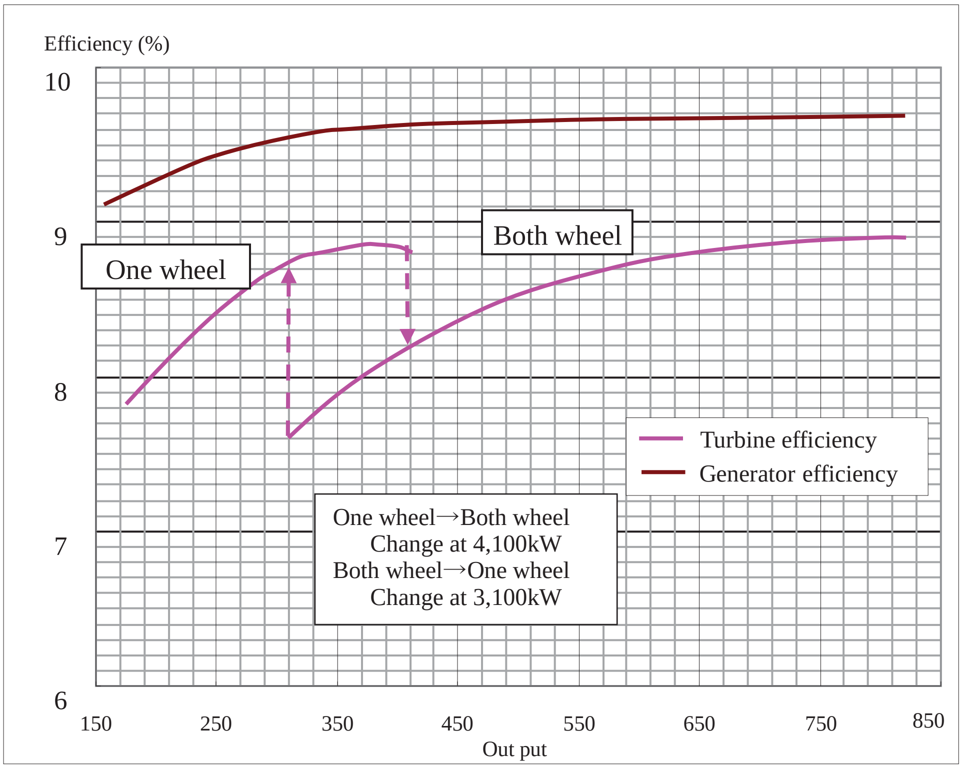
The maximum output was increased by 200kW to 8,200kW by improving efficiency. As for the generated energy, taking advantage of the strong point of this new turbine type, until 50% of the output range is reached, one wheel is run, and for more than 50% to 100% the operation is switched to two wheels operation, thus increasing output by high efficiency operation. Operation switching between one wheel operation and both wheels operation is to be conducted depending on the generator output and head tank water level (water control). Switching from one wheel operation to both wheels is to be carried out at 4,100kW, and switching from both wheels back to one wheel is to be done at 3,100kW. (The turbine/generator efficiency curve is shown in Table 3)

Table 2: Result of the comparison of the turbines

Items	(Case 1) Horizontal shaft, Two runner Single discharge, Double, Spiral case Francis turbine	(Case 2) Vertical shaft double discharge Francis turbine	(Case 3) Vertical shaft single discharge barrel type Francis turbine
Conceptual diagram			
Maximum output	8,200kW	8,200kW	8,200kW
Annual generated energy*1	(3)	(1)	(2)
Construction works cost*1	(1)	(2)	(3)
Construction unit cost*1	(1)	(2)	(3)
Advantages Disadvantage	◎ Shortest work period and small over flow power during construction work. ○ though 2 turbines, but one generator, so lower running cost than Case 2. ○ because of single discharge type, easy to convey materials into turbine room ▲ necessary to conduct building reinforcing work ○ because minimum discharge is small, it is possible to operate efficiently in a dry spell	○ longer installation work period than case 1. ▲ because of 2 sets of turbine/generator, running cost is high. ○because of double discharge type, difficult to convey materials into turbine room ○ no need of building reinforcing work ○ because minimum discharge is small, it is possible to operate efficiently in a dry spell	▲the longest installation work period, and large overflow power during construction work. ◎because of one set of turbine/generator, running cost is the lowest. ◎easiest to convey materials into turbine room ▲building replacement cost is required ▲minimum discharge is large, so impossible to operate efficiently in a dry spell.
Evaluation	◎	○	△

*1: Ranking is as follows: “Annual generated energy”; from large to small (1) to (3) order : “Construction work cost” and “Construction unit cost”; from small to large (1) to (3)

Table 3: Turbine/generator efficiencies curves



(Selection of rotation speed and flow rate)

900, 720, 600, 514 rpm, the basic evacuation amount, installation space and pump out height were compared and reviewed, and it was determined to select 600 rpm. (Comparison chart of the turbine rotation speed is shown in Table 4)

Table 4: Comparison chart of the turbine rotation speed

Rotation speed (rpm)	900	720	600	514
Basic evacuation amount	×	×	○	○
Installation space	○	○	○	×
Pump out height (m)	×	×	○	○

For single machine discharge rate, a possible 3.8, 4.1, 4.4 and 4.7m^3/s were compared, from the view point of reuse of the existing facilities (turbine discharge before renewal: 4.7m^3/s), as a result, 3.8m^3/s was adopted as being the most economically efficient.

(1)-2 Elimination of the pressure governor

Since the existing steel pipe was reused, the acceptable water pressure variable value and the water pressure variable rate are limited, so the system was planned so that the pressure governor was able to be eliminated.

(1)-3 Cooling water for the turbines

In order to prevent the turbine, which runs at idle when in one wheel operation, from overheating, a strainer was installed so as to supply cooling water into the runner sealing area. (Cross-section of the turbine is shown in Fig. 2).

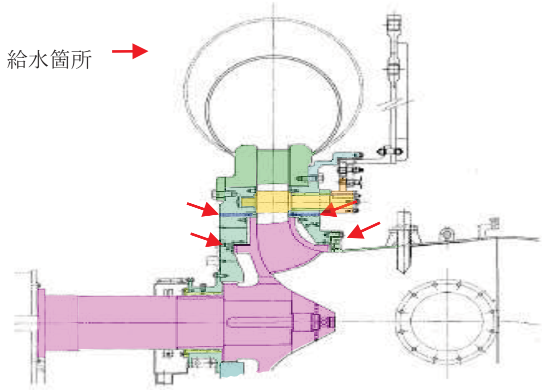


Fig.2: Cross-section of a turbine

(1)-4 Transformer

Considering economic efficiency and maintainability, generator output voltage was decided to be 6.6kV.

In accordance with this selection, the main transformer and the distribution transformer (LR separated installed type) which were necessary to be replaced due to aging, were integrated, and by adopting a switch gear (encapsulated type) on the generator main line, the facilities were able to be downsized. (Main circuit connecting diagram is shown in Fig. 3)

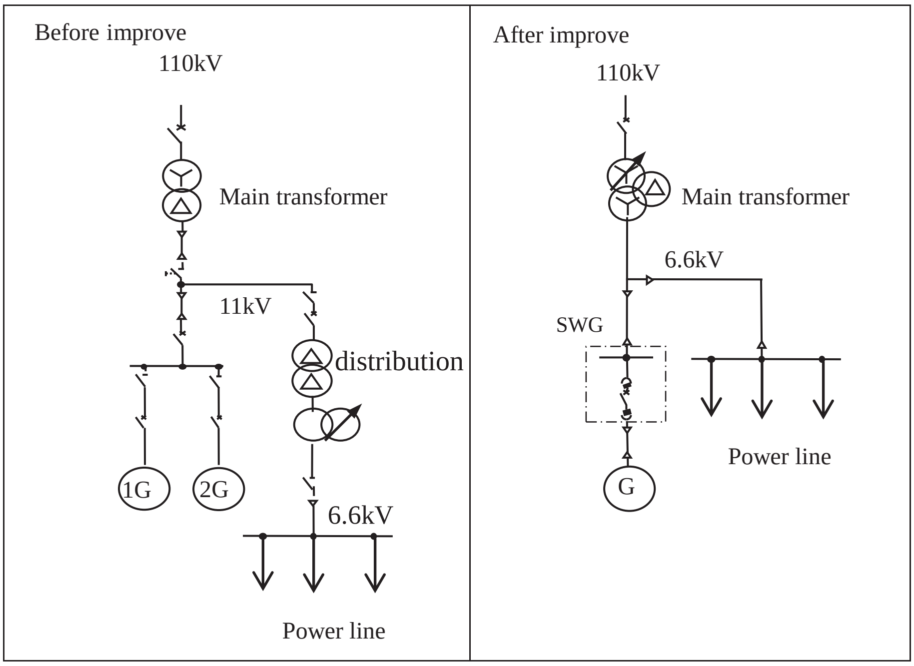


Fig. 3: Main circuit connecting diagram

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

(2)-1 Demolition work of the existing turbines and foundation in the powerhouse.

In the switchboard room of the existing powerhouse building, there was a power protection system which was not allowed to stop the electricity supply. There was however, a possibility that the protection system might malfunction due to excessive vibration and dust contamination which might occur during demolition work, leading to an electrical system shutdown. Therefore, it was necessary to take countermeasures to reduce vibration and dust occurrence when the base foundation was demolished, which is the riskiest time for malfunctions to happen. Accordingly, a method which cuts concrete into block shapes by combining the use of both the Slot Drilling method (SD Method) and wire-saw method was adopted.

(Supplemental remarks)

- SD method: construction method to cut a groove (slot) in bedrock or concrete by a specific slot miner's drill (SD machine) so as to separate several unrelated parts (blocks) enabling easier handling.
- Wire-saw method: cutting method to cut object by rotating a chain wound around the object at high speed (20 - 30m/sec) while under a tensile force from a motor drive. The chain has cutting beads attached along its entire length.

(2)-2 Structural change of the powerhouse building (for reinforcement)

In the building structure around the existing turbine room, there were 5 main beams, making up the major structure of the powerhouse foundation. In this construction work, the foundation of the turbine/generators was changed from two floors to a single floor, and in consideration of conveying the machinery such as generator rotor and others into the room and maintainability, it was determined to remove one large beam. Therefore, in order to reinforce the building's structural strength which is expected to decrease when an earthquake occurs, building reinforcement work was conducted (Schematic view of the building reinforce construction works is shown in Fig. 4).

