Power Plant Technologies for Thermal and Geothermal Power Plants

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ABSTRACT

In construction of thermal and geothermal power plants, many kinds of elemental technologies are concerned. This paper describes about main technologies in plants completed in recent years. The Yoshinoura Thermal Power Station is Okinawa Electric Power Company's first LNG-fueled single-shaft type combined-cycle thermal power plant, and has the largest capacity generator in Okinawa Island. Governor-free control system is adopted both for gas turbine and steam turbine to enhance response to variation of frequency. The Ulubelu Geothermal Power Station is the first geothermal power plant developed under the Second phase of Indonesian government's electricity crash program, and has received attention as a model case. Hybrid gas-extractor facilities and overall optimization in arrangement of major equipment have been achieved.

1. Introduction

The Yoshinoura Thermal Power Station (Unit No. 1) of the Okinawa Electric Power Company, Incorporated and the Ulubelu Geothermal Power Station both started operation in 2012. In both cases, since the power generating facilities supplied by Fuji Electric would become the main facility in each regional power system, each project was carried out under the watchful eye of the stakeholders and customers.

The Unit No. 1 of the Yoshinoura Thermal Power Station is the largest capacity gas turbine combined cycle (GTCC) generator built by Fuji Electric as a turnkey (EPC) project, and is also the largest capacity generator on the main island of Okinawa. The Ulubelu Geothermal Power Station has been built at a highland on the Indonesian island of Sumatra, where the power grid infrastructure is fragile, and is also the largest capacity geothermal power plant on that island.

The plant technology used in large-scale thermal and geothermal projects is described below using these power plants as examples.

2. Yoshinoura Thermal Power Station of the Okinawa Electric Power Company, Incorporated

2.1 Plant overview

Fuji Electric and Siemens AG delivered a single-shaft type combined-cycle power plant to the Yoshinoura Thermal Power Station of the Okinawa Electric Power Company, Incorporated. Figure 1 shows a panoramic view of the Yoshinoura Thermal Power Station. As a measure to curb global warming, this power plant is a liquefied natural gas (LNG) combined cycle thermal power plant that is more efficient than and has approximately one-half the CO_2 emissions as a coal-fired power plant. The Unit No. 1 and the Unit No. 2 both have output power of 251 MW, which is the largest capacity on the Okinawa Main Island, and they provide approximately 20% of the power for the local prefecture.

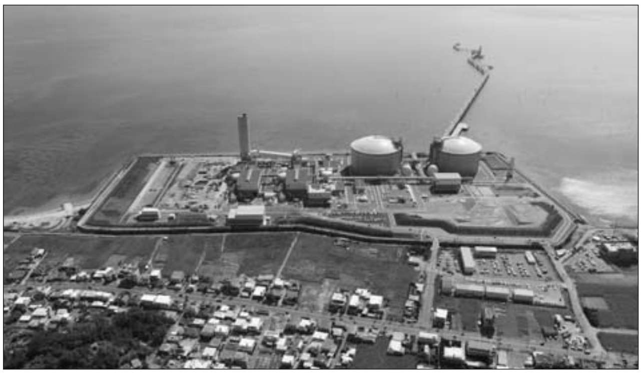

Fig.1 Panoramic view of the Yoshinoura Thermal Power Station

Using a 1,400 °C class SGT6-4000F type (F class) gas turbine, made by Siemens AG a single-shaft type combined cycle generation system configured from a gas turbine, generator, clutch and steam turbine was used. The generator employs a static frequency converter in the startup electric motor, and at startup, the clutch is operated to disengage the steam turbine and realize lower startup loss. The Unit No. 1 started commercial operation in November 2012, and the Unit No. 2 in May 2013.

2.2 Plant technology relating to layout design and construction

For the Unit No. 1, the installation of an exhaust

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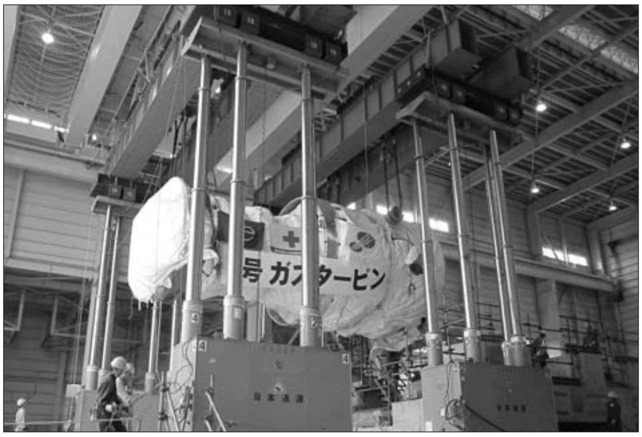

Fig.2 Installation of a gas turbine on a foundation.

heat recovery boiler began in March 2011, and the installation of a gas turbine, generator and steam turbine began in May 2011. These large pieces of equipment were loaded into the power plant from a newly constructed loading wharf, carried onto the site via a low-floor trailer, and then were installed on the foundation inside the turbine building with a power jack.

