Small-Scale Hydropower System

Hiroaki Fujimori

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Abstract

For small-scale hydropower systems, we reinforced our offerings of product line-ups to meet various needs such as cost reduction, improvement of profitability by increasing annual power yield labor saving, and various operation control capability.

The control unit is the dedicated unit for small-scale hydropower systems. We commercialized a simplified switchgear panel to realize a lower cost and smaller footprint model. There are different models for synchronous generators or induction generators.

We developed a small-scale variable speed hydropower system that comes with a combination of a Permanent Magnet Generator (PMG), an inverter, and a converter. This generator system is expected to increase the annual power yield amount, supported by extended water turbine operation range thanks to variable speed operation and high-efficiency operation at proper rotating speed.

1 Preface

While the self-sufficiency rate of energy supply is very low in Japan, hydropower systems are precious energy resources because they use water resources producing entirely domestic clean energy. Although suitable candidate sites for large-scale hydropower projects are few in our present situation, undeveloped or reusable points for small-scale hydropower (1000kW or less) are still abundant. Due to high construction cost, however, profitability level is very challenging. Since the enforcement of the Feed-in Tariff (FIT) System on 1 July 2012, the profitability level for the hydropower project has been improved and projects for new development or renovation plans for existing facilities are increasing. In this connection, the Japanese market is ripe. This paper introduces small-scale hydropower systems that we are working on.

2 Application of Small-Scale Hydropower

Compared with other renewable energy resources like wind power and solar power, the small-scale hydropower system can offer a longer lifetime and stable good quality power can be supplied. For this reason, small-scale hydropower systems are applicable to various sites such as dams, rivers, agricultural channels, city water and sewage water plants, and factories.

(1) Use of maintenance water discharge from small-scale dams

This system is used to generate power based on the use of maintenance water discharge from a small-scale dam. The generated power is used as a power supply for the dam management office.

(2) Use of river water

River water is directly used for power generation without any storage facility. Since power generation is dependent on the flow rate of the river water, annual power yield always fluctuates throughout the year.

(3) Use of agricultural water

Power generation is dependent on agricultural water used for the irrigation of rice and vegetable fields. The generated power is fed to agricultural water irrigation facilities in order to reduce the maintenance cost.

(4) Use of industrial water

Power is generated with the use of the residual pressure at the industrial water intake tank.

3 Small-Scale Hydropower System

3.1 Water Turbine and Generator

Fig. 1 shows a small-scale water turbine selection diagram. An applicable water turbine can be chosen based on the effective head and flow rate. The generator type can be determined from synchronous generators, induction generators, or Permanent Magnet Generators (PMG) according to the purpose and system configuration. Some examples of small-scale hydropower systems are shown below.

(1) Horizontal-shaft Francis turbine generator (**Fig. 2**)

The applicable ranges of the effective head and the flow rate are 10～300m and 0.3～15.0m³/s, respectively. The horizontal-shaft Francis turbines are most generally adopted in small-scale hydropower plants.

(2) Crossflow water turbine generator (**Fig. 3**)

The applicable ranges of the effective head and flow rate are 5～80m and 0.1～8m³/s, respectively. When the guide-vane split type is adopted, it can assure high efficiency down to the low flow rate domain.

(3) Turgo impulse turbine generation system (**Fig. 4**)

The applicable ranges of the effective head and flow rate are 28～400m and 0.2～0.8m³/s, respectively. This type of turbine is adopted between the application range of Pelton water turbines and that of Francis turbines.