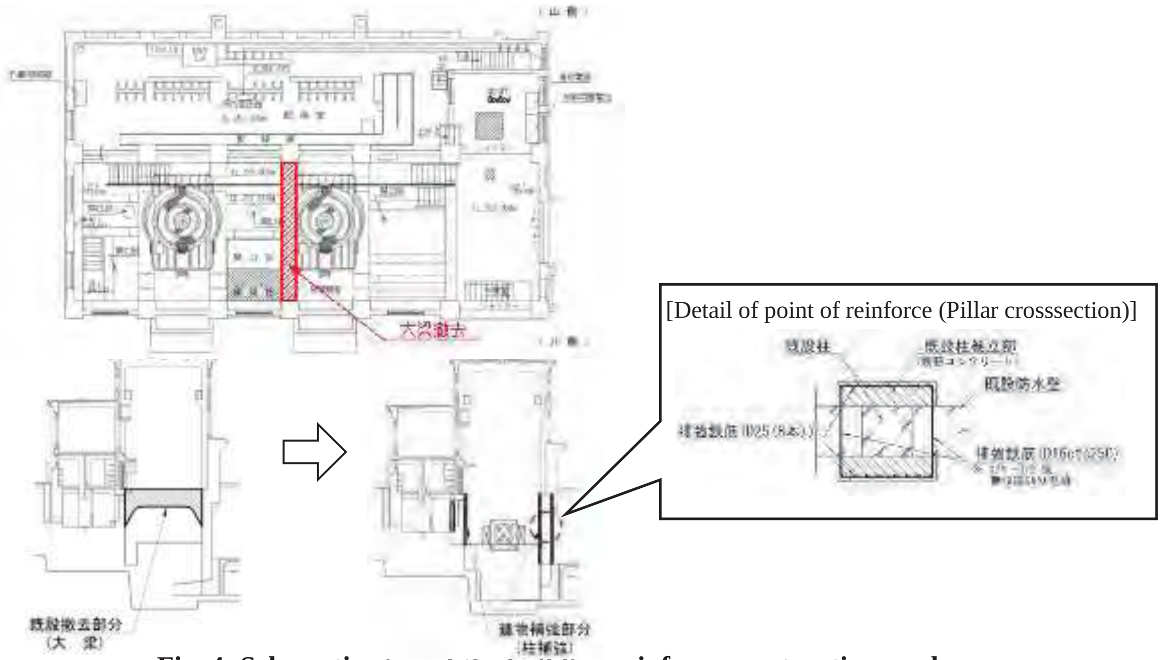


Fig. 4: Schematic view of the building reinforce construction works

(2)-3 Bridge reinforcement works

Access to the Doi powerhouse is only possible through the existing bridge (Doi bridge). The Doi bridge is a hybrid bridge (7 traverse steel beam bridge + one traverse truss bridge) constructed around 1955 with a span length of 105m. Since aging was occurring, weight limitations had been imposed restricting vehicle traffic weight to less than 4 tons.

In this replacement work, it became clear that the bridge's load bearing ability for conveying the heavy machinery such as the turbines, generators and others would be inadequate, so reinforcement work was conducted.

The reinforcement work which was required for conveying of the heavy machinery was planned and conducted so that the work would be carried out in a dry season (October 26 to June 10) in coordination with relevant parties. This is because the steel materials for the reinforcement work were stored inside of the river area. (Conceptual diagram of the Doi bridge reinforcement and photo of the construction works status is shown in Fig. 5)

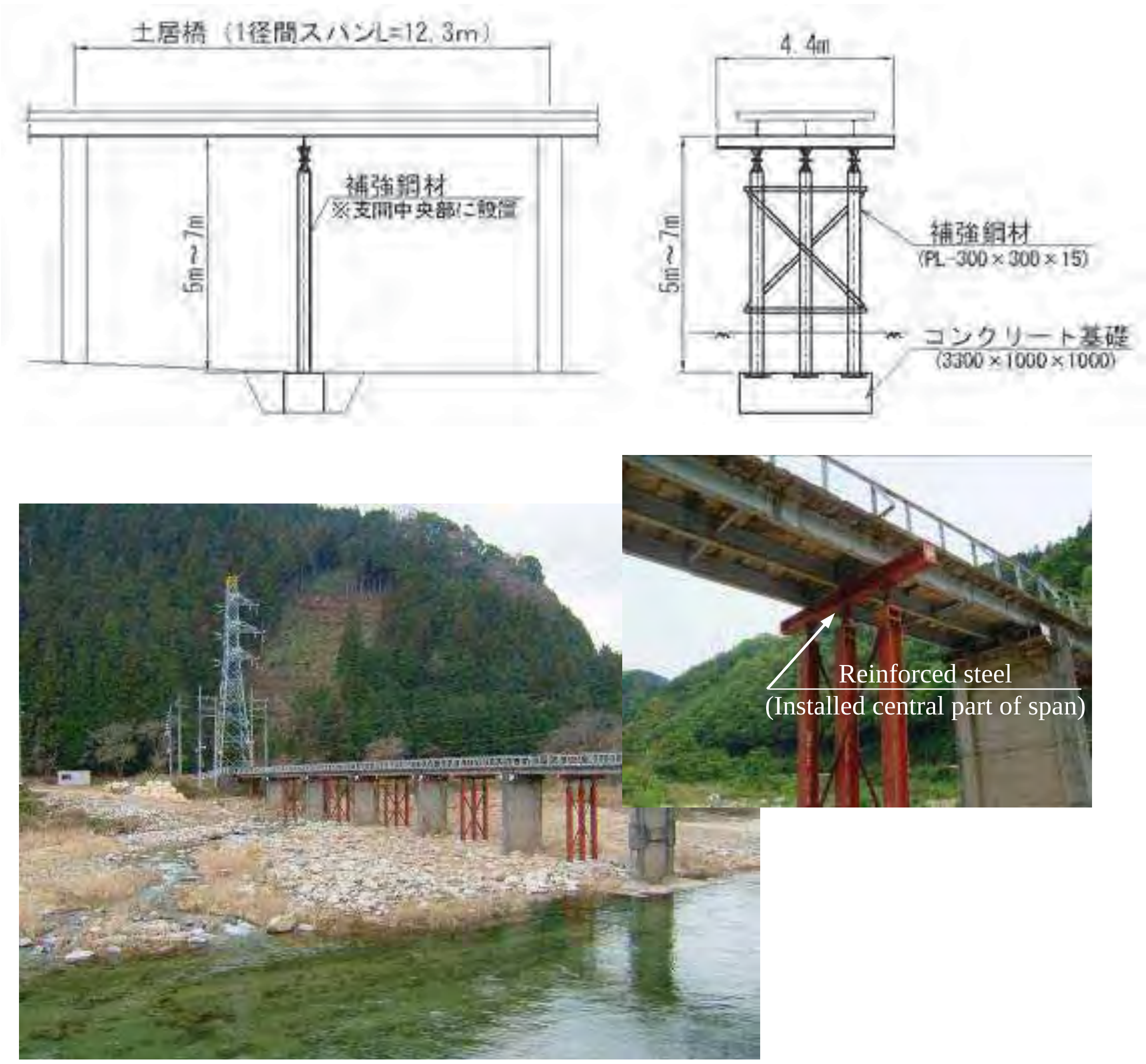


Fig. 5 Conceptual diagram of the Doi bridge reinforcement and the construction works status

(2)-4 Prevention of river water from entering the powerhouse site

Prior to the demolition work on the foundation of the powerhouse, a makeshift closing structure (waterproof concrete wall) was installed in front of the tailrace so as to prevent river water from entering into the powerhouse site during construction. For this installation, the first phase makeshift closing facility (steel gate) was placed at the outlet and after that, water was temporally drained from the tailrace and construction proceeded (Makeshift closing structure site and photo of the work status is shown in Fig. 6.).

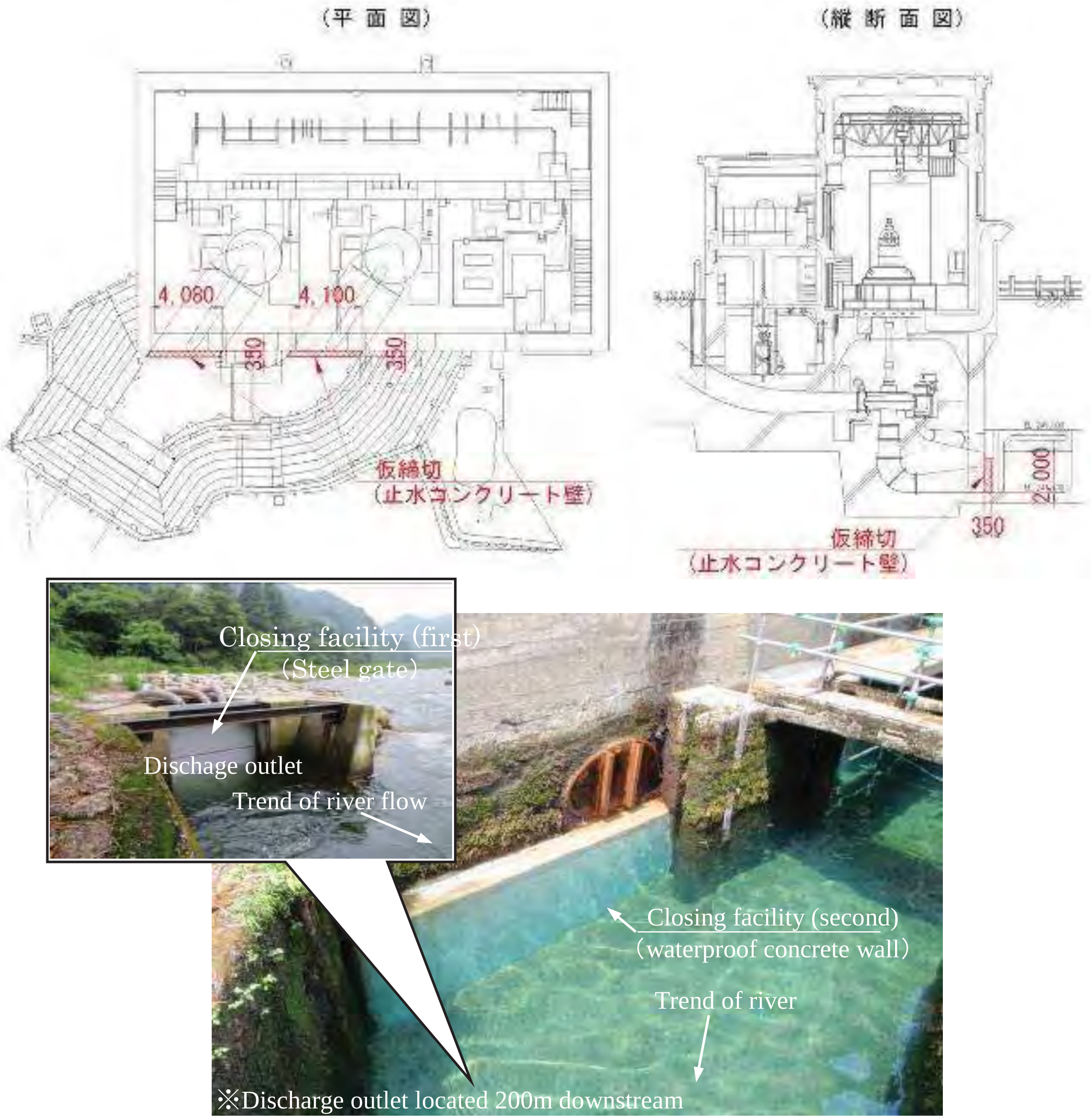


Fig. 6: Makeshift closing structure site and photo of the work status

(3) Specifications of the facilities after renewal

Facility specifications, renewal status photos and renewal plan diagram are shown in Table 5, Fig. 7 to 9.

