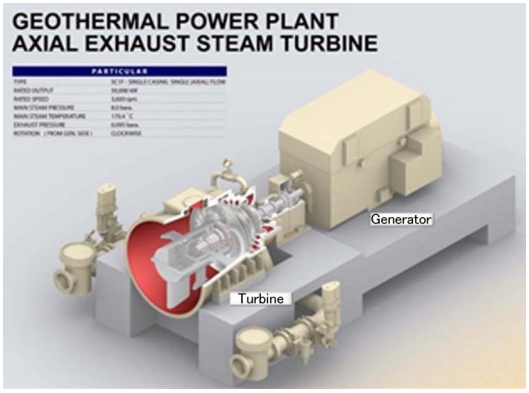
High-Availability (99.6%) Geothermal Power Plant for Mexico



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In geothermal power generation, the steam is mostly saturated at the inlet to the steam turbine and the amount of moisture in the turbine is high, and as such erosion tends to occur. In addition, impurities contained in the steam or hot water cause the deposition of scale in various devices or the corrosion of metal materials. Therefore, it is essential for stable operation to ensure and enhance the performance and reliability of power generating facilities including steam turbines. This article describes our efforts to enhance performance and to ensure the reliability of the power generating facilities we have delivered in recent years.

1. Introduction

Mitsubishi Hitachi Power Systems, Ltd. (MHPS) has supplied geothermal power generating facilities including more than 100 steam turbines exceeding 3 GW since 1951, when we delivered a test steam turbine for power generation in Japan. With the experiences and technologies for geothermal power generation facilities we have obtained through our history, we have developed a variety of techniques to prevent corrosion and have made efforts to enhance the performance of facilities including the specifications of entire plants so that they can be adapted to the properties of geothermal steam, which vary from one region to another.

This article describes our latest performance and reliability enhancement technologies based on the experience obtained through the work on the Los Azufres Geothermal Power Plant in Mexico, which we delivered with our cutting-edge technology in February 2015, and for which the operational rate guaranteed for one year was satisfied in February 2016. In March 2016, our company delivered geothermal power generating facilities to the Domo de San Pedro Geothermal Power Plant in Mexico, and our efforts on this plant are also introduced here.

2. Los Azufres Geothermal Power Plant

2.1 Project Outline

This power plant is located in Los Azufres, Michoacan State, which is 250 km west of Mexico City, the capital of Mexico (**Figure 1**). This project was ordered by Comision Federal de Electricidad (CFE, Head office in Mexico City) to Mitsubishi Heavy Industries, Ltd., (MHI) which is the direct ancestor of MHPS, as the geothermal power plant for the Los Azufres III Phase I Power Plant. Our company oversaw the design, manufacture, procurement, installation, civil work and commissioning of the main equipment including the steam turbine and auxiliary machines, while Mitsubishi Electric Corporation supplied the generators.

Our company has delivered 5 geothermal power plants for the Los Azufres geothermal field, as well as 6 plants for the Cerro Prieto geothermal field in Mexico, which is ranked No. 5 in the world in terms of geothermal resources. With these existing plants, the new plant has met brisk demand for electric power in Mexico, where steady economic growth is expected.

Figure 1 Overview of Los Azufres III Phase I

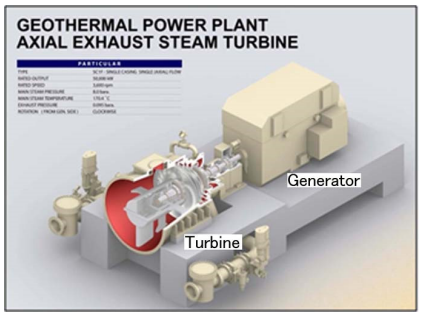

Figure 2 Cutaway View of Los Azufres III Phase I Turbine

2.2 Project Features

At this geothermal power plant with a sending-end output of 50,000 kW, the performance was enhanced by adopting a single casing axial flow turbine (**Figure 2**), and the construction period was shortened by lowering the height of the turbine housing. Unlike thermal power generation using fossil fuel, etc., in geothermal power generation, the pressure and temperature of the main steam are very low and the amount of thermal energy that can be converted in a turbine (adiabatic heat drop) is very small. Therefore, the performance improvement rate resulting from the reduction of exhaust loss becomes much larger than that in thermal power generation.

In an axial flow turbine, a diffuser with which pressure recovery can be expected without changing the flow direction of the turbine exhaust can be installed between the turbine exhaust and the condenser. Therefore, the exhaust loss can be reduced compared with that in upward and downward exhaust turbines.

In the case of a downward exhaust turbine, the condenser is installed first, and then the turbine casing is set up. By adopting an axial flow turbine, however, the installation work for the turbine and that for the condenser can be conducted in parallel, which can shorten the time for installation compared with a downward exhaust turbine. Furthermore, with an axial flow turbine, the height of the turbine housing can be substantially reduced, resulting in a reduction in construction costs.

2.3 Combination of axial flow turbine and direct-contact condenser

One end of the axial flow turbine is coupled with a generator at the governor side, and the other end of the turbine is in the exhaust chamber. Therefore, a second turbine cannot be coupled to it. Accordingly, an axial flow turbine is applied only to a single flow turbine. In this project, an integral shroud blade, which is the longest in the world for a 60Hz-area geothermal turbine, was applied to the final-stage blade of the steam turbine. The application of the long and large blade realized a single flow turbine, contributing to the enhancement of performance, as well as making the facility more compact than a double flow downward exhaust turbine facility. The turbine housing was downsized as much as possible, which minimized the effect on the landscape. In addition, our company adopted a combination of an axial flow turbine and direct contact type condenser for the first time. Photos of the axial flow turbine and the direct contact condenser delivered to the Los Azufres Power Plant are shown in **Figures 3 & 4**, and a comparison of the differences in turbine performance and the height of the turbine housing by exhaust direction is presented in **Figure 5** and **Table 1**.