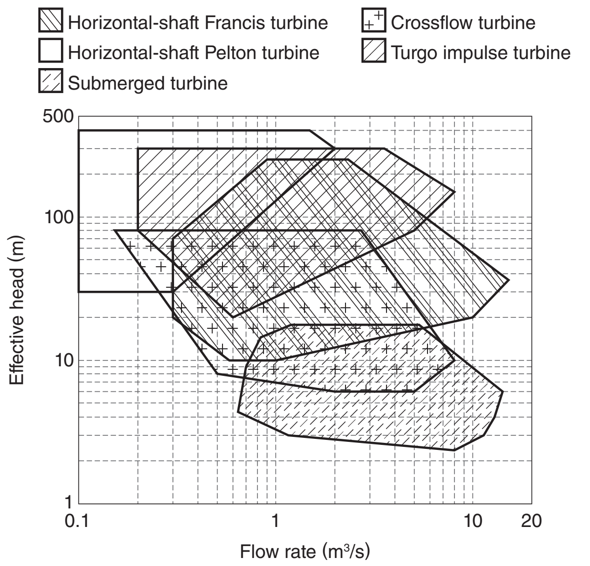

Fig. 1 Small-Scale Water Turbine Selection Diagram

A water turbine selection diagram applicable to small-scale hydropower is shown. A suitable water turbine can be selected based on the effective head and flow rate.

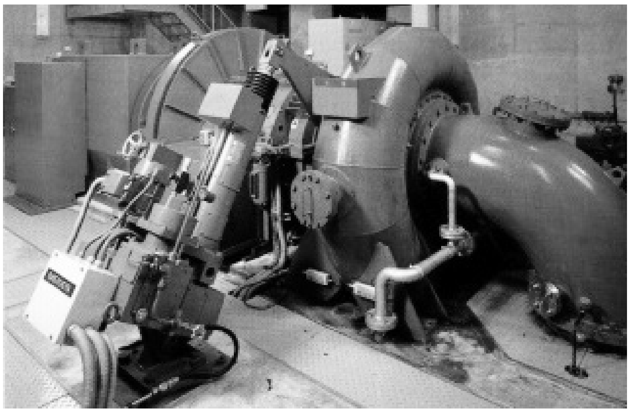

Fig. 2 Horizontal-Shaft Francis Turbine Generator

This is a water turbine generator that has a wide application range. The electrically powered servomotor is located on the left front side.

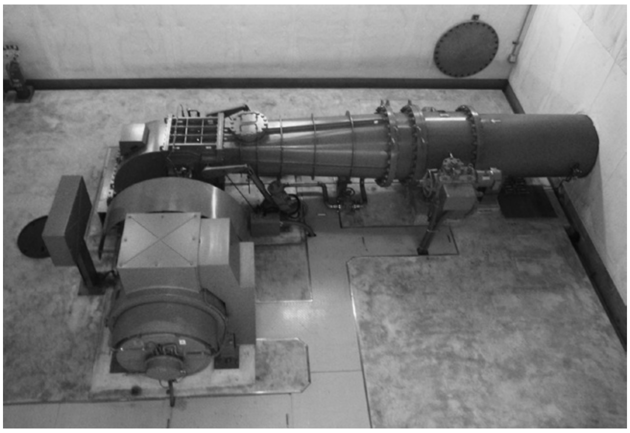

Fig. 3 Crossflow Water Turbine Generator

The crossflow turbine generator is applied to many dam type power stations where changes in the head are enormous.

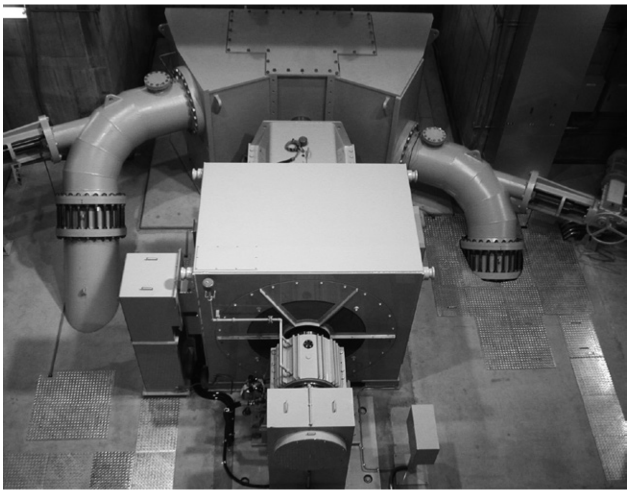

Fig. 4 Turgo Impulse Turbine Generation System

A series of water turbines made in foreign countries is adopted.