Table 5: Specifications of the Doi Hydro-Power Station (before and after renewal)

Item		Before renewal	After renewal
Turbine	Type	Vertical shaft single runner single discharge Francis turbine	Horizontal shaft Two runner Double Francis turbine
	Output	5,000 [kW]	8,470[kW]
	Flow rate	4.7 [m^3/s]	7.6(3.8×2 turbines) [m^3/s]
	Rotation speed	600 [rpm]	600 [rpm]
	Draft tube	Elbow	Elbow
	Number of turbine	2 turbines	2 turbines
Inlet valve	Type	Butterfly valve	Biplane valve
	Inside diameter	1000 [mm]	1000 [mm]
	Operation method	Hydraulic pressure drive	Electric drive
Governor	Type	Electric type	Electric type
	Class	Y class	Y class
	Operation method	Hydraulic pressure drive	Electric drive
Pressure governor	Type	Horizontal type	None
	Operation method	Hydraulic pressure drive	
Oil pressure supply system	Method	Central type	None
	Operation method	Electric drive – electric drive	
Lubricating oil system	Type	Central type	None
	Operation	Directly connected to oil hydraulic pumps	
Water supply equipment	Method	Central type	Unit type
Generator	Type	Vertical three-phase synchronous outlet ventilation type	Horizontal three-phase synchronous outlet ventilation type
	Output	5,000 [kVA]	8,450 [kVA]
	Electric voltage	11 [kV]	6.6 [kV]
	Power factor	80 [%]	97.1 [%]
	Rotation speed	600 [min^{-1}]	600 [min^{-1}]
	Stator coil insulation type	B type	F type
	Number of machine	2 machines	1 machine
	Control method	Hydraulic pressure drive	Electromagnetic drive
Exciter	Method	Static exciting type	Brushless AD exciting type
Neutral grounding device	Method	Resistance grounding 50 [Ω]	Ungrounded (neutral point lightning arresters)
Overhead travelling cranes	Load rating and pump head	Main：load rating 30[t] Sub：load rating 10[t]	Reuse of existing cranes
Penstock			Reuse of existing cranes
Tail race			Reuse of existing cranes
Building			Reuse of existing cranes (some part was reinforced)

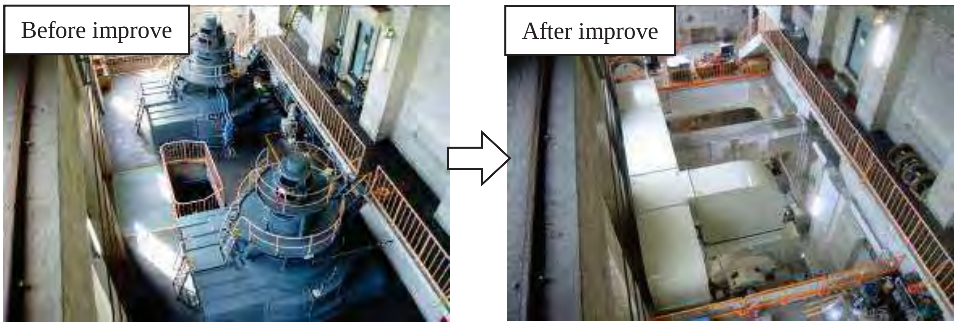


Fig.7: Status of the generator room

Fig. 8: Status of the turbine room

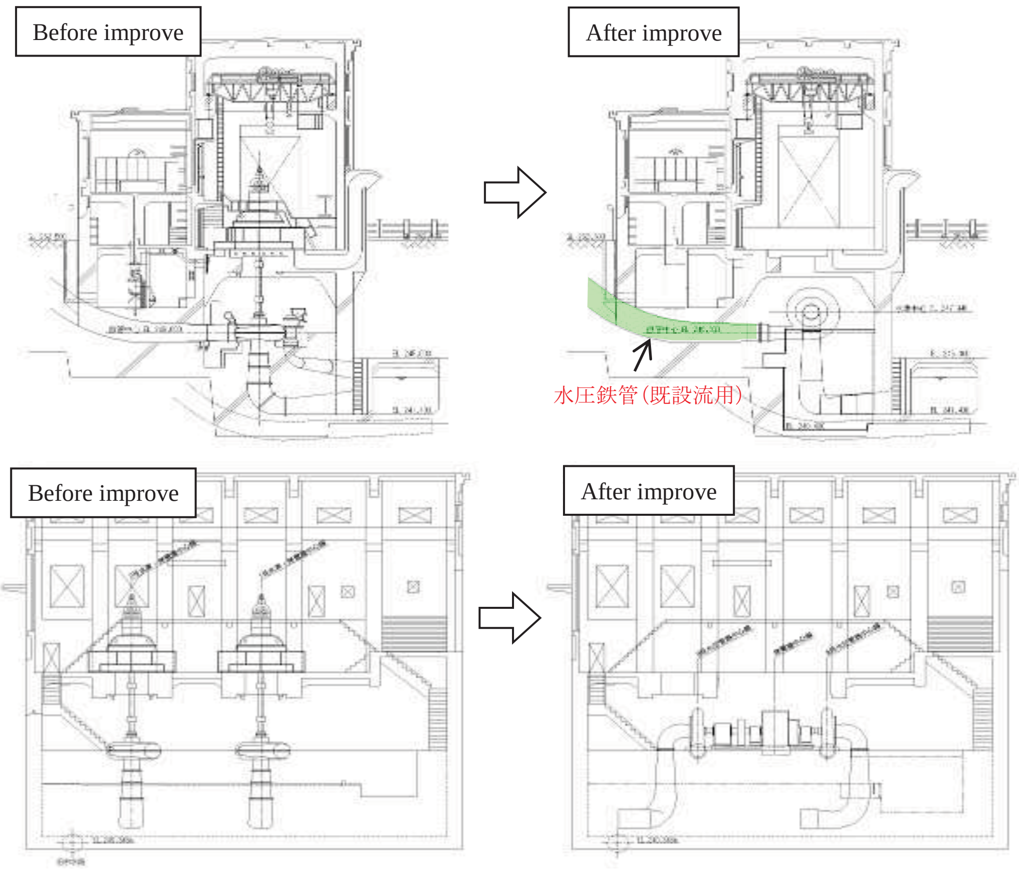


Fig. 9: Renewal plan diagram

3. Feature of the Project

3.1 Best Practice Components

- tried to minimize the renewal work into the minimum necessary range by reusing the existing facilities as much as possible.
- made the turbines, generators and accessory equipment oil-less and water-less systems, and tried to simplify them.
- the work was conducted while paying close attention to the impact (vibrations, etc.) on the operating machinery.

3.2 Reasons for Success

In the plan investigation stage, the working group was organized, and discussion of the renewal policy, construction work method and others, with the related parties in our company had been conducted.

4. Points of Application for Future Project

- When existing hydraulic steel pipes are reused, it is necessary to survey and investigate the impact of vibration on the existing pipe body which may occur from the change of the turbine type. (In this work, laser displacement sensors were placed at two points (one point at a horizontal direction, one point at a vertical direction) in a circumferential direction of the steel pipe, and the frequency and half amplitude were measured. Measurements were conducted as follows: by infrared ray, distances from the laser displacement sensor to the measurement point were measured, and displacement wave shape data were continuously recorded. Then the obtained displacement wave shape data were frequency analyzed and half amplitudes were calculated for each frequency. As a result of this measurement, the maximum half amplitude width was small (0.01mm), which is less than the 0.77mm allowable value based on the calculation formula defined by the Water Gate Steel Pipe Technical Standard. So, it was confirmed that there was no adverse vibration developed which would have an adverse effect on the pipe body.)

- During the construction work period, if some machinery is to be operated, it is necessary to consider and figure out a way which enables conducting the construction work without having any influence on this running machinery.

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

None

6. Further Information

6.1 Reference

New Energy Foundation, Hydropower Division, “Plan, Design and Construction of the Renewal of the Doi Hydroelectric Power Station”, *Text for the workshop for the small and medium-sized hydroelectric power station, No.90,* 2010.

Electrical Review Co., Ltd., “The renovation work of the turbines and generators”, *Electrical Review,* January, 2011

6.2 Inquiries

Chugoku Electric Power Company

URL: http://www.energia.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-a) Technological innovation & deployment expansion of electro-mechanical (E/M) equipment

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

Project Name:

Renewal Project of Kamishiiba Power Station

Name of Country (including State/Prefecture):

Japan, Miyazaki prefecture (Asia)

Implementing Agency/Organization:

KYUSHU ELECTRIC POWER CO. INC.

Implementing Period:

from August, 2006 to March, 2010

System number one: August, 2006 to December, 2007

System number two: September, 2008 to March, 2010

Trigger Causes for Renewal and Upgrade:

(A) Degradation due to ageing and recurrence of malfunction

(B) Environmental deterioration

(C) Needs for higher performance

Keywords:

Degradation due to aging

Increase of output

Francis turbine

Abstract:

In September, 2005, Kamishiiba Power Station was badly damaged by Typhoon No. 14 with the destruction and burnout of some instruments and also with flooding of the turbines -power generators. This power station is important in terms of demand and supply control, and river system operations. Therefore a long shutdown due to a disaster puts a restriction on water system usage for power stations downriver and increases overflow power loss by excess discharge of water from the dam. Thus, so as to reduce overflow power loss, System number two, whose damage was relatively minor, was temporarily restored by cleaning, drying and maintenance of the turbines - power generators, and operations were restarted by the following June.

For System number one, in August, 2006, full scale restoration / renewal work of the turbines - power generators was begun and operations were restarted in December, 2007. Furthermore, System number two, which was temporarily restored, had been seriously deteriorated due to aging, therefore after System number one restoration in September, 2008, renewal work on the turbines - power generators was begun, and operations were restarted in March, 2010.

In the case of renewal, two targets were pursued. The first target was to increase power station output (90,000kW (45,000kW×2 systems) → 93,200kW (46,600kW×2 systems)) by the adoption of high efficiency runner and by increasing the generators' efficiency. The second target was to reduce the environmental burden and to improve maintainability by eliminating hydraulic oil systems through adoption of electrically-driven guide vane and inlet valve servomotors.

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

Kamishiiba Power Station is a dam and conduit type power station with an output of 93,200kW (46,600kW×2 systems) which is located on the upper stream of the Mimikawa river system in Shiiba-son Higashi Usuki-Gun Miyazaki prefecture. The operation was started in May, 1955.

(Initial power station output when operation started was 90,000kW (45,000kW×2 systems)).

The location map, external appearance and specifications of this power station are shown in Fig. 1, 2 and Table 1.

