Renewal Work for Hydro Turbine Facilities for Asahi Power Plant

Seiki Fukuhara,
Hideki Doi,
Mitsuru Fukuma

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Abstract

For the Asahi Power Plant owned by Energia Solution & Service Co., the water is sourced from the Hino River system in Tottori Prefecture. It runs through a 2,339.766 m canal and passes through a penstock. It uses a hydro turbine generator to supply up to 675 kW of electricity. This power plant began operation in 1921. Although it underwent several renovations, it has been 98 years since it began operation, and as such, it has deteriorated. This power plant was recently renewed to be an optimal one suitable for the current flowrate of the river. A special design for the hydro turbine was adopted that satisfies the constraints while making effective use of existing civil structures. New operation began in May 2020.

1 Preface

Asahi Power Plant was constructed by San'in Electric Co., Ltd. (1907-1926) in 1921. Since 1951, it had been owned and operated by The Chugoku Electric Power Company, Incorporated. and has been in operation for 98 years while undergoing inspections, repairs, and renovations. Facilities have been noticeably deteriorating. Along with the start of the Shin-Kawahira Power Plant belonging to the Hinogawa water system, the water supply for the Asahi Power Plant was reduced and its operation rate decreased. Against such a historical background, Energia Solution & Service Co. (hereinafter referred to as "ESS") received the transfer of this power plant from The Chugoku Electric Power Company, Incorporated. ESS utilized the Feed-in Tariff (FIT) to update facilities in line with current river flow conditions. EAML Engineering CO., LTD., a Meiden Group company (hereinafter referred to as "our company") has delivered a complete set of the updated facilities. The premise of the renewal plan was to make effective use of the existing civil structures, and to solve the problems caused by these constraints, we adopted a special design for the hydro turbine that differs from the usual design. This paper introduces the facility renovation work for the Asahi Power Plant.

2 Overview of Existing Facility and Renovation Facility Plan

2.1 Overview of Existing Facility

Fig. 1 shows a panoramic view of the Asahi Power Plant building. This hydropower plant is a hydroelectric power plant with a total length of 2,339.766 m and a maximum approved output of 2000 kW. The main specifications are as follows. Fig. 2 shows the existing generation facility.

Fig. 1 Panoramic View of Asahi Power Plant Building

A panoramic view of the Asahi Power Plant constructed in 1921 is shown. This building makes us feel a long history of operation.

(1) Hydro turbine: 2 horizontal axis Francis hydro turbines
(2) Effective head: 24.40 m
(3) Maximum water usage: 11.13 m^3/s
(4) Maximum output: 2400 kW (Power plant output: 2000 kW)
(5) Penstock: inner diameter 1818 mm, length 24.86 m 2 lines

2.2 Facility Renovation Work Plan

In 1979, the Ebi Power Plant was closed and the redeveloped Shin-Kabira Power Plant started operation. The water intake area of the Asahi Power Plant became a low water section. For the replacement of aging facilities, ESS presented a basic replacement plan with the following design specifications, with a facility plan that matches the current flow conditions.
(1) Hydro turbine: 1 horizontal shaft Francis hydro turbine
(2) Effective head: 24.92 m
(3) Maximum water usage: 3.55 m^3/s
(4) Maximum output: 735 kW (power plant output 675 kW)

In addition, there were plans to partially replace and renovate civil structures such as the power plant building, water intake, headrace channels, penstock pipes, and tailrace channels, with the assumption that the existing structures would be utilized.

Fig. 2 Existing Generation Facility

Hydro turbine generation facility operated for 97 years is shown. They are beautifully rearranged by inspection, repairing, and updating services.