Figure 3 Photo of Los Azufres III Phase I Turbine

Figure 4 Photo of Los Azufres III Phase I Direct-Contact Condenser

Exhaust direction	Downward	Upward	Axial	
			Surface	Direct contact
Turbine generator pedestal	Tall	Middle	Low	Low
Turbine house (Crane hook height)	Tall (FL 16.4m)	Middle (FL 13.5m)	Low (FL 10m)	Low (FL 10m)
Pressure loss in exhaust	≈ Zero	High	Recover	Recover
Number of exhaust flow	Can be multiple	Can be multiple	Only 1 flow	Only 1 flow

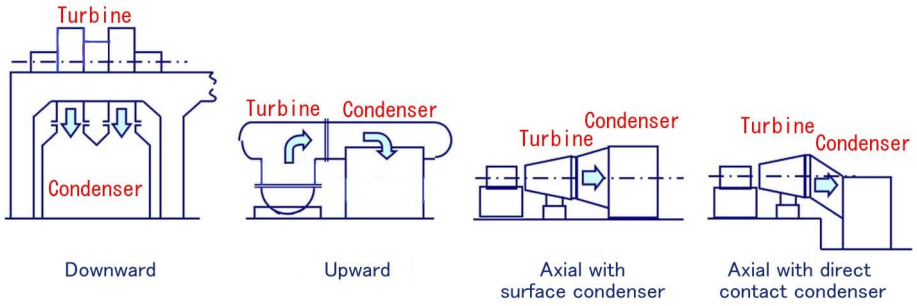

Figure 5 Comparison of Turbine Exhaust Direction

Table 1 Specifications of Los Azufres III Phase I Turbine

Delivery	2015
Type	SC1F: Single Casing Single (Axial) Flow
Rated output	50,000 kW at net output
Rated speed	3,600 rpm
Main steam pressure	8.0 bara
Main steam temperature	170.4°C
Exhaust pressure	0.095 bara

2.4 Plant Optimization

Since the delivery location of the spray jet type direct contact condenser was 2,909 m above sea level, the relationship between the cooling tower basin water level and the condenser water level was optimized in order to ensure sufficient spray pressure, even under low barometric pressure conditions. In addition, the condenser water level control was verified in the design stage in advance, and turbine water induction could be prevented.

2.5 Project Execution & Availability

In this project, substations, transmission lines, optical communication and remote control rooms, in addition to the plant facilities, were included in the supply range, and CFE's original design standards had to be followed for each facility. We entrusted Power Engineers, Inc. (PEI, USA) with some of the design and successfully accomplished the project as an exclusive EPC contractor.

During the one-year period for which a certain operation rate was guaranteed a high availability of 99.6% in terms of electric power (kWh) throughout the year was accomplished without any serious problems arising in the major facilities, and the guaranteed operation was successfully completed, exhibiting high reliability.

3. Domo de San Pedro Geothermal Power Plant

3.1 Project Outline

This power plant is located in Domo de San Pedro, Nayarit state in the mid-west region of Mexico (**Figure 6**). In 2014, our company received the order of this project for a geothermal power generation facility with 25,500 kW net output, under a full turnkey contract, from GEODESA (Geotermica para el Desarrollo S.A.P.I. de C.V.), a Mexican power generation company, and delivery was completed in 2016. This was the 13th geothermal power generation facility we provided in Mexico.

Figure 6 Overview of Domo de San Pedro

To this point, we had received orders for a total of 12 geothermal power plants from CFE, 6 plants for each of the two geothermal power fields including Los Azufres, and this geothermal power plant follows these orders. Our company commands an approximately 40% share in terms of the capacity of thermal and geothermal power generation facilities in Mexico, which is one of our most important markets.

3.2 Project Features

A single casing upward exhaust turbine, the same as we delivered to Cerro Prieto IV in Mexico, was adopted for this 25,500-kW geothermal power plant. Thus, both the enhancement of reliability and the shortening of the design and installation period were achieved.

This was a project for Mexico's first geothermal power plant operated by a private company, and high proposal capabilities of the supplier were required. Based on our abundant experience as not only a geothermal turbine manufacturer, but also an EPC contractor, we could successfully deliver this plant.

3.3 Plant Optimization

For the turbine type, the turbine that we delivered for Cerro Prieto IV in Mexico was used as the model plant. However, the condenser, ejector, inter-condenser and after-condenser were integrated so that the narrow site could be effectively used (**Table 2**).

Table 2 Specifications of Domo De San Pedro Turbine

Delivery	2016
Type	SC1F: Single Casing Single (Upward) Flow
Rated output	25,500 kW at net output
Rated speed	3,600 rpm
Main steam pressure	8.0 bara
Main steam temperature	170.4°C
Exhaust pressure	0.136 bara

4. Conclusion

Our company applied the world’s longest final-stage blades to a 3,600-rpm geothermal turbine at the Los Azufres geothermal power plant. In spite of the turbine’s compact size, these blades significantly improved the turbine efficiency, achieving the high availability of 99.6% during the one-year period for which a certain operation rate was guaranteed.

The subsequent construction of the Domo de San Pedro geothermal power plant was also successfully completed. As the exclusive EPC contractor, we successfully completed a total of two geothermal power plants in Mexico in 2015 and 2016.