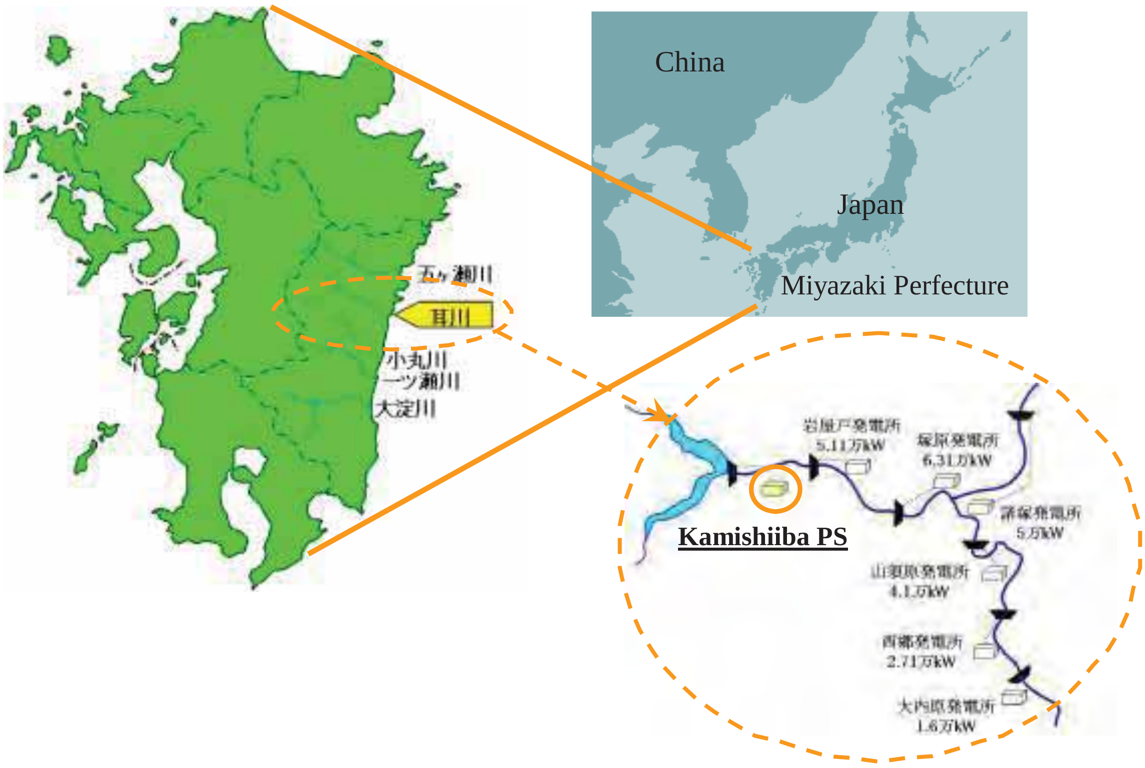


Fig. 1: Location map of Kamishiiba Power Station

Fig. 2: External appearance of the power station

Table 1: Specifications of Kamishiiba Power Station

Items		Specifications
Powerhouse	name of power station	Kamishiiba Power Station
	maximum output	93,200kW (46,600kW/ system×2 systems) (reference: before renewal: 90,000kW (45,000kW/ system ×2systems))
	maximum plant discharge	73.0 m^3/s
	effective head	144.0 m (for maximum water usage)
Dam	name of dam	Kamishiiba Dam
	name of river system	Mimikawa river system; Mimikawa, Tonegawa, Kuwanokibarugawa and others
	type	arch dam
Reservoir	total storage capacity	91,550,000 m^3
	effective storage capacity	76,000,000 m^3
	effective head depth	45.0 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

(A)- (a) Degradation due to aging and frequent failures – improvement of efficiency

(A)- (b) Degradation due to aging and frequent failures – improvement of durability and safety

(A)- (d) Degradation due to aging and frequent failures – easy maintenance with less labor

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

(2) Improvement of value (functions)

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

In the Kamishiiba Power station, two turbines - power generators have been used for more than 50 years since its operations began, and facilities have since deteriorated. Therefore, as a long and medium-term plan, renewal of the turbines - power generators was planned.

However, the 2 turbine - power generator systems were renewed ahead of schedule because of the following reasons,

- Deterioration of the turbines - power generators was accelerated by flooding from Typhoon No.14, and
- If the turbines - power generators were upgraded, an increase of generated power is expected by efficiency improvement,

Renewal work was carried out by the following schedule so as to reduce overflow power loss, allowing early restarting of the operation due to the shutdown from the typhoon disaster;

- First, turbines - power generators of System number two were temporarily restored by cleaning, drying and replacement of some damaged parts, and the operation was restarted.
- After temporary restoration of System number two, System number one was restored and upgraded. After that, the temporarily restored System number two was also full-scale upgraded.

In this renewal/upgrading, two targets were pursued, that is, the first target was to increase power station output (90,000kW (45,000kW×2 systems) → 93,200kW (46,600kW×2 systems)) by the adoption of high efficiency runner and by increasing generator efficiency. The second target was to reduce the environmental burden and to improve maintainability after operation restart by eliminating equipment such as hydraulic systems by adopting electrically-driven servomotors for guide vanes and inlet valves.

(3) Necessity in market

(not applicable)

2.2 Process to Identify and Define Renewal and Upgrade Work Measure

May, 1955	: partial operations began (output: 70,000kW)
October, 1955	: full operations began (output: 70,000kW → 90,000kW)
September, 2005	: some systems were damaged by Typhoon No. 14 (turbines – power generators were flooded)
June, 2006	: operation of System number two started (temporary restoration)
August, 2006	: full repair/renewal work began on turbines - power generators of System number one
December, 2007	: operation of System number one started (output：90,000kW → 91,600kW)
September, 2008	: full repair/renewal work began on turbines - power generators of System number two
March, 2010	: operation of System number two started (output：91,600kW → 93,200kW)

2.3 Description of Work Undertaken (detail)

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

In the renewal of the turbines - power generators, with a view to reduce the environmental burden and to improve maintainability, the operating systems of guide vanes and inlet valves have changed from a conventional hydraulic system to electrically-driven systems.

By these countermeasures, the backup function by electric servomotor was limited to flowing water cutoff of inlet valves only. Therefore, in order to confirm whether or not the backup mechanism functioned fully and was secured, and to confirm that there was no impact on the inlet valve and turbines body, our company conducted a flowing water cutoff test for inlet valves using full water flow which we have not carried out in the past (nationally as well, there were very few cases where such a full test was conducted).

The electrically-driven servomotors which were adopted for the 47,600kW class turbines in this case are the largest class in Japan (until this point, the largest was 39,000kW).

Besides, in consideration of adoption, records in large systems and their reliability in recent years, resin-metal bushings have been adopted for the thrust guide bearings.

Table 2. Specifications of electrically-driven servomotor

Items		Specification
number		one per system
Electrical motor	output	11kW
	power voltage	DC110V
	rotation frequency	1,500min^{-1}
stroke		485mm
Maximum electric servomotor power (thrust force)		294kN

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

To remove the foundation of a power station, a wire-saw method was adopted which is high in efficiency in operation and able to cut reinforced concrete and complicated shapes. This was done in consideration of the possible effects of dust and vibration created by these machines on the operation of the power station equipment.

3. Feature of the Project

3.1 Best Practice Components

- Most suitable design specification of turbines - power generators which take into consideration the cost and maintenance workability.

3.2 Reasons for Success

In the renewal process, though the system design used was similar to newly built power plants in recent years, for individual equipment, lower price specifications, simplification of systems and adoption of new technology was pursued. One reason for the success is thought that in the construction phase, various factors such as economic efficiency, reliability, maintenance and quality control were considered being based on information obtained from manufacturers and actual application performance reported by other power stations.

In 2005, Kamishiiba Power Station was badly damaged by Typhoon No. 14 such as with the burnout of some instruments and other equipment. Therefore, taking into account the impact to the river environment and possible fire disaster and also in order to simplify system constituents, the servomotors of guide vanes and inlet valves were changed from conventional hydraulic types to electrically-driven types, eliminating the use of hydraulic oil completely. Furthermore, by changing the control systems from analog to digital, simplification of maintenance and reduction of the number of control panels was achieved.

The concepts of the main specifications are as follows:

Table 3 Renewal specifications of turbine-generator in Kamishiiba Power Station

Name of component	Renewal specification	Existing specification	Concepts, reasons
Turbine	Vertical shaft - Francis turbine (47,600kW 300r/min)	same as on the left (47,200kW 277r/min)	- Pursue high efficiency by improvement of production technologies - Increase to 300rpm/min by downsizing turbines-power generators and increasing efficiency by speeding up under the restricted design conditions of diverting steel penstock and lower draft tube.
Speed governor	Electrical Type	Hydraulic Type	- Hydraulic systems were excluded by adopting electric servomotors for speed governors because there were no problems even slowing down guide vane closing speed, with due consideration for functions required for supply-demand control such as frequency control and maintainability. - Adoption of 47,600kW class turbines was the first case in Japan (before this, 39,000kW was the largest)
Pressure regulator	Not used	Used	- Pressure regulators were excluded because it was possible to control the increase of water pressure by securing rotating part strength and making rotational speed variation larger when load rejection was conducted.
Inlet valve	Thruflow valve	Butterfly valve	- Thruflow valves whose head loss was the smallest have been adopted due to the head-flow rate.
Generator	Three-phase synchronous generator (50,000kVA(PF93%) 300r/min)	same as on the left (50,000kVA(PF90%) 277r/min)	- Generator capacity was the same as the existing systems (maximum capacity, 50,000kVA/ machine, which enables operating 2 generators by one main transformer) - Generator power factor was increased from 90% to 93% by increasing maximum output (+1,600kW)
Excitation system	Alternating current excitation method	same as on the left	- Alternating current excitation method was adopted to reduce maintenance work because there are no problems in mechanical strength even with alternating current excitation method under the condition of capacity and rotation frequency of excitation equipment.
Bearing material	Resin-metal (new material)	white metal (WJ2)	- Resin-metal was adopted in view of reliability and recent adoption records into larger machines. - Resin-metal enables the reduction of running costs because high surface pressure was available, bearings can be downsized and their service life can be prolonged when compared to white metal.
Control system	Integrated type (Digital method)	discrete type (analog method)	- An integrated control system which combines control equipment into one unit was adopted from the workability and economic efficiency points of view (power source is separated and duplicated by functions)
Feed water supply systems	Draft water intake (Direct water supply method)	Draft water intake (Water supply by cooling water tank)	- Direct draft water supply method was adopted because of good reliability, high efficiency of maintenance, and economic efficiency.

4. Points of Application for Future Project

(View point for the selection of equipment specifications)

The electric servomotor used for the Kamishiiba Power Stations are the largest class in Japan, thus, when the guide vane operating power (Kamishiiba Power Station 30t) which is to be determined by effective head, used water volume and closing speed becomes larger than this, it is necessary to consider factors such as reliability, maintenance workability and others.

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

- After renewal of the equipment, both Systems number one and two have been operating smoothly without any trouble.

6. Further Information

6.1 Reference

None

6.2 Inquiries

Company name: Kyushu Electric Power Company

URL: http://www.kyuden.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-a) Technological innovation & deployment expansion of electro-mechanical (E/M) equipment

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

Project Name:

Construction Project of Kawabaru Ecological Discharge Power Station

Name of Country (including State/Prefecture):

Japan, Miyazaki Prefecture

Implementing Agency/Organization:

Kyushu Electric Power Co., Inc.