3 Special Design Due to Constraints on Facility Renewal

3.1 Consideration and Countermeasures for Hydro Turbine Intake (Existing Penstock) and Hydro Turbine Installation Level

Due to the use of the existing building and penstock, there were restrictions on how to connect the updated penstock to the hydro turbine intake. To suppress losses to a minimum, it is preferable to design the hydro turbine installation level by installing the penstock and the intake port in mutually straight positioning. **Fig. 3** shows the ideal arrangement of the penstock and turbine installation level. To realize this layout, it was necessary to raise the foundation level of the hydro turbine, but due to height constraints of the existing building (height required for inspection, etc.), it was difficult to raise the foundation level. Based on this, we considered changing the joint shape of the penstock. **Fig. 4** shows a study plan for changing the shape of the penstock. To minimize changes in the rise in the hydro turbine foundation level and to match the level with the hydro turbine intake, we considered installing a gradually curved pipe between the penstock and the hydro turbine intake. The effective curved pipe length that can be installed, however, could not meet technical standards for gates and penstocks. We, therefore, adopted a special design for the shape of the hydro turbine joint that has as little effect as possible on hydro turbine loss. **Fig. 5** shows a schematic diagram of the specially designed turbine casing. This structure is our first designed shape.

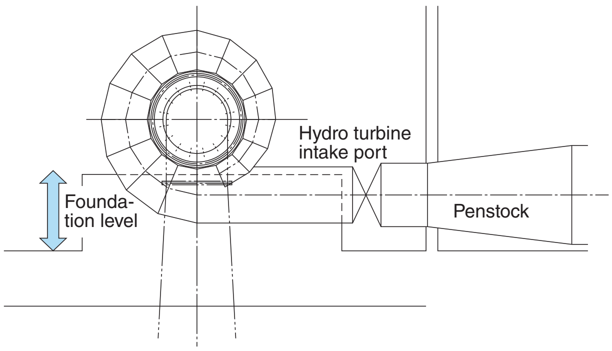

Fig. 3 Ideal Arrangement of Penstock and Turbine Installation Level

Since the hydro turbine has a structure designed to suppress the water resistance to a minimum, it is preferable to install the penstock and the hydro turbine intake port to meet their centers at the same level.

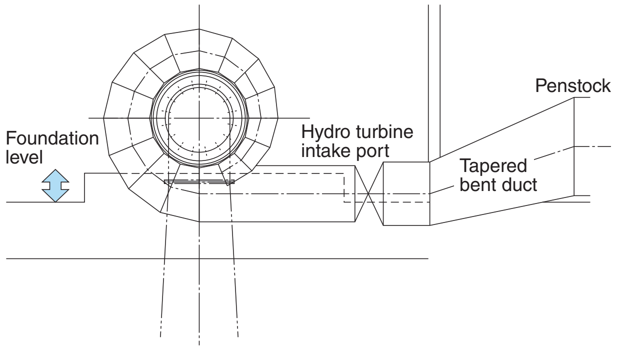

Fig. 4 Study Plan for Changing Shape of Penstock

For the initial installation plan, a bent tapered duct was to be used between the turbine intake port and the penstock so that the foundation level for hydro turbine installation meets the requirements of plant building restrictions. Since the bending of the tapered duct was too much, it was impossible to conform to technical standards for gates and penstocks.

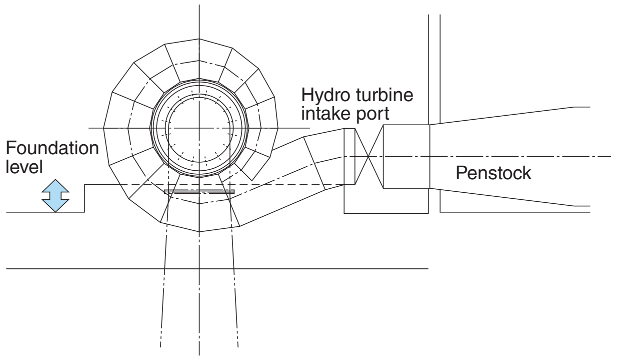

Fig. 5 Schematic Diagram of Specially Designed Turbine Casing

A specially designed method was then adopted for the turbine casing. The initial plan was modified to a construction where a reasonable balance can be secured between the hydro turbine intake port and the penstock. Such a structure assures that there is almost no influence on hydro turbine loss as a result of this modification.

Fig. 6 Carry-in Entrance of Existing Plant Building

Since this plant building was a historical landmark, it was impossible to modify the carry-in entrance. We had to use an existing opening of a wall hole (approx. 2.2 m wide and 3.0 m high) to carry facility inside.

3.2 Restrictions and Countermeasures for Hydro Turbine Entrance

Fig. 6 shows the carry-in entrance of the existing plant building. Building structures are required to be constructed without altering their exterior appearance, and since it is impossible to carry in an integrated hydro turbine structure through the existing entrance, the hydro turbine casing was constructed in two parts. As this was a special design for a small hydro turbine, and this was the first time in 25 years that we had designed and manufactured the special design hydro turbine, we held detailed discussions and studies on the design and manufacturing methods, including welding of casing and machining

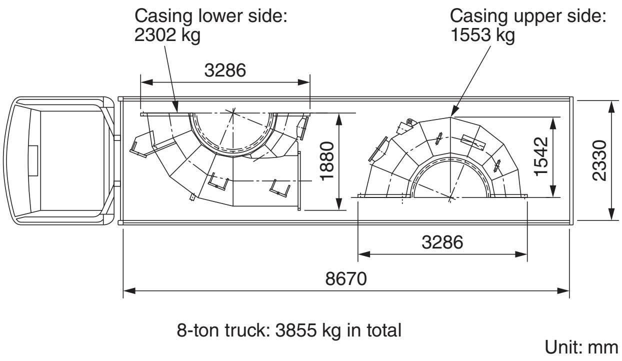

Fig. 7 Packing Diagram by Casing Split

The casing was split into two portions so that they could be carried by the aid of an 8-ton truck. For small scale hydropower systems, no split-type construction is generally used. For our company, this was a rare experience of design and production. This was the first time in 25 years that we designed and manufactured a specially designed hydro turbine.

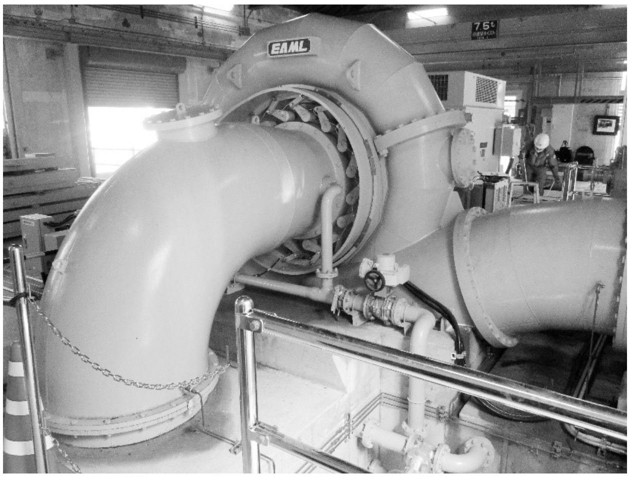

Fig. 8 Facility after Completion of Upgrade

An external appearance of facility after an upgrade is shown. This modification was realized after 95 years. The updated machines are based on the latest hydro turbine generator design policy.

process, with due consideration given to the split surface. We were able to carry it in and install it without incident. **Fig. 7** shows the packing diagram by casing split, and **Fig. 8** shows the appearance of the facility after the completion of upgrade.

4 Postscript

We introduced the details of facility renovation work of the Asahi Power Plant owned by the ESS.

Many hydropower plants have been in operation for more than 60 years and will be gradually renewed. In Japan, which has many mountainous areas, this water resource is a renewable energy that can be used stably and over the long term. In its renewal, it is important to plan to avoid wasting resources from the perspective of promoting the 3Rs (Reduce, Reuse, Recycle), so facility design and manufacturing skills that match local constraints, which are different from new construction design, are required. To effectively use the existing renewable energy resources, we will continue to refine our renewal plan design technology that puts less of the environmental footprint.