A Case Study of Our Small Hydraulic Power Generation Business

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Abstract

After the nuclear power plant damage caused by the Great East Japan Earthquake in March 2011 and the subsequent long-term power shortage resulting from stoppage of nuclear power generation, there has been an increasing interest in securing energy from renewable energy resources. As a result, in July 2012, the Agency for Natural Resources and Energy of the Ministry of Economy, Trade and Industry enacted the "Feed-in Tariff Law (FIT) for Renewable Energy Resources." As a result of this law, there have been growing demands for renewable energy-based power generating facilities such as photovoltaic power and small hydraulic power. As a part of Business Continuity Plan (BCP), in order to manage emergencies like natural disasters, there is an active trend of installing in-house power generating systems for stand-alone operations to feed essential facilities.

1 Preface

A dam must store a dam's downstream river water in a reservoir at a designated volume in order to keep a constant volume of discharge to maintain the natural habitat and ecosystems of aquatic life. By the enactment of "Feed-in Tariff Law (FIT) for Renewable Energy Resources," small hydraulic power generation facilities, which utilize the discharged water from the dam, have increased in many places in Japan. These small hydraulic power generation facilities can feed electric power and also perform stand-alone operation in the case of a power outage so that power is continually supplied to specific important facilities.

This paper introduces an example of new construction work at the Aha Dam in Okinawa for small hydraulic power generation facilities that can perform the stand-alone operation. The Aha Dam is managed by the Cabinet Office of the North Dam Integrated Control Office of Okinawa General Bureau (Japan). The newly constructed facilities are composed mainly of a reverse pump water turbine, Permanent Magnet Generator (PMG), and Power Conditioning Subsystem (PCS).

2 A Case Study

2.1 Outline of the Facilities

The Aha Dam is a concrete gravity dam, the largest on the main island of Okinawa. It was constructed as part of the North River Integrated Development Project for the Okinawa General Bureau for the purposes of flood control, maintaining normal dam functions to keep the constant flow rate even during the dry season, and the supply of tap and industrial water. It is situated upstream about 3.5km from the mouth of the Ahagawa River (drainage area 42.1km^2, stream length 8.5km). The height of the dam is 86 meters.

The power plant is in an area at the lower right bank of the dam.

The small hydraulic power generation facilities introduced in this paper are installed for the following purposes:

(1) Reduce running cost for the dam by installing a hydropower plant that makes use of normal discharged water from the dam.

(2) Realize a stand-alone operation in the case of a power outage from the grid to feed a power supply for dam control.

This power station is designed for automatic control. Its remote monitoring and control method is from wherever necessary and can perform local control at the plant.

2.2 Operation System of the Power Plant

Electric power from these power generation facilities is generated by utilizing normal discharge water from of the Aha Dam. The generated power is used as a power supply for dam control. The excess power goes to a 6.6kV utility system of The Okinawa Electric Power Company, Incorporated. The power supply for dam control is described below.

(1) When the power system is stable and the water turbine generator is in normal operation, the water turbine generator feeds the power for dam control and the excess power is transmitted to a 6.6kV grid power network.

(2) The power system is stable, but the water turbine generator is stopped or out of operation

(a) When the water turbine generator fails, the generator circuit is promptly disconnected from the internal grid system. The dam control power is then fed from the external 6.6kV power grid system.

(b) During the stoppage of the water turbine generator, the dam control power is fed from the 6.6kV system.

(3) When a power grid system error occurs in the middle of operation of the water turbine generator

The water turbine generator is immediately stopped and a standby emergency generator begins to generate the dam control power. Subsequently, the turbine generator is turned to the stand-alone operation mode in order to maintain the dam control power supply. The amount of electric power exceeding the load of the dam control is consumed at a dummy load by using the inlet valve that regulates the flow rate. (Surplus volumetric flow rate is transferred to the existing water discharged facility for the river.)

(4) When a grid power system error occurs in the middle of stoppage of the water turbine generator, the standby emergency generator begins to maintain the dam control power supply.

2.3 Outline of the Facility

Table 1 shows the major equipment.