Implementing Period:

From 2010 to 2011

Trigger Causes for Renewal and Upgrade:

(C) Needs for higher performance

Keywords:

Ecological Discharge, Unutilized Energy, Submersible turbine

Abstract:

The Kawabaru Ecological Discharge Power Station is a hydroelectric power station with an output of 150kW, with the idea of effectively utilizing an ecological water resource which the active-working Kawabaru Power station (maximum output of 21,600kW) discharges downstream of the Kawabaru Dam.

In this project, a Submersible turbine, which integrates a turbine and a generator, was adopted for the first time by our company. By this strategy, we eliminated a power station building and we achieved an improvement in economic efficiency and maintainability by simplification of the facilities.

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

The Kawabaru Ecological Discharge Power Station is a dam waterway type hydroelectric power station with an output of 150kW located in Kijyo-cho, Koyu-gun, Miyazaki Prefecture mid-stream of the Onarugawa River in the Omarugawa water system. This power station began its operation May, 2011.

Specifications, location and external appearance of the power station are shown in Table 1, Fig. 1 to 4.

Table 1: Specifications of the Kawabaru Ecological Discharge Power Station

Item		Specification
Power station	Name of power station	Kawabaru Ecological Discharge Power Station
	Maximum output	150kW
	Maximum plant discharge	1.40 m^3/s
	Effective head	12.78 m (when maximum plant discharge used)
Dam	Name of dam	Kawabaru Dam (use of the existing dam)
	Name of water system	Omarugawa water system, Omarugawa River
	Type	Concrete gravity dam

Fig. 1: Location map of the Kawabaru Ecological Discharge Power Station

Fig. 2: External appearance of the power station

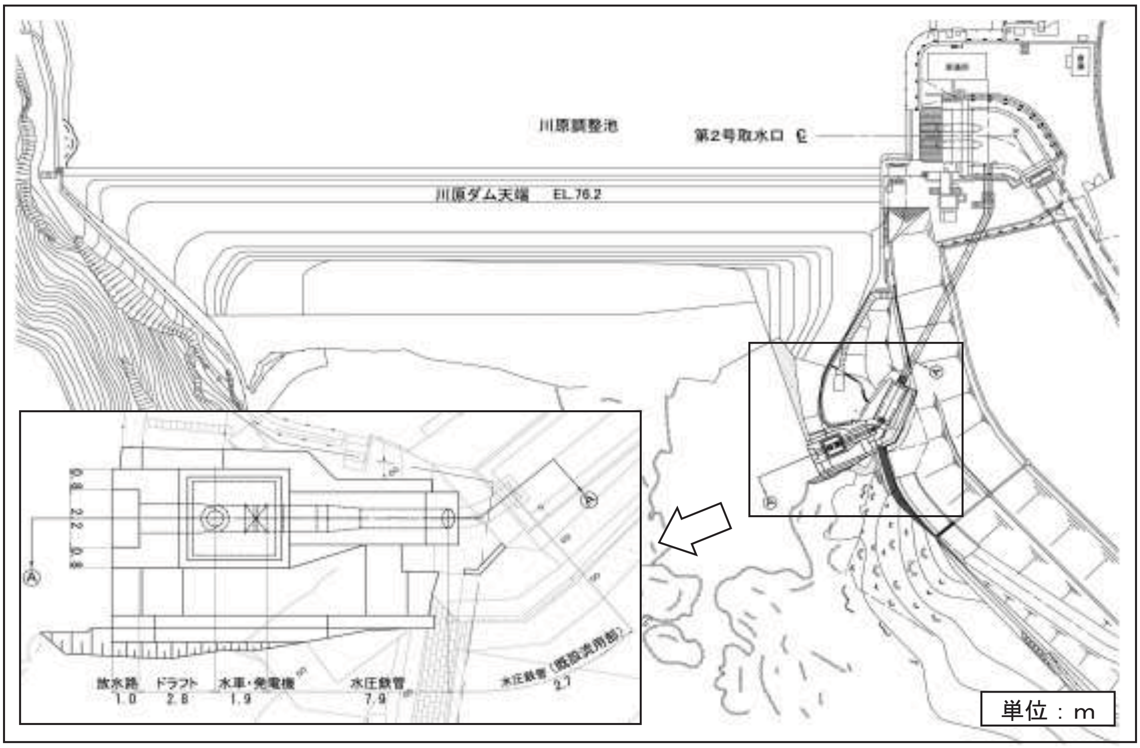


Fig. 3: Plan view

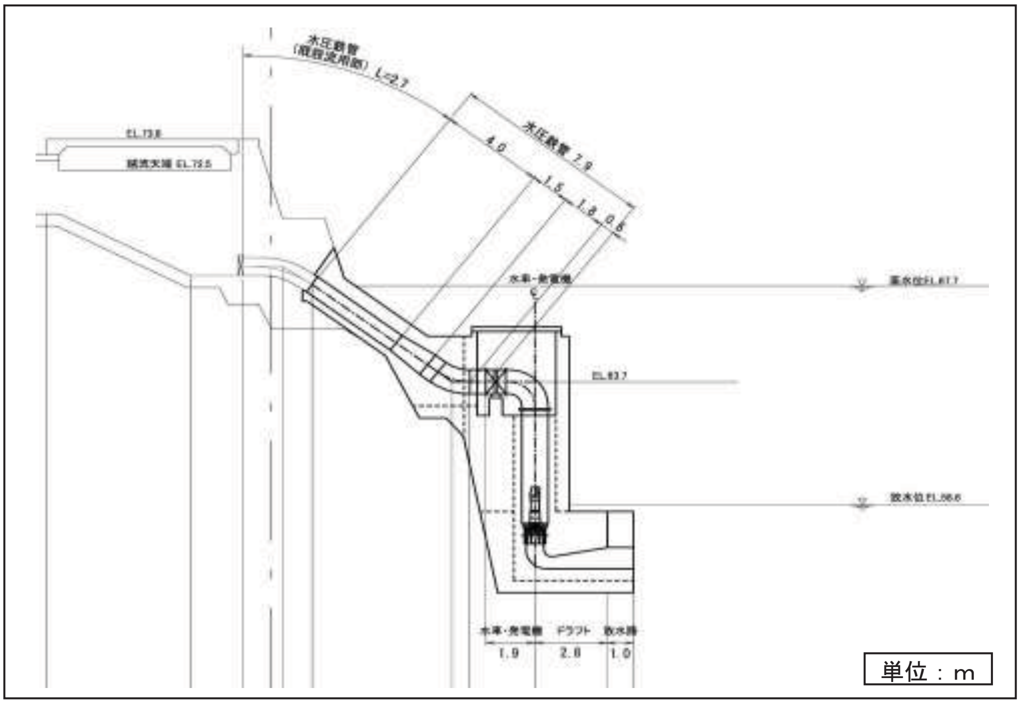


Fig. 4: Cross section view

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 – improvement of efficiency, Addition power & energy. Loss redution

In consideration of the measures against global warming and for effective utilization of domestic energy sources, we have actively developed and introduced renewable energy. In line with such a policy, we have developed the Kawabaru Ecological Discharge Power Station which is a hydroelectric power station with an output of 150kW which utilizes unused energy, that is, the ecological discharge from the Kawabaru Dam.

This power station produces 1.3 million kWh annually (equivalent to 360 households' usage) and is expected to reduce CO_2 by 480t annually.

In this project, the Submersible turbine, which integrates turbine and generator, has been adopted for the first time in our company. This made it possible to simplify the facilities and eliminate the power station building, allowing the construction of a power station which is excellent in terms of economic efficiency and maintainability.

(3) Necessity in market

(Not applicable)

2.2 Process to Identify and Define Renewal and Upgrade Work Measure

March 2009:	Supply plan was submitted
November 2010:	New construction work on the Kawabaru Ecological Discharge Power Station began.
May 2011:	Operation began
June 2011:	New construction work was completed

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)

- Accepted grant money from the "Ministry of Economy, Trade and Industry" as "New Energy Operators Support Project Subsidy"

  Subsidy rate: less than 1/3 of the project costs.
- RPS law (Act on Special Measures for the Promotion of New Energy Usage, etc. by Electrical Power Supplier) was approved.

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

As the main machine, the Submersible turbine which integrates the turbine and generator has been adopted for the first time in our company. This enables operation without a power station building, achieving great space savings and cost reductions.

In addition, by adopting the Submersible turbine, the following advantages were achieved and the facilities were able to be simplified:

- because of being an underwater type, even when submerged by a flood, there is no need for concern.
- because it is operated underwater, the noise level is low
- the installation space is minimized and adjustment at the site is easy.

Table 2: Specifications of the turbine/generator

Turbine	Type	Vertical exposed type fixed blade propeller turbine (Submersible turbine)
	Turbine output (kW)	159 kW
	Plant discharge(m^3/s)	1.40 m^3/s
	Effective head (m)	12.78 m
	Rotation speed (rpm)	915 rpm
	Specific rate (m-kW)	247.5 m-kW
	Unrestrained speed (rpm)	1,725 rpm
Generator	Type	Vertical three-phase induction generator
	Generator output (kW)	150 kW
	Rated voltage (V)	480 V
	Rated current (A)	285 A
	Power factor (%)	78 %

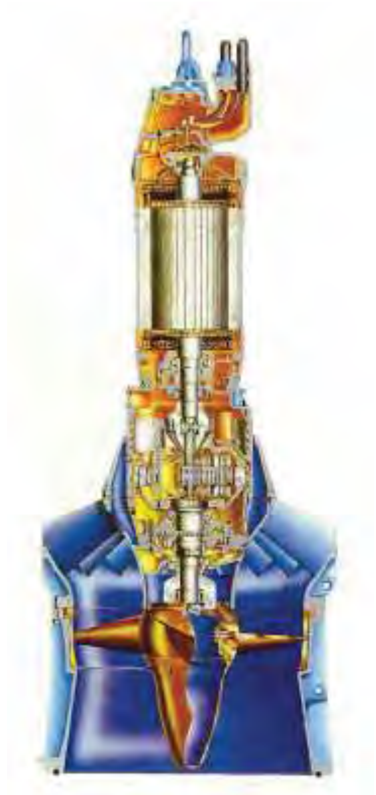


Fig. 6: Submersible turbine

Fig. 5: Submersible turbine structural drawing

Fig. 7: Turbine runner

3. Feature of the Project

3.1 Best Practice Components

- Development of the hydroelectric power station which utilizes unused energy, that is, ecological discharge from the dam to generate energy.
- Adoption of the submersible turbine, which integrates the turbine and generator, for the first time by our company.

3.2 Reasons for Success

In the development and introduction phase for the main machine, we have studied not only the conventional turbine types (typically, for a small hydropower station, a Horizontal Francis turbine, or cross-flow turbine has been used) but other turbines which various manufacturers are developing including a micro turbine. From a variety of view points such as economic efficiency, maintainability, control performance and quality control, we conducted a detailed study and selected the turbine type. Accordingly, we were able to reduce costs and expand the introduction of the renewable energy. We believe that these things are reasons for our success.