3.2 Recent Technical Trends in Small-Scale Hydropower Generation

(1) Cost reduction

Since the power output of a small-scale hydropower system is small, reduction of initial cost is always called for. We make every effort to reduce equipment cost by promoting standardization, simplification of mechanical structure, and by the compact design. During design work for power plant planning, the efforts resulted in the smaller footprint of the plant building. It also produced shorter periods for civil and construction work.

(2) Labor-saving Maintenance

For water turbines, the non-water-supply type labyrinth system or non-water-supply type self-cooled bearings are adopted. For generators, air-cooled bearings are used to achieve maintenance labor saving. Currently, equipment operation without using oil and motor-powered operation are the main currents to prevent oil flow-out into rivers. Each sliding part of the turbine is made of an oil-less metal to operate auxiliary devices for the water turbine, the inlet valve, and guide vane servomotor. We motorized these units and removed the oil-hydraulic unit. In particular, the servomotor was first used in the world by our company for hydraulic power plant in 1982.

(3) Simplified digitization for control unit

As a control unit for hydropower plants, we developed a general-purpose controller type all-function-integrated control and protection unit (MYGENEQUE Series) with enhanced price competitiveness. We have many supply records.

During such engineering resources and supply records, we have developed a very compact design simplified low-cost switchgear panel suitable for small-scale hydropower systems of hundreds of kW class. The simplified switchgear panel is for a synchronous generator. It includes the performance of sequence control, governor control, exciter control, and all controls for general-purpose protective relays, inlet valve main circuit, and control circuit in a single enclosure (W800 × H2350 × D600mm).

Sequence control for the main machine and governor control are carried out with the use of a general-purpose controller. A touch-panel system is adopted for monitoring and control. A digital AVR (IGBT type) of the YNEX06D Series is adopted for exciter control. In this manner, we worked to realize low cost and space saving. For standard functions of secondary regulation, functions of water level regulation control and automatic power factor regulation control are available. The simplified switchgear panels have lineups for induction generators. Fig. 5 shows a system configuration diagram for the simplified switchgear panel (for synchronous generators) and Fig. 6 shows an external appearance of the simplified switchgear panel.

(4) Wider variety of control functions

(a) Maintenance flow rate control (for dam type power station)

For a hydropower system which uses the flow rate of maintenance water discharge from a dam, the water flow passing through the water turbine is

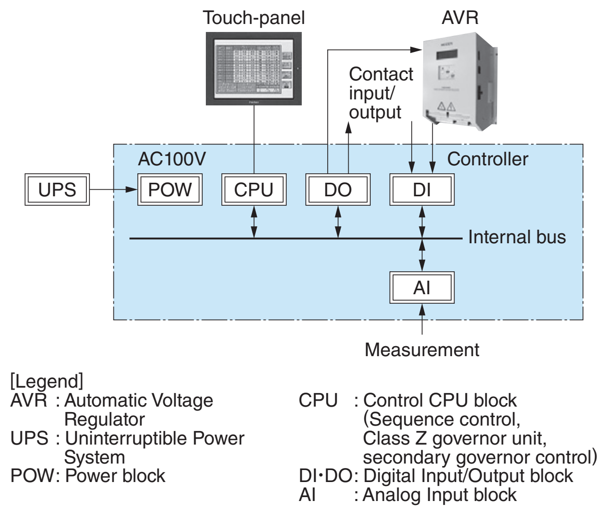

Fig. 5 System Configuration Diagram for the Simplified Switchgear Panel (for Synchronous Generators)

The standard system voltage for equipment is AC 100V. According to the user's request, specifications for DC 24V are also available.