2.3.1 Penstock

The penstock runs from the energy dissipator tank on the right bank of the dam to the water turbine location of the power station. It is made of stainless steel pipe duct (SUS304) 400A・350A, and is locked and installed on the stainless-made duct rack (of SUS) located in the slope of the bank.

Table 1 Major Equipment

Major equipment is shown.

Hydropower plant facilities	Type	Quantity	Remarks
Generator	63kW horizontal shaft permanent magnet type 3-phase synchronous generator	1 unit	Excitation by permanent magnets
Water turbine	67kW horizontal shaft double suction reverse pump water turbine	1 unit	
Inlet valve (350A)	Cavitation suppression type motor-powered butterfly valve	1 unit	Provided with flow rate control function
Electromagnetic flowmeter (400A)	Watertight type	1 unit	
Generator bus tie	Indoor steel-plate self-standing type	1 panel	
Incoming/local panel	Indoor steel-plate self-standing type	1 panel	
Generator control panel	Indoor steel-plate self-standing type	1 panel	
Auxiliary panel	Indoor steel-plate self-standing type	1 panel	
Converter panel	Indoor steel-plate self-standing type	2 panels	Converter unit Inverter unit
Resistor for converter panel	Indoor self-standing type	1 panel	
DC source panel	Indoor steel-plate self-standing type	1 panel	
Dummy resistor panel	Indoor self-standing type	1 panel	
Supervisory control unit	Desk type	1 unit	Monitoring console
Outdoor facilities	VCT for selling (assembling)	1 unit	
	VCT for purchasing (assembling)	1 unit	Existing item reused
Strainer (400A)	Packet type	1 unit	
Penstock (350A 400A)	SUS304 TP	1 set	Total length Approx. 85m

Fig. 1 shows a view of penstock installation.

(1) Total head: 42.45m

(2) Effective head: 40.56m

2.3.2 Water Turbine Generator Equipment

The hydraulic power generation facilities are a combination of the horizontal shaft double suction pump reverse water turbine, PMG, and PCS. They have few components and inspection is easy to carry out.

Since the PMG has a structure where permanent magnets for excitation are embedded in the rotor, it does not require an AC exciter, transformer, or exciting circuits. Fig. 2 shows an outline of the PMG construction.

The PCS functions to maintain a constant power frequency in the conversion process of AC →

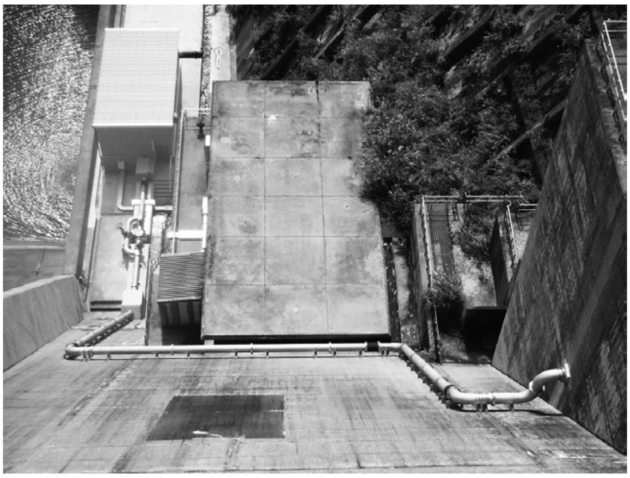


Fig. 1 **A view of Penstock Installation**

A view of penstock installation is shown.

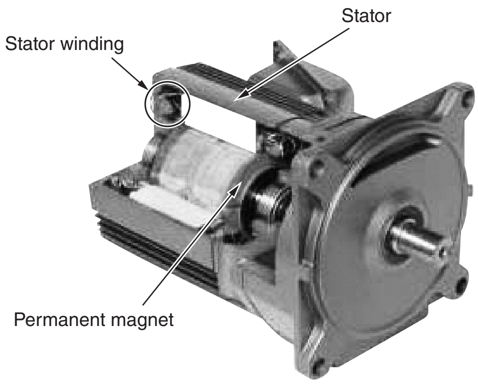


Fig. 2 **Outline of PMG Construction**

Outline of PMG construction is shown.