4. Points of Application for Future Project

(View point of the selection of machinery specifications)

When a new micro turbine which a manufacturer has newly developed is adopted as in the case of the Kawabaru Ecological Discharge Power Station, because of a shortage of knowledge and experience, it is necessary to assess its adoption in advance by detailed study including with manufacturing personnel, and collecting data such as usage performance and actual trouble history.

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

Since the operation of the Kawabaru Ecological Discharge Power Station was started, foreign materials clogged the submersible turbine blade causing water to enter into the stator housing (this phenomena is a turbine specific event). Therefore, the countermeasure to prevent foreign material from entering was conducted (March 8, 2013) by replacing the inlet screen mesh with a smaller size (screen pitch 25mm).

6. Further Information

6.1 Reference

None

6.2 Inquiries

Company name: Kyushu Electric Power Company

URL : http://www.kyuden.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-a) Technological innovation & deployment expansion of electro-mechanical (E/M) equipment

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

Project Name:

Refurbishment of the Tagokura Hydropower Station

Name of Country (including State/Prefecture):

Japan, Fukushima Prefecture

Implementing Agency/Organization:

Electric Power Development Co., Ltd.

Implementing Period:

From 2004 to 2012

Trigger Causes for Renewal and Upgrade:

(A) Degradation due to aging and recurrence of malfunction

Keywords:

Refurbishment of hydropower station, Turbine, Generator

Abstract:

In 1999, JPOWER (Electric Power Development Co., Ltd.) established a working group in the company and has conducted a feasibility study of the “Refurbishment of hydropower stations” for the 17 power stations which had been operated for a very long time (mainly 32 systems). As a result, the Tagokura Power Station was selected as the first power station which should be completely refurbished. The Tagokura power station started its operation in 1961 with an output of 380,000kW, and has supported economic activities of the Tokyo metropolitan district as a peak power support resource, and its importance seems likely to not diminish greatly in the future. The Refurbishment work was conducted from November, 2004 to May, 2012 by changing the 4 main machine systems in order, and the Tagokura Power Station was renewed as a hydroelectric power station with a maximum output of 400,000kW. In this report, the reason why the Tagokura Power Station was selected, the decisions on the renewed machinery range, design, construction methods, construction actual status and the effect of this Refurbishment work is described.

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

The Tagokura station is located in the area with the heaviest snowfall in Japan; Tadami-machi, MinamiAizu-gun, Fukushima Prefecture. This station is one of the biggest hydroelectric power stations in Japan with a maximum output of 380,000kW (with 4 turbine generators). This power station is located immediately downstream of the Tagokura Dam whose total pondage is $494x10^6m^3$ at an upstream point of the Tadamigawa River as part of the Aganogawa water system which flows along the border between Fukushima and Niigata Prefectures. Tadamigawa River starts to flow from the Ozenuma (altitude 1,665m) which includes Gunma Prefecture and Fukushima Prefecture. It then passes through the Ozegahara Swamp, continuing to flow north along the Echigo Mountain Range, then, in the vicinity of Aizuwakamatsui-shi, merges with the Aganogawa River. After that, the river flows west to enter Niigata Prefecture, passing through Niigata Plain and finally enters the Japan Sea. The river has a total length of 272km and a basin area of $7,710km^2$, and along this river including the Aganogawa main river, many hydropower stations were constructed. The construction of the Tagonokura Power Station was started in September, 1955, and the first phase of construction (3 turbine generators: output 285,000kW) was completed in May, 1960. In November, 1961, the second phase of construction was completed and the operation of the 4^{th} generator began. Electric power generated by the Tagonokura Power Station is used as a peak time power resource for the Tokyo metropolitan district, supporting its economic activities, and is an important power source.

Fig. 1 is a location map of the Tagonokura Power Station. Fig. 2 shows a longitudinal profile of the Tadanogawa hydro-electric power area, and Table 1 shows the main specifications of the Tagonokura Power Station (as for electric related machinery: specification before Refurbishment).

Fig. 1: Location map of the Tagonokura Power Station

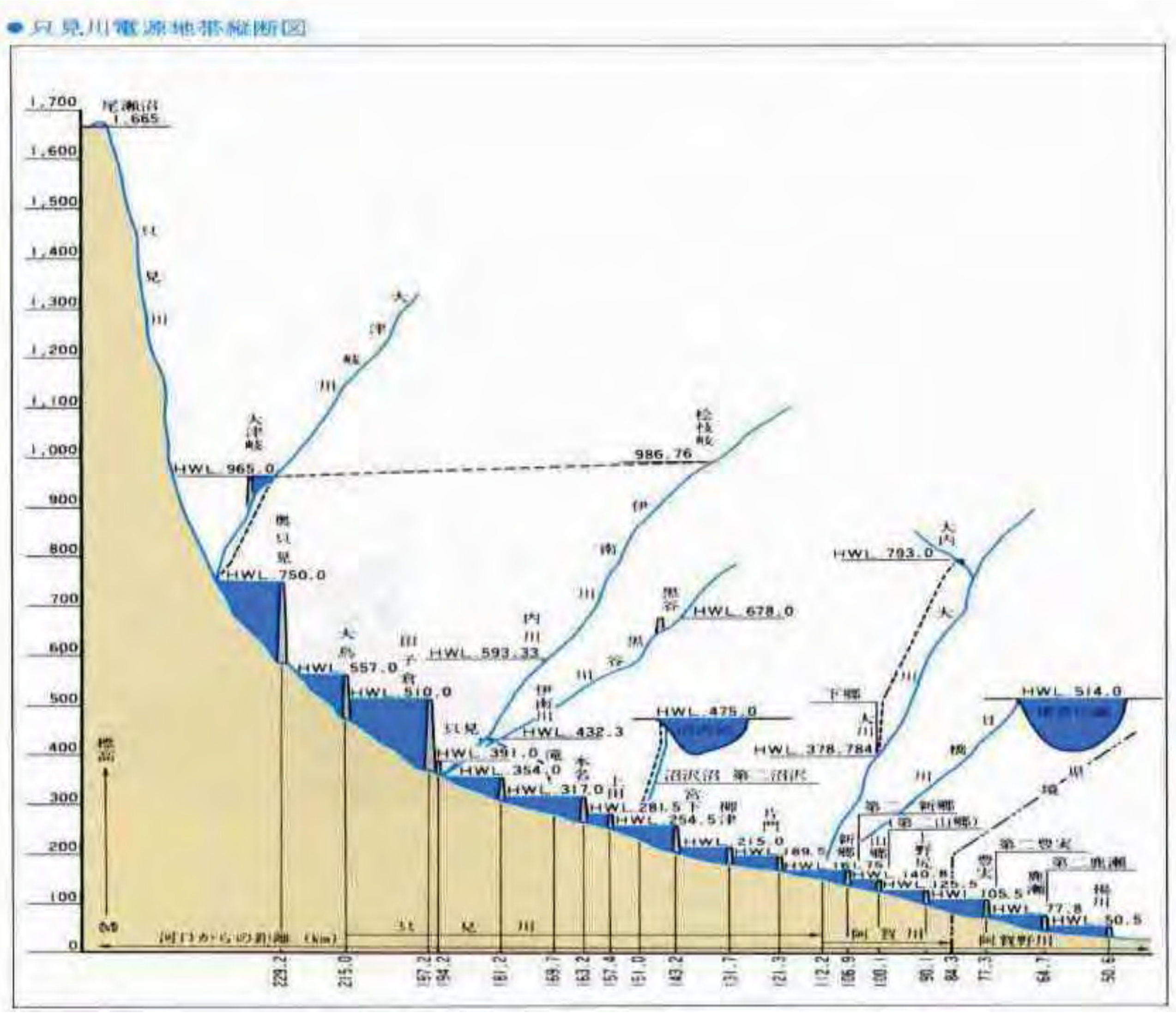


Fig. 2: Longitudinal profile of the Tadanogawa hydro-electric power area

Table 1: Main specifications of the existing Tagonokura Power Station

Approved output	Maximum/ Normal time	(kW)	380,000 / 43,200
	Firm peak	(kW)	170,300
Plant discharge	Maximum/ Normal time	(m^3/s)	420 / 55.07
Effective head	Maximum/Normal time	(m)	105 / 93.82
Reservoir	Total pondage /Effective pondage	(10^6m^3)	494 / 370
	Full reservoir level	(EL.m)	510.00
	Effective depth	(m)	52
	Ponding area	(km^2)	9.95
Dam	Type		Concrete gravity dam
	Top length × Height	(m)	462 × 145
Dam	Dam volume	(10^3km^3)	1,949.5
	Gate × number of gates		Radial × 4
Hydraulic steel pipe	Numbers of lines × Length	(m)	4 × 123.5
	Inside diameter	(m)	5.0 - 4.4
Turbine	Rated output	(kW)	108,000
	Number of machines	(machines)	4
Generator	Rated output	(kVA)	105,000
	Frequency	(Hz)	50
Main transformer	Rated capacity	(kVA)	105,000
	Voltage (first/second)	(kV)	13.0 / 287.5, 275, 262.5

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) Improvement of efficiency

By applying the latest Computer aided fluid analysis technology (CFD) to the design of a turbine and by increasing rotation speed by one rank, partial load efficiency was improved by 5,000kW per generator and the total power station output was increased from 380,000kW to 400,000kW.

(A)-(b) Improvement of durability, safety and reliability

Since the whole system including generators and auxiliary machinery were replaced, a wide range of machinery was renewed. Thus, steel items such as the upper and lower covers for the turbine, generator frames, upper and lower blankets which were damaged with age, cracks, and fatigue breakdown at welded areas were replaced. Also insulation breakdown of the generator stator and rotor coils and fatigued, broken rotation parts were replaced. Further, by adopting plastic resin for the bearings, and by replacing the water supply equipment, oil supply equipment and various sensors, durability, safety and reliability of the power station has been greatly improved to an almost new power station level.

(A)-(c) Cost reduction

By conducting a blanket order of machinery and parts, and adopting overseas sub-vendors, less expensive procurements were able to be achieved than by doing partial replacements.

(A)-(d) Improvement of maintainability

The whole system, from main machinery to auxiliary machines was replaced, so except for the initial failure, the failure rate is expected to be improved to a level equivalent to a newly constructed generation plant. Also the process of failure handling and inspection are now well defined procedures and the maintainability was improved.

(2) Improvement of value (functions)

By increasing maximum output, peak power source value was increased as the generated power was increased.

(3) Necessity in market

(Not applicable)

2.2 Process to Identify and Define Renewal and Upgrade Work Measure

1961: Operation of the all generators of the Tagokura Power Station (existing power station) began

1999: Tagokura Power Station was chosen as the first case for the Refurbishment (complete replacement) as a result of the feasibility study of 17 power stations which had been operated for many years.

2004: Refurbishment work of the No.4 machine of the Tagokura Power Station began

2006: Refurbishment work of the No.4 machine of the Tagokura Power Station was completed.

2006: Refurbishment work of the No.2 machine began

2008: Refurbishment work of the No.2 machine was completed.

2008: Refurbishment work of the No.3 machine began

2010: Refurbishment work of the No.3 machine was completed.

2010: Refurbishment work of the No.1 machine began

2012: Refurbishment work of the No.1 machine and all units were completed.