In the past, a main turbine consisting of a No. 1 gas turbine, generator and steam turbine would be located on the 3rd floor of the turbine building, and therefore the building was required to have a height of at least 25 m. At the Yoshinoura power plant, however, the building was planned in consideration of its economic efficiency and the shaft center of the main generator is positioned at +5.5 m above FL (1st floor height) so that the turbine building can have a height of approximately 20 m, which is lower than in the past. Inside the building, machinery, piping and electrical equipment are compactly arranged both vertically and horizontally, and although it was expected that the installation work would become crowded, the processes and work tasks were coordinated, and installation of the Unit No. 1 was completed without accident. Figure 2 shows the installation of the gas turbine on the foundation.

In transporting the equipment, it was assumed that typhoons, which are an Okinawa region-specific weather condition, would occur frequently. In consideration that shipping vessel delivery schedules would be cancelled, so that processes would not be delayed due to the suspension of outdoors work or while waiting for the repair of damages due to strong winds, we anticipated the expected path of typhoons on a daily basis, and substituted work processes and processed remaining loads. As a result, the effect on the installation process was minimized, and testing could begin in May 2012.

2.3 Control technology and plant technology

In May 2012, as the initial event in the trial operation of the Unit No. 1, the first firing of the gas turbine was carried out. Subsequently, the gas turbine was operated under no-load conditions and combustion tuning was carried out, the exhaust heat recovery boiler was cleaned with hot water and blow-out of the steam piping was carried out. In June 2012, the Unit No. 1, was put into parallel operation*1 (i.e., connected to the power grid) for the first time at 6 MV, and comprehensive trial operation of the plant was initiated. In the comprehensive trial operation that spanned a six-month period, confirmation of the static characteristics of each device prior to the load rejection test, and confirmation of the dynamic characteristics of each device after the load rejection test were advanced steadily with the cooperation of the Okinawa Electric Power Company, Incorporated.

The power grid on the Okinawa Main Island is independent of the power grids of the other power companies. When this power generating facility, which has capacity equivalent to 20% of the power grid, is connected to the power grid, there was concern over the possibility of a significant adverse effect on power availability on the Okinawa Main Island should a problem occur during testing. For this reason, the 100% load rejection testing was carried out under particularly tense circumstances (see Fig. 3).

In order to limit the effect of fluctuations in the amount of power supplied during trial operation, i.e., to maintain the balance between supply and demand in the power grid, the Okinawa Electric Power Company, Incorporated has made elaborate plans for a supply system that is coordinated with other power plants that are connected to the power grid. At the power plant, after the load rejection, the steam turbine was disengaged via the clutch (a disengageable connecting device positioned between the turbine and the generator) and stopped, and testing proceeded to the gas turbine no-load independent operation.

Because this power generating facility has a capacity equivalent to 20% of the power grid, it also plays

Fig.3 Central control room during load rejection tests

*1: Parallel operation: The connection of a generator to a power transmission system and the start of transmitting power.

an important role in maintaining the frequency of the power grid. It is important to provide the power generating facility with a load change function capable of responding rapidly to short-duration changes in the electric power demand to stabilize grid frequency. This power generating facility is also provided with an operating function that can incorporate economic dispatching control (EDC), automatic frequency control (AFC) and governor free (GF)*2 control over the normal range of operation, from minimum load to maximum load. As characteristic functions, in addition to governor free control provided for the gas turbine, governor free control is also provided for the steam turbine to utilize effectively the heat stored in a high-pressure steam drum. As a result, the slight delay of the gas turbine output control due to the fuel control system is supported by the function of the steam turbine, and by adjusting the response performance and the load response width in the responsivity test, the requirements were satisfied.

In plant performance tests conducted in October, it was confirmed that the efficiency of at least 51% (HHV basis), which is the highest level for a 1,400 °C gas turbine (F class) installed in Japan, is possible. As a result of the combination of a two-stage combustor and a denitration apparatus that are used to realize low NO_X emissions in the normal operating load range, NO_X emissions well below 5 ppm (corresponding to 16% oxygen) were confirmed.