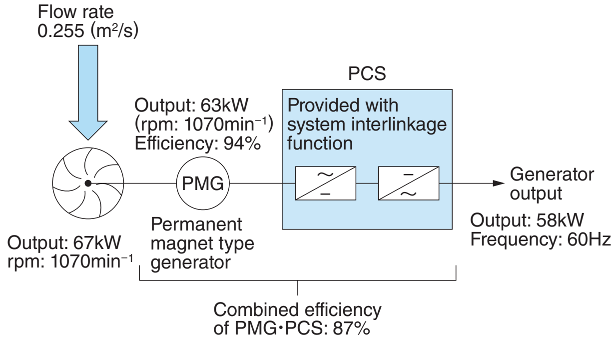


Fig. 3 **System Configuration of PMG and PCS**

A systematic configuration diagram of PMG and PCS is shown.

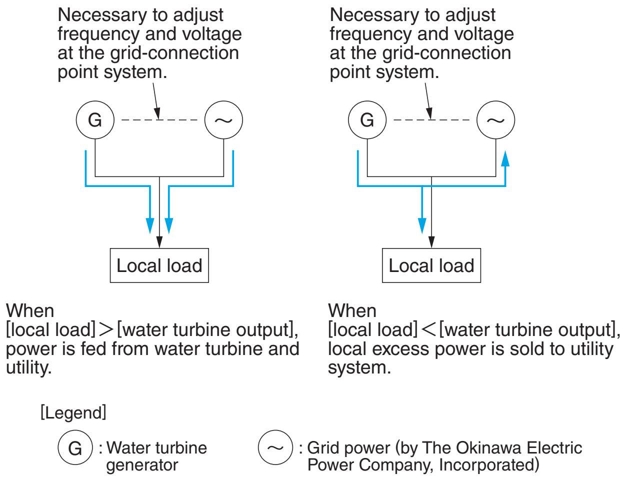


Fig. 4 **Configuration of Grid-Connection (for Parallel Operation)**

A configuration diagram of grid-connection (for parallel operation) is shown.

DC → AC for the PMG output. It performs the grid-connection and stand-alone operation.

(1) Grid-connection

(a) Power generating facilities and related equipment are grid-connected with the power network system (of a power company) for parallel running.

(b) In order to perform parallel running, it is necessary to synchronize voltage and frequency with the grid power.

(2) Stand-alone

(a) Without parallel running with grid power, power generating facilities supply power independently to the load of dam control station (local load).

(b) It is necessary to keep balance between generator output and load power.

(c) Power generating facilities are required to maintain output at a constant frequency and voltage.

Since the PCS is provided with a function to detect islanding operation, it is unnecessary to separately install an islanding operation detector. Since no exciter and islanding operation detector are needed, overall equipment configuration can be simplified.

Fig. 3 shows a system configuration of the PMG and PCS. Its features are as follows:

(1) Constant speed operation is not required.

(2) Irrespective of the rpms of the generator (water turbine), control is possible with the PCS.

(3) It is possible to perform stand-alone operation and grid-connection by using a water turbine that has no governor function.

(4) Since permanent magnets are used, no exciter is needed.

(5) It is unnecessary to use any islanding operation detector unit.

Fig. 4 shows a configuration of grid-connection (for parallel operation), **Fig. 5** shows a configu-

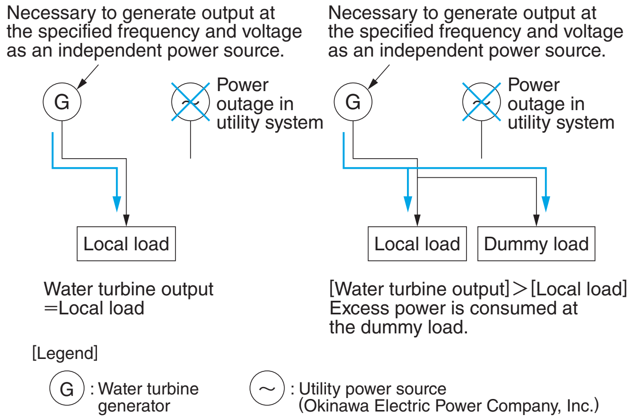


Fig. 5 Configuration of Stand-Alone Operation

A configuration diagram of stand-alone operation is shown.