2.3 Description of Work Undertaken (detail)

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) Refurbishment work plan of the main machinery was determined

The Refurbishment work plan of the main machinery were investigated for the selected 17 hydroelectric power stations (main systems: 32 machines) by the working group which was organized in 1999. Criteria for the selection of the power stations which are subject to the study are as follows:

- As of 1999, power stations which had been operated for more than 50 years.
- Power stations which had been in operation for less than 50 years, those which were aging seriously
- Exclude pumped-up power stations and power stations (including dams) which are already planned to be redeveloped.

The reason why power stations which had been operated for more than 50 years were subject to consideration was because we had many power stations (36 power stations, 63 main machines) which started their operation during 1954 to 1965, and for these power stations, large scale renewal plans such as for turbine runners, etc. were considered. In addition, renewal plans for inlet valves, governors, exciters and auxiliary equipment were planned as well.

In 1999, the general survey was conducted and 17 possible power stations were narrowed down to 4 power stations. Then in 2000 and 2001, a detailed investigation of these 4 power stations was conducted. Finally, an economic comparison was conducted between the case in which the conventional method, that is, existing machinery was partially renewed (submerged parts of turbines were not able to be replaced) and the case in which a complete replacement was conducted. As a result, it was determined that the complete replacement plan was better in economic performance, therefore, in 2002, that plan was decided to be conducted.

(2) Advantages of the complete replacement plan of the main machinery

By replacement of the main machinery, the following advantages are obtained:

1) Lengthening of the service life of power stations

By replacing all electrical equipment which will become necessary to be replaced anyway at some point in the future at the same time, trouble caused by aging of the turbines/generators was able to be reduced, enabling the extension of the service life of the power stations.

2) Improvement of the reliability of the facilities.

By replacing all electrical equipment, and by installing newly manufactured turbines/generators, the latest and the optimum design was able to be adopted, and the reliability of the facilities is improved.

3) Generated power and increase on generated power

With an increase of the machinery efficiency caused by the adoption of the latest design technologies, and by the optimum operation set up which became possible from the actual operation data of the existing facilities, an increase of the generated power was expected.

4) Reduction of the number of the days of generation stoppage in the future

In the past, since partial replacements and partial repairs had been conducted and the number of inspections and their frequency increased, and the working period got longer, the frequency and duration of unexpected and unscheduled systems stoppage increased. Therefore, by replacing the whole system with a new one, it became possible to reduce future system stoppage days.

5) Labor saving on maintenance

By replacing the whole aging turbines and generators with new machines, and by reducing inspection items and inspection frequencies by adoption of the latest technologies, maintenance labor saving was achieved.

6) Improvement of technical capabilities and technology succession

Through the experience of the specific large scale construction work in this project, the technological skill was increased, and in the future, the new construction work and also special scrap and build type construction projects including consultation work are able to be handled.

7) Others

With the adoption of the high speed turbine/generator (downsizing) and by the purchasing of the system as a whole replacement at once, system renewal costs were reduced. In the case of the Tagokura Power Station, by increasing the turbine operation oil pressure, an inlet valve operation time was shortened (from 6 minutes to 3.5 minutes), and it was able to reduce the time needed to connect to the power grid.

(3) Range of the whole replacement work of the main machinery.

The basic policy for the whole replacement work of the main machinery is as follows:

- Water usage specifications: The maximum plant discharge was kept at the amount which was approved for the existing power station as a water usage approval value (no change).
- Electric facilities: The basic configuration was not changed. From the view point of performance and structures, all of the main facilities which needed repair were replaced at once so as to maintain the operation for long years in the future as well.
- Civil engineering facilities: Only the excavated area which was needed because of the renewal of the turbines and generators was restored and the main facilities were not changed. In the whole replacement of the No.4 machine of the Tagokura Power Station, the casing and the generator barrel were able to be reused. Thus, renewal range for the turbines was: inlet valves, upper and lower covers, speed rings, guide vanes and upper vertical draw pipe. For the generator, the renewal range was everything except the foundation of the power station. And as for the civil engineering work, the restoration range was able to be limited only to that necessary for the replacement of the speed links, lower covers, and upper vertical draw pipe. The renewal range per unit is shown in Fig. 3.

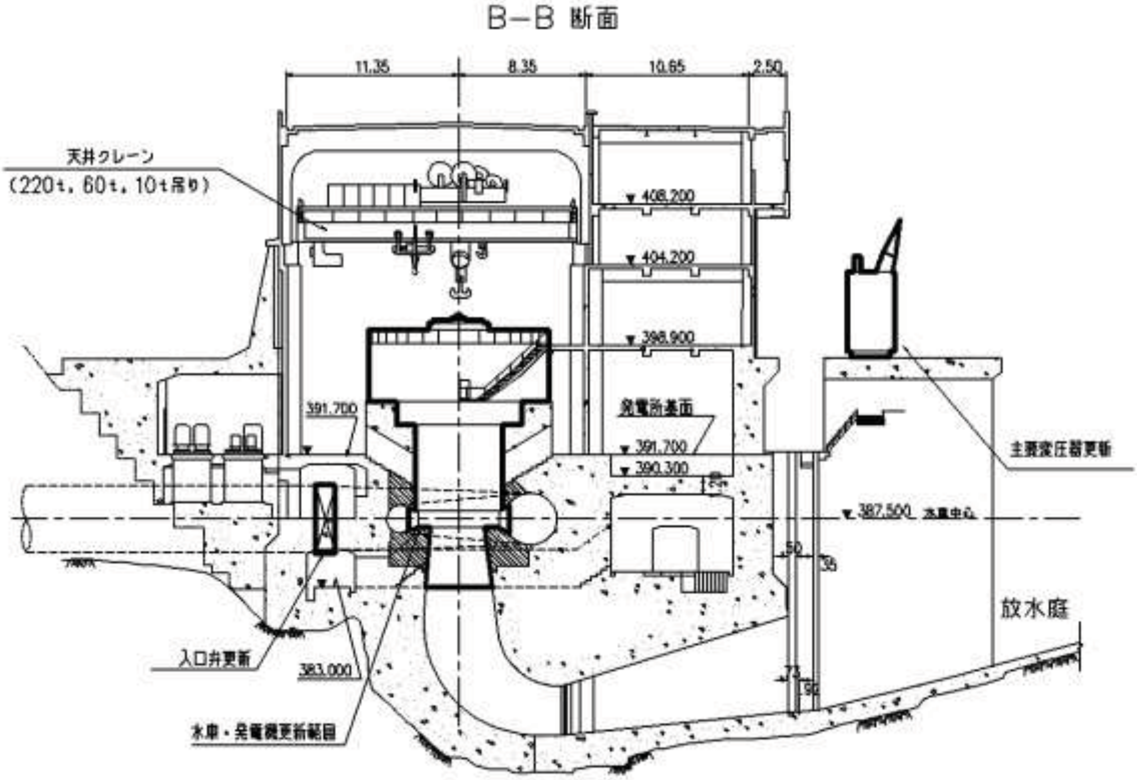


Fig. 3: Whole, simultaneous renewal work range of the Tagokura Power Station (per unit)

(4) Comparison of the specification of the machineries (before and after the whole renewal work)

Table 2 shows the machinery specifications before and after complete renewal, and Photos 1 and 2 show the whole internal appearance of the Tagokura Power Station.

Table 2: Comparison of the specifications of the main machineries of the Tagokura Power Station

Item			Unit	Before Renewal	After Renewal
Output of the power station			(kW)	380,000	400,000
Turbine	Type			Vertical Francis turbine	Vertical Francis turbine
	Output	Maximum	(kW)	108,000	102,300
		Standard	(kW)	102,000	102,300
		Minimum	(kW)	45,000	48,000
	Effective head	Maximum	(m)	118.2	120.6
		Standard	(m)	105	106.8
		Minimum	(m)	67	66.0
	Plant discharge	Maximum	$(m^3)/s$	100.7	94.2
		Standard	$(m^3)/s$	107.8	105
		Minimum	$(m^3)/s$	81	80.8
	Rotation speed		rpm	167	188
	Manufacturer			Mitsubishi Heavy Industries, LTD	Mitsubishi Heavy Industries, LTD
Generator	Type			Closed air duct circulation type	Water cooling heat exchanger type
	Rated output		(kVA)	105,000	112,000
	Rated voltage		(kV)	13.2	13.2
	Power factor			0.9	0.9
	Frequency		(Hz)	50	50
	Manufacturer			Mitsubishi Electric Corporation	Mitsubishi Electric Corporation
Main transformer	Type			General three phase oil filled type	Special three phase oil filled type
	Rated capacity		(kVA)	105,000	112,000
	Voltage (first phase/second phase)		(kV)	13.0/275.0	12.8/275.0
	Manufacturer			Mitsubishi Electric Corporation	Mitsubishi Electric Corporation

Photo 1: Full view of the Tagokura Power Station generator room (Before renewal)

Photo 2: Full view of the Tagokura Power Station generator room (After renewal)

(5) Design condition of the replaced machinery and the result of investigation

Basic design conditions of the replaced machinery are as follows:

High speed: Develop a main machine able to operate at high speed within the range for which necessary vertical draw height is secured

Short-circuit ratio: 1.0 for over 100MVA, 0.8 for less than 100MVA

Maximum output: The maximum output of the existing power station is maintained no matter what.

Turbine efficiency: For the existing turbine, turbine model test results were transferred to an actual machine via a standardized equation and applied to the design. As for the replacement machines, an actual conversion equation by JIS standards was applied.

Generated energy: The optimum operation point was found from the actual operation data of the existing dam, and based on it, generated energy is pursued to increase as much as possible.

As a result of the investigation, the output of the power station increased by improvement of the machinery's performance and reviewing the basic effective head, without changing the maximum plant discharge. (Total output has been increased by 20,000kW to 400,000kW versus the original power station)

The turbines were designed optimally based on the actual operation studies, the standard effective head was reviewed to be 106.8m, and rotation speed was increased by one step to 188rpm.

To determine if it was possible to reuse the foundation of the power station, applied load conditions (8 points of the stator foundation, 8 points of the lower bracket foundations) were measured under each operation condition of the generators (stoppage, braking, normal operation, single phase short-circuiting and earthquake). It was confirmed that there were no civil engineering problems against keeping the structure.

(6) Improvement of the turbine efficiency

Improvement of the efficiency of the new turbine is thought to be achieved by the following 3 factors:

1) Application of the Computer Fluid Dynamics (CFD)

When the existing power station was designed, since CDF technology was not yet available, the design accuracy was poor in terms of casing shapes, fixed vanes and other parts which had an influence on the turbine efficiency. This led to a design which had a larger loss than the case designed with the latest Fluid Dynamics Design method. In this project, as for the new turbines, the shapes of speed ring and runner vanes were improved by using the latest Computer Fluid Dynamics.

By this, the highest efficiency point was achieved and also the efficiency in the partial load range of 40 – 50% of the rated output was improved.