A heat run test, which is the last voluntary test before use, was performed from November 26th to 27th in 2012, and successful commercial was started on November 27th.

2.4 Future developments

In this project, for the first time in Japan, a large, industrial-use gas turbine made by Siemens AG was used for the combined-cycle power generation facility. Siemens AG has a track record of delivering gas turbines throughout the world, and Siemens AG's gas turbines have maintained a share of 40% or more of this market. In addition to their F-class gas turbines which have a successful track record of many deliveries, orders for their H-class gas turbines (SGT-8000H) are also brisk.

Fuji Electric intends to build upon its successful record of delivering the Yoshinoura Thermal Power Station and will continue to focus on delivering combined-cycle thermal power plants in Japan.

3. Ulubelu Geothermal Power Station

3.1 Overview of Ulubelu Geothermal Power Station project

For this project, Sumitomo Corporation (hereinafter, Sumitomo) was the main contractor, and in February 2010, orders for 2×55 MW geothermal power block (Portion A), a substation block (Portion B) and a transmission line (Portion C) were received in an EPC contract from PT.PLN (hereinafter, PLN), a state-owned power company in Indonesia. Fuji Electric and a local engineering company, PT. Rekayasa Industri (hereinafter Rekayasa), received sub-contracts from Sumitomo. The main services provided by Fuji Electric, as a technical leader, were in the design, production, procurement and commissioning of main equipment that includes the steam turbine. Rekayasa was responsible for the design, procurement of balance of plant (BOP), construction and installation.

The Indonesian government is promoting a second-phase electricity crush program to solve their domestic power shortage. From 2010 through 2014, approximately 9,500 MW of power will be developed, and of that amount, approximately 4,000 MW will be geothermal power. The Ulubelu Geothermal Power Station is the first geothermal power plant developed under this program and therefore attracted attention as a model plant.

The plant site is located approximately 100 km west of the provincial city of Bandar Lampung in South Sumatra at an elevation of 780 m above sea level, and requires about 3 hours to be reached by car (see Fig. 4).

The time to completion of the project after the contract until delivery was 28 months for the Unit No. 1 and 32 months for the Unit No. 2.

The Ulubelu Geothermal Power Station applies single-flash power generation. The water dominant geothermal resource is separated into steam and brine (hot water) by a separator installed at the production well pad. Steam is sent to the power plant and the brine (hot water) is returned to a reinjection well. The steam is controlled to a constant pressure by a venting system provided in the vicinity of the tie-in point to the power plant, and a demister installed at the power plant performs the final moisture removal, and then the steam is fed to the steam turbine to generate power. Figure 5 shows the main power system of the power plant.

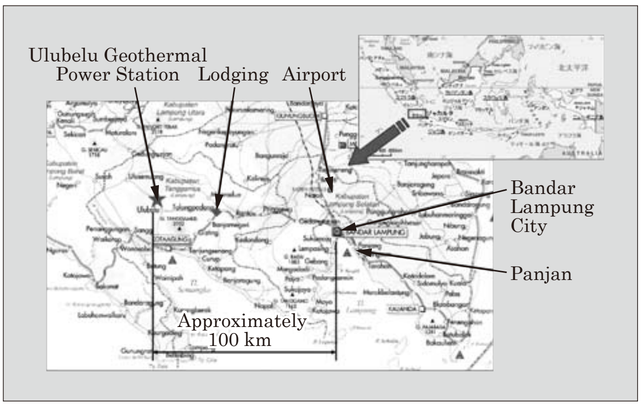

Fig.4 Construction site of the Ulubelu Geothermal Power Station

*2: GF (governor free) control: Function for varying the load according to system frequency fluctuations

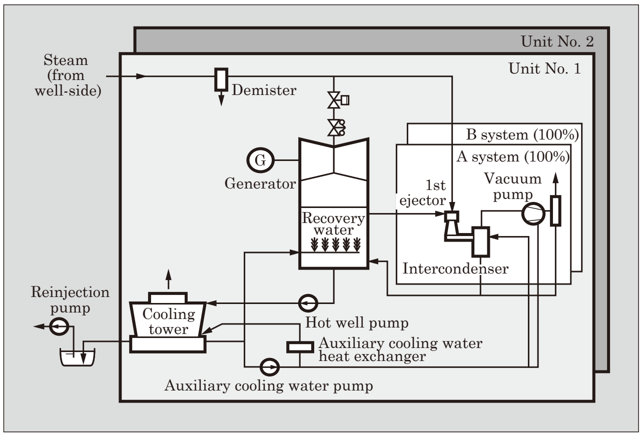

Fig.5 Ulubelu Geothermal Power Station main power system

The main equipment of the power plant – the steam turbine, the generator and the steam condenser – are made by Fuji Electric. The cooling tower, non-condensable gas extraction system, hot well pump, piping, valves and the like were procured from Japan as well as third countries, while the electrical equipment, FRP pipes, cables and the like were procured from Indonesia.

The geothermal resource supply and reinjection systems were managed separately by PT. Pertamina Geothermal Energy (hereinafter PGE); a steam purchase agreement was entered into with PLN, and tie-ins to the steam and reinjected water are in the vicinity of the power plant site.

3.2 Plant technology employed at the time of design and construction

For the steam turbine, Fuji Electric's "GK Series" steam turbine for geothermal applications was used (see Fig. 6). This is a single cylinder, double flow, reaction type condensing turbine. A 21.8-inch blade size, which has a proven record of success in geothermal power generation applications, was selected as the size of the final stage low-pressure blades. At the turbine inlet steam conditions of 0.76 MPa and 168 °C, the rated output is 55 MW (max. output is 57.75 MW)

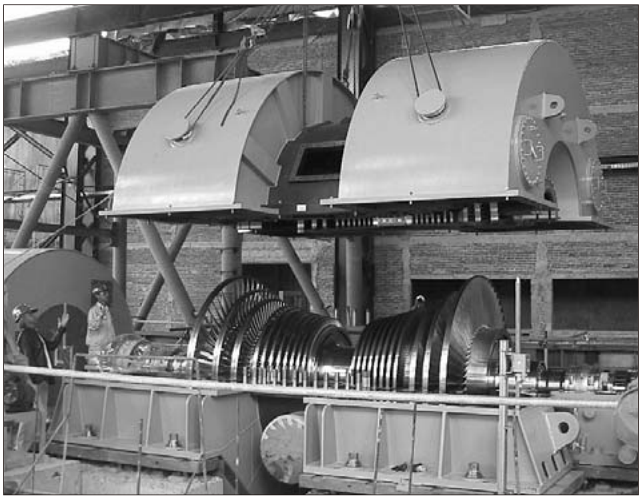

Fig.6 Steam turbine in installation process

The generator has a rated capacity of 68.75 MVA, and because it is used in a geothermal (corrosive) environment, is provided with a 2-pole fully enclosed air-cooling system that implements proven geothermal countermeasures such as a hydrogen sulfide gas removal filter system and the like.

The condenser and cooling system consists of a condenser, hot well pump, cooling tower and circulation water piping. In consideration of the optimum operating point for the equipment capacity of the system as a whole, we set a design vacuum rating of 0.01 MPa as the optimum point and designed the various systems. The condenser used has a proven record for geothermal power generation and is a highly-efficient direct contact condenser.

The gas extraction system that extracts large quantities of noncondensable gas, which is a major feature of geothermal power generation, is a hybrid system that uses a steam ejector and a vacuum pump. An optimum combination of ejector and vacuum pump capacities was designed to realize a highly efficient system configuration.

Focusing on the main devices described above, we comprehensively optimized the layout. At the same time, we optimized the size and routing of large diameter pipes such as the main steam pipe and the circulating water pipe. As a result, plant efficiency was improved due to the decrease in pipe pressure loss, and the quantity of piping could be reduced.

Additionally, since the construction of Unit No. 1 and No. 2 would be carried out simultaneously for a while, we coordinated with Rekayasa in advance concerning the construction procedures for common parts and for mutually interfering parts, and set deadlines for material delivery that also considered partial deliveries so that necessary equipment and materials could be delivered to the site in a timely manner. For particularly important items, delivery date management that included checking the delivery progress was carried out thoroughly.

During the construction period, there was a relatively large amount of rainfall even during the dry season (April to September), and heavy construction machinery will be inoperable due to heavy muddy land condition when it rains. Thus the construction progress was affected considerably by the weather.

Moreover, because the construction work was performed in the mountains on the island of Sumatra, it was difficult to secure workers or to add additional workers, and so the construction proceeded with limited manpower. Fuji Electric also dispatched advisors to the site, and these advisors proposed efficient work processes and endeavored to implement process control.

In the future, it is expected that geothermal power plants will increasingly be constructed at locations having even