(a) Overall view of water turbine generator

(b) Control panels

(c) Remote monitoring and control equipment

Fig. 6 Hydropower Plant Facility Installation

Hydropower plant facility installation is shown.

ration of stand-alone operation, and Fig. 6 shows a hydropower plant facility installation.

2.4 Installation

(1) Working period on the site: December 2014 to March 2015

(2) Contents of installation work: one complete set of small hydraulic power generation facilities in combination with a 67kW horizontal shaft double suction pump reverse water turbine, PMG, and PCS

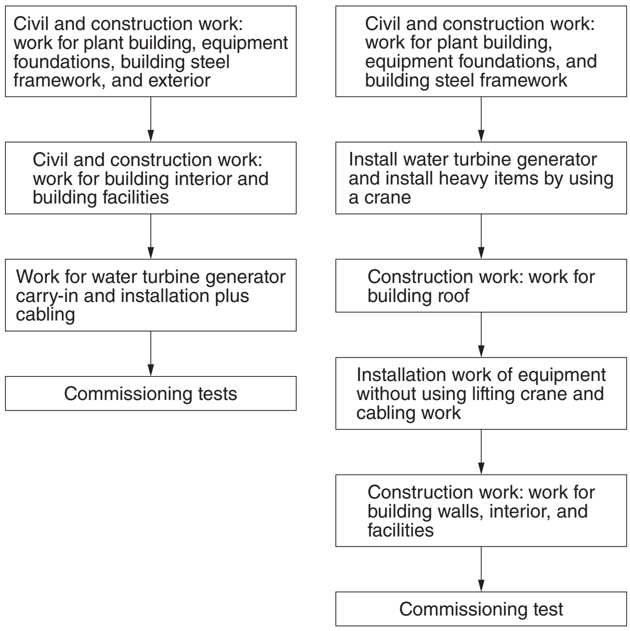
One set of SUS (350A・400A) penstock in a total length of about 85 meters

Fig. 7 shows procedures for hydropower plant facility installation. This installation work was carried out in parallel with the engineering work. Since it was different from ordinary installation procedures, we conducted the installation work bearing in mind the following points:

(1) Coordinate the project schedule with civil engineering work (check the progress status and confirm and coordinate any schedule changes during progress)

(2) Coordinate who will use the cargo lifting facility [crawler crane] (Lifting tools are procured and managed by civil engineering contractor.)

(3) Perform the installation work without a roof or walls. Care for equipment daily and check its condition.



(a) General procedures

(b) Procedures adopted for this time

Fig. 7 Procedures for Hydropower Plant Facility Installation

Generally adopted procedures and the procedures adopted for this time are shown.

2.5 Safety Control

The construction site for the power station is situated on the downstream right bank of the dam. Since there was no carry-in route to the power station, we shared the use a 200t crawler crane at the top of the dam, which was installed by the civil engineering contractor when moving equipment (including penstock). In order to avoid competing for the use of the crane among contractors, daily, weekly, and monthly schedules were carefully made. Since the penstock was installed along on the slope of the bank, the difference of about 40 meters in height from the energy dissipator tank to the water turbine position, plans for the scaffold plan were submitted to the regional labor bureau. We took measures against any falling accident during the work (by installing carrier cables and making sure to use Rolip, a fall arresting gear). In order to avoid the occurrence of accidents, we prepared well in advance.

3 Postscript

This is a new construction work for small hydraulic power generation facilities. Since it is expansion work for dam facilities currently in operation, utmost care was taken in order not to cause any adverse effect on dam management. For the time of the switchover work from existing facilities, a power outage was required, we checked the operating status of the load facilities (dam facilities) and studied in advance the limited conditions for the shutdown of the facility. Based on such study, we drafted an installation work plan. We also conducted meetings with the project owner for detailed coordination. As a result, we completed the project successfully.

We express our deepest gratitude to the Okinawa General Bureau and project-related staff for their kind cooperation during the installation work.