Fig. 6 Simplified Switchgear Panel

There are applicable product lineups for both synchronous generators and induction generators.

immediately regarded as the maintenance water discharge of the river. In this power system, it is necessary to maintain a constant flow rate at all times despite a variation in the water level of a dam. For this reason, flow rate control is carried out always considering the conditions downstream. This is to avoid adverse influence on nature and fishery activities by sudden changes in the levels of water releasing into the river.

(b) Self-supporting mode operation

For dam type hydropower generation systems, there is demand for self-supporting mode of operation of water turbine generators in order to secure power for the dam management office in the event of an extended power outage from the grid.

In the self-supporting mode operation, it is necessary to constantly control both voltage and frequency using the governor unit and the AVR unit in the hydropower system. If the operation limit is needed due to frequency changes by load fluctuations, the system allows the manual operation of the self-supporting mode.

(c) Establishment of a variable speed power generation system

Our small-scale hydropower system is designed to be a variable speed power generation system supported by a combination of a PMG, a converter unit, and an inverter unit. It offers outstanding features of high-efficiency operation and easy maintenance.

Even though there is a change in the head, the small hydropower system can maintain high-efficiency operation by making the water turbine change its running speed to fit the present head. In addition, it can use an operational range that was once considered to be the out-of-operation domain as the cavitation domain of the water turbine. As a result, we can expect an increase in total annual power yield.

We produced a variable speed power generation system by using submersion type turbines made by EAML Engineering Co., Ltd. Three such systems were supplied to Laos. For the market in Japan, we supplied one unit of this system using a pump-reversing submerged turbine. Going forward, we will try to expand the application range for Francis turbines and crossflow water turbines. **Fig. 7** shows a small-scale variable speed hydropower system and **Fig. 8** shows an external appearance of PMG for submersion type turbine.

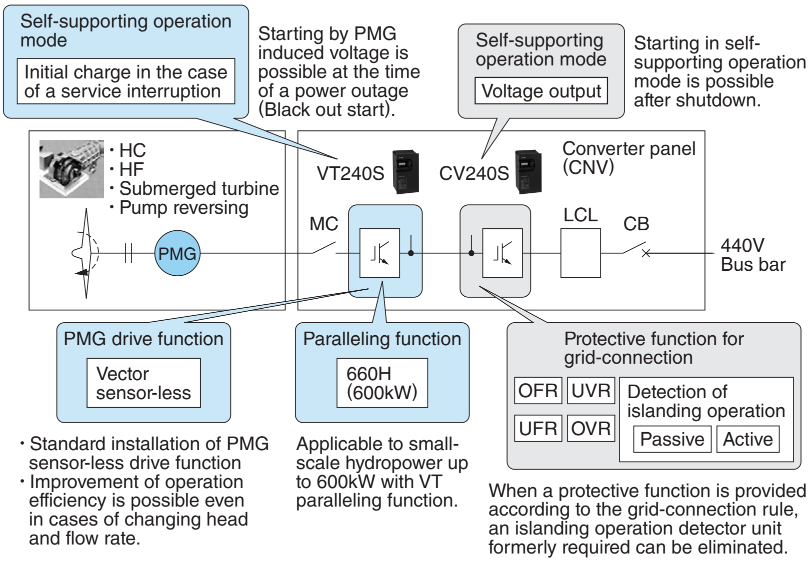

Fig. 7 **Small-Scale Variable Speed Hydropower System**

This is a high-function hydropower generation system that is capable of efficiency improvements when it is applied to a head-changing point.

Fig. 8 **PMG for Submersion Type Turbine**

A PMG for submersion type turbine is adopted.

4 Postscript

This paper introduced our small-scale hydropower systems. Even in the field of small-scale hydropower systems, many technologies developed for general hydropower plants, such as self-supporting mode operation, digitized control, and variable speed operation applied conventionally to large hydropower systems, are being applied.

Going forward, we will work on to improve our engineering level to realize low-cost, highly reliable, and highly stabile hydropower systems. In so doing, we would like to help the wider introductions of renewable energy resources.

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