2) Adoption of the high rotation speed

It is said that in the latest design of a vertical Francis turbine, the most efficient specific speed which has the highest efficiency is 180 – 190 m-kW. In this project of the turbine replacement, by increasing the rated rotation speed, the specific speed at the standard effective head was increased from 158 m-kW of the existing turbine to 185 m-kW, and the system efficiency was able to be achieved.

* Specific speed is the rotation speed at which a model turbine geometrically-similar to the actual turbine generates a unit output of 1kW by a unit head (1m). The comparison of the turbine efficiencies (standard head) are shown in Fig. 4.

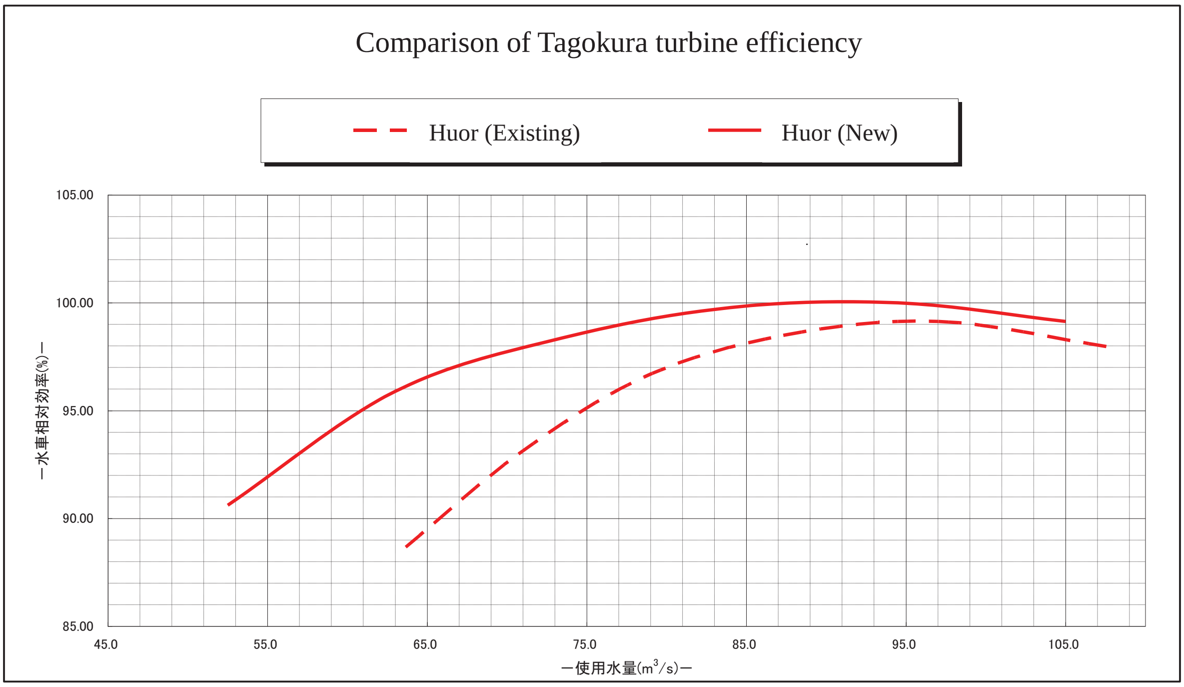


Fig. 4: Comparison of the turbine efficiencies (standard head)

3) Modification of the design points of the turbine

For 4 years from 1998 to 2001, operation actuals (dam water level, plant discharge, output and others) were surveyed and analyzed, and the turbine design point was moved close to the area (effective head, plant discharge) where the operations were run most frequently. The operation diagram of the water level of the Tagokura Dam is shown in Fig. 5.

Water level operation of Tagokura Dam

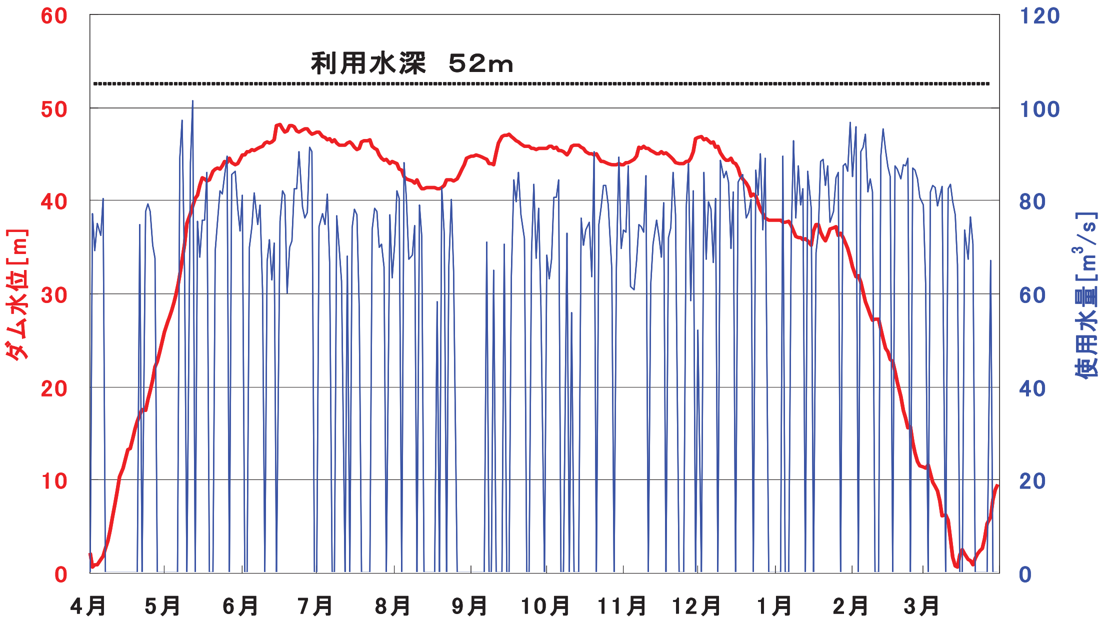


Fig. 5: Water level operation diagram of the Tagokura Dam
(Dam water level: EL.458.00m = available depth 0m)

(7) Implementation of the Refurbishment (complete replacement) of the hydropower plant

While paying attention to the adjacent machines still operating, for 2 years, the replacement of the No.4, No.2, No.3 and No.1 machines was conducted (construction periods: 18 months) in that order With the aim of cost saving, by using overseas sub-vendors, the project were conducted as scheduled, and in May, 2012, the final No.1 machine was able to be replaced.

3. Feature of the Project

3.1 Best Practice Components

- Cost saving and reliability recovery by the replacement of the highly aged power station machinery
- Adoption of one rank higher rotation speed for the turbine so as to improve efficiency
- Adoption of the high efficiency turbine design developed by Computer Fluid Dynamics (CFD)
- Review of the design point based on actual operation records
- Utilization of the existing spiral casing
- Cost saving by the using the overseas sub-vendors and the necessary quality control system

3.2 Reasons for Success

In the selection of the power station to be subject to the Refurbishment, economic efficiency was compared between the case in which a partial repair would be continued, and the case in which the complete replacement would be conducted. The Tagokura Power Station, which showed the most preferable value, was chosen. Though the Tagokura Power Station is a large scale and important plant, since the main components were not replaced properly, a large cost saving was able to achieved by blanket purchasing of the machinery for replacement.

With the aim of cost saving, overseas sub-vendors were adopted, therefore, so as to secure the original planned quality, when they manufactured the machines, close checks and quality control inspections were conducted. Even so, there were many minor non-conformances found, so we believe that we have been able to achieve the planned quality by great efforts of the engineers at the vendors' sites and head offices, and also by the cooperation between the prime contractor and the overseas sub-vendors.

It is worth noting that an advantage was obtained because the design point of the existing turbine was changed to the point where high efficiency has been obtained by adopting a high specific speed by the current technology. In addition, the conditions of the spiral casing which was embedded in the concrete were good and it was a welded structure. It was therefore possible to cut and separate the speed ring and the fixed vanes, and later on re-weld them back in place. Besides, downsizing by the change of the rotation speed kept the concrete excavation work at a minimum, enabling reduction of the civil engineering work cost. The fact that the amount of concrete excavation was small was one factor making it possible to remove one subject machine for replacement at a time while the other machines were running and to install the new one, minimizing the stoppage of power generation.

4. Points of Application for Future Project

For machinery which has been operated for a very long time, it is necessary to compare the economies between the case in which a partial repair would be conducted versus the case in which complete replacement would be conducted. Based on that it is necessary to judge which is better.

Since the investment is to be conducted by stopping machinery which is running, it is necessary to survey and understand precisely the various factors such as an increase of efficiency, cost savings, improvement of reliability, reduction of maintenance work and reduction of future stoppages for each individual subject plant.

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

Thus far, after the renewal/reinforcement construction work was completed, a periodic monitoring has not been conducted. In order to confirm whether or not the improvement of performance, economic efficiency and other benefits have been achieved by the Refurbishment work as originally planned, ex-post evaluation was carried out. In that evaluation, the following items were evaluated:

(1) Construction Actual

The construction work period was as planned. Machinery was manufactured in foreign countries, and installation was conducted in Japan without any problems, and it was confirmed that quality was able to be maintained. Some non-conformances that happened in this renewal project were shared with other organizations.

(2) Performance and economic efficiency

It was confirmed that planned efficiency and output increases have been definitely achieved, by calculating generated energy before and after the Refurbishment from the annual operation records. It was also confirmed that the project was able to be finished within the original planned budget, and economic efficiency targets including the increase of generation energy were achieved as planned.

(3) Expansion of the service life and improvement of reliability

Concerns in the Refurbishment work such as the insulation degradation of stator coils were all resolved including ancillary apparatus problems. By evaluating failures before, versus reliability after the Refurbishment, the improvement of reliability was confirmed.

(4) Acquisition of the technical knowledge

In this project, knowledge of manufacturing, the installation process and quality control of the products manufactured in foreign countries were obtained.

The Refurbishment method which reused the casing and replaced the speed ring was conducted for the first time anywhere in the world (according to our survey). The Refurbishment (complete replacement) construction work of a large scale power station like the Tagokura Power Station is an effective method which enables an electric power company to continue the energy generation business with high competitiveness by using very old power stations, and achieve both cost savings and improvement of performance and reliability.

On top of that, by using the removed machinery from this project, the research and development to improve the accuracy of the evaluation of the remaining life of the generators, turbines and main transformers was conducted and valuable knowledge was obtained.

(5) Human resource development and technology succession

Under a situation where construction work and large scale projects are becoming less common, in order to maintain competing power in the hydropower generation business in the future and strengthen it, for each system, at least one young engineer who has less than 10 years experience since joining the company was deployed. They were allowed to experiment and learn design, construction and control jobs, leading to a technology succession.

6. Further Information

6.1 Reference

1) "Plan, Design and Construction of the Refurbishment of the main machinery of the Tagokura Power Station" *Text for the NEF workshop for the technologies of the small and medium-sized hydroelectric power station, No.90*, 2006.

2) Hydro 2007 New technical solution for the refurbishment of hydropower plant

3) "Refurbishment of the Main Machinery of the Tagokura Power Station", *Electrical Review,* January, 2007

6.2 Inquiries

Company name: Electric Power Development Company

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