Hydro Turbine Generator for the Yamba Power Plant

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Abstract

Hydropower generation is used throughout the world as a clean energy resource that helps mitigate global warming. By drawing on our know-hows in rotating machines and hydropower generation that we have cultivated over many years, we delivered numerous hydro turbine generators for Japan and international markets that are still in operation.

A feature of the Yamba Power Plant, to which we recently delivered a hydro turbine generator, is that the water level and flow rate of the dam fluctuate depending on the season. To generate electricity with high efficiency, we have adopted a horizontal-shaft double-runner Francis hydro turbine, which uses two hydro turbines to drive one generator. Normally, the hydro turbine is only on one side, but at the Yamba Power Plant, the hydro turbine is placed on both sides of the generator. Since the space inside the power station is limited, workability during installation, disassembly, and inspection was taken into consideration for the generator design.

1 Preface

In Gunma Prefecture, which is rich in water resources, the main power generation business is hydropower generation, which is a clean energy that does not emit carbon dioxide during power generation. The newly constructed Yamba Power Plant is the 33rd prefectural hydropower plant. This power plant is a dam-type power plant that uses water discharged from the Yamba Dam located in the midstream of the Agatsuma River. It has a maximum output of 11,700 kW and an annual power output of approximately 42 million kWh. It can supply power to approximately 12,000 households.

Over our 120-year history, we have manufactured and delivered numerous hydro turbine generators. This paper introduces the horizontal shaft Francis hydro turbine generator that was delivered to the Yamba Power Plant.

2 Power Plant Overview

The Yamba Dam is a multi-purpose dam with a flood control capacity of 65 million m^3. The Yamba Power Plant was newly constructed along with the construction of the dam and has an effective head of 105.8 m ,and a maximum discharge of 13.6 m^3/s. Fig. 1 shows the hydro turbine generator equipment of the Yamba Power Plant.

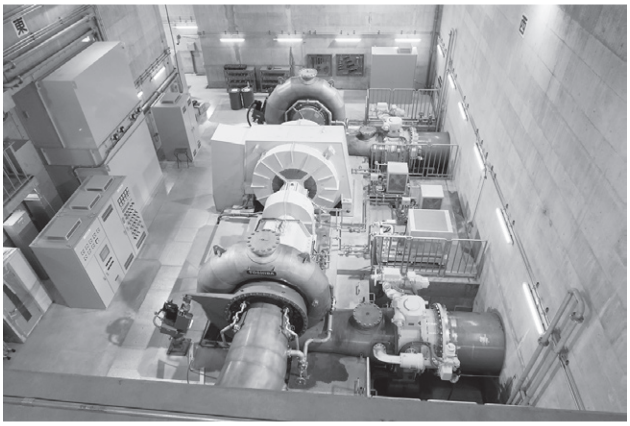

Fig. 1 Hydro Turbine Generator Equipment

The hydro turbine generator equipment installed at the Yamba Power Plant is shown.

3 Generator Design

Table 1 shows the specifications of the generator. The output of this generator is 12,400 kVA, making it one of our largest single horizontal axis machines.

Table 1 Specifications of Generator

Specifications of the generator main body and the AC exciter are shown.

Equipment	Item	Specifications
Generator	Type	Horizontal, guarded, outlet duct circulation type, rotary field salient pole type
	Type of rating	Continuous
	Rated output	12,400 kVA
	Rated voltage	6600 V
	Rated frequency	50 Hz
	No. of phases	3-phase
	Power factor	95%
	Current	1085 A
	Rotational speed	600 min^{-1}
	Heat resistant class	155(F)
AC exciter	Type	Horizontal, guarded, outlet duct circulation type, rotary armature type
	Type of rating	Continuous
	Rated output	91 kVA
	Rated voltage	80 V
	Rated frequency	100 Hz
	No. of phases	3-phase
	Power factor	90%
	Current	657 A
	Rotational speed	600 min^{-1}
	Heat resistant class	155(F)

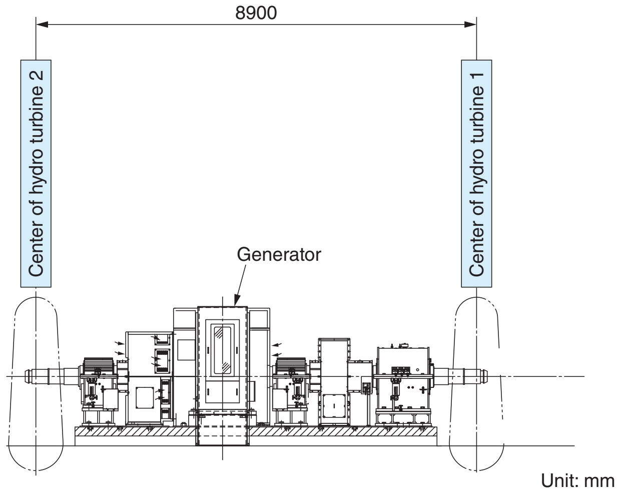

Fig. 2 External Dimensions of Generator

External dimensions of the generator are shown. Hydro turbines are installed on both sides of the generator.

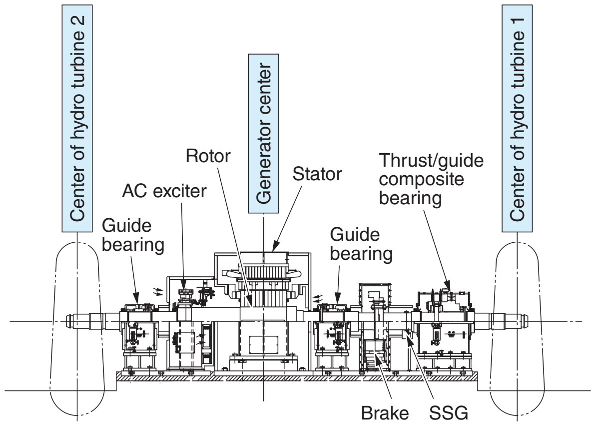

Fig. 3 Cross Section of Generator Structure

The cross section of generator structure is shown.

3.1 Generator Configuration

Fig. 2 shows the external dimensions of the generator, and Fig. 3 shows the cross section of the generator structure. The generator consists of a stator, rotor, bearings, AC exciter, and brake. Additionally, a three-bearing system was adopted in which the rotor is supported by three bearings.

3.2 Stator Design

The coils used in the stator are made of a material that has high insulation performance against high voltages, and the iron core is also made of a material with low loss and high efficiency, are impregnated together to improve reliability.

3.3 Rotor Design

The rotor has a structure that has sufficient strength even at the maximum runaway speed of the hydro turbine. Additionally, an AC exciter and a Speed Signal Generator (SSG) that detects the rotational speed are usually placed at the end of the shaft. The hydro turbine used at the Yamba Power Plant, however, is a horizontal shaft, double-runner, single-discharge, double-hook Francis turbine (HF-2RS) to help cope with seasonal fluctuations in flow rate. Since both shaft ends of the generator are connected to the hydro turbine runner, the AC exciter and SSG were placed in the middle of the rotor.

The hydro turbine generator is assembled with the turbine casing installed. The rotor was designed in a split structure so that it could be disassembled and assembled in the limited space of 8.9 m between hydro turbines.

3.4 Bearing Design

To support a rotor with a mass of approximately

27 tons that rotates at 600 Revolutions Per Minute (RPM), a three-bearing system was adopted, consisting of one thrust/guide combined bearing and two guide bearings. Each bearing is introduced below.

3.4.1 Thrust/Guide Composite Bearing

Fig. 4 shows the thrust/guide composite bearing structure. Because the generator receives the water thrust force from the hydro turbine and the mass of the rotor at the same time, a composite bearing consisting of a thrust bearing and a guide bearing was used. In addition, bearing lubricating oil can be used more efficiently.

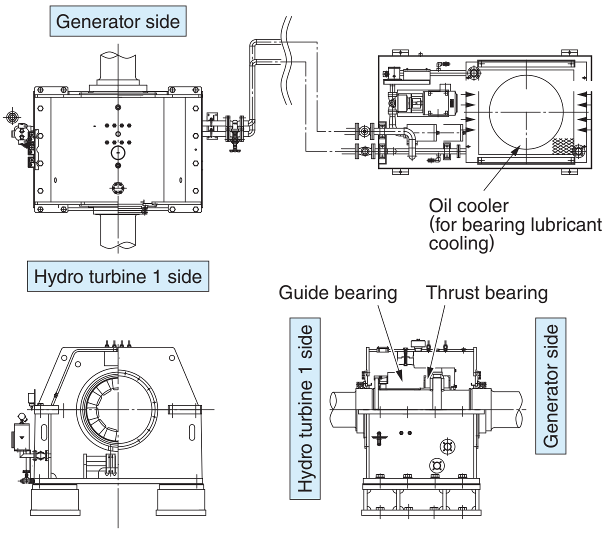

Fig. 4 Thrust/Guide Composite Bearing Structure

Thrust/Guide composite bearing structure and oil cooler are shown.

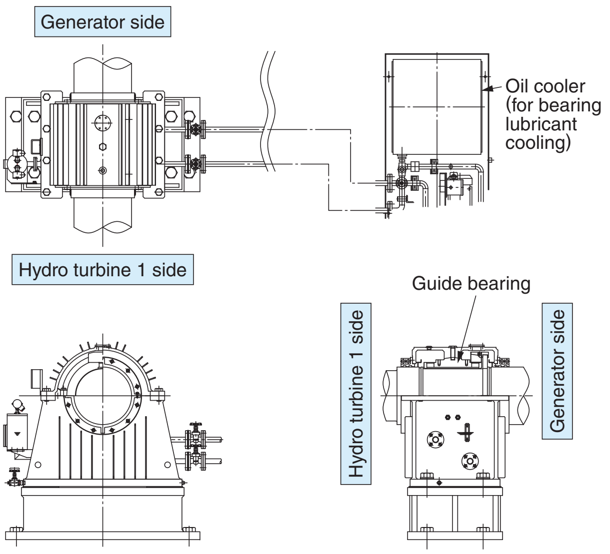

Fig. 5 Guide Bearing Structure

Guide bearing structure and the oil cooler are shown.

To ensure proper cooling, an oil cooler and lubricating oil circulation pump were installed outside the bearing.

3.4.2 Guide Bearing

Fig. 5 shows the guide bearing structure. Guide bearings were used for Units 1 and 2 hydro turbine bearings. An external circulation oil cooler was installed in the same way as the combined thrust/guide bearing.

3.4.3 Disassembly and Assembly of Bearings

In a limited space with hydro turbines on both sides of the generator, it is extremely difficult to pull out the rotor when conducting an open inspection of the bearing. Each bearing has, therefore, a structure that can be disassembled and assembled without pulling out the rotor.

4 Installation of Generator

Hydro turbine generators require installation accuracy of 1/100 mm unit. Construction work was, therefore, carried out by skilled and experienced engineers. **Fig. 6** shows the generator installation flow.

The generator was brought in by being lowered approximately 30 meters from the entrance at the top of the power plant building. **Fig. 7** shows a rotor carry-in view. For generator installation, sole plates are arranged first and the stator is then tentatively installed. Bearings are then installed tentatively, and the rotor is inserted into the stator. **Fig. 8** shows the

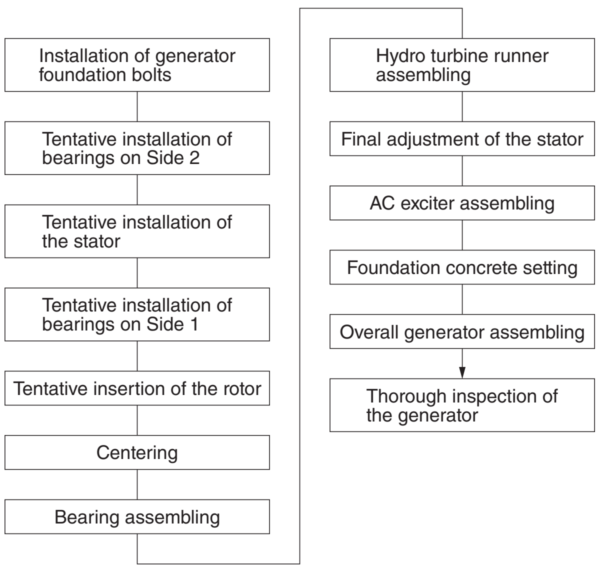

Fig. 6 Generator Installation Flow

A simplified flow diagram for generator installation is shown.

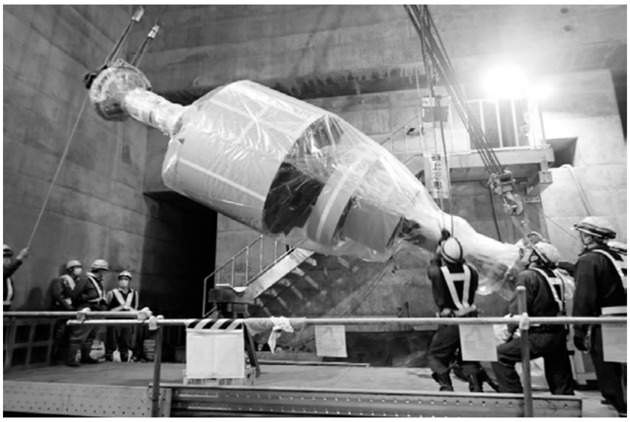

Fig. 7 **Rotor Carry-in View**

To carry the generator in a limited space through the plant roof service entrance, the rotor was suspended slantwise and lowered about 30 meters onto the installation place.

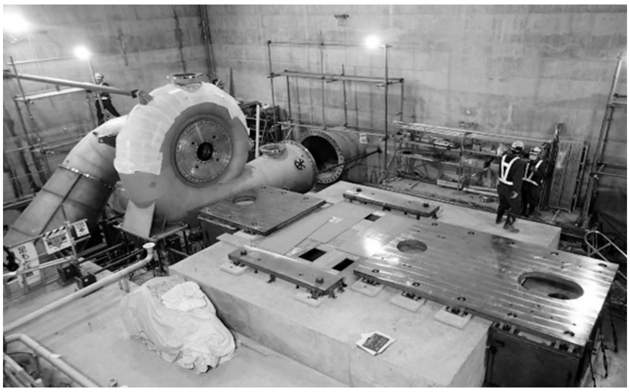

Fig. 8 **Placement of Sole Plate**

The placement of sole plate is shown.

Fig. 9 **Insertion of Rotor**

A view is shown such that the rotor is inserted into the stator and this rotor is supported by three bearings. The hydro turbine can be seen on the left.

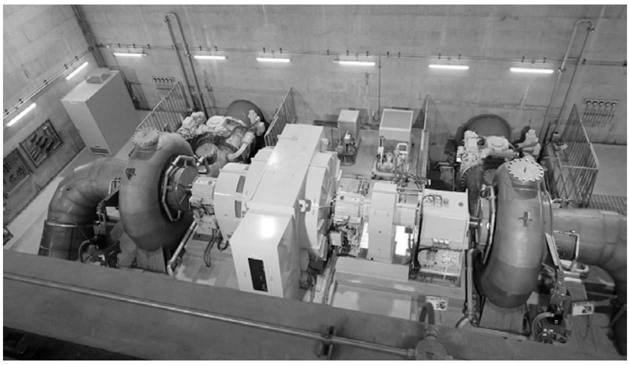

Fig. 10 **Completed State of Generator**

This view shows the finished overall assembly of the generator.

placement of the sole plate, and Fig. 9 shows the insertion of the rotor. After, rotor centering was carried out and bearings were assembled. The hydro turbine runners were then mounted and the stator was adjusted to complete overall assembly of the generator. Fig. 10 shows the completed state of the generator.

5 Postscript

We introduced the design and on-site installation of the horizontal shaft Francis hydro turbine generator delivered to the Yamba Power Plant.

In Japan, interest in decarbonization is increasing due to the government's 2050 Carbon Neutral Declaration, and there is a growing movement to introduce renewable energy. Furthermore, in Japan, which is blessed with abundant water resources, further utilization of hydropower generation is expected.

We will continue to contribute to the spread of renewable energy resources to realize a decarbonized society.

Finally, we would like to express our deepest gratitude to the many people who have given us guidance and cooperation in writing this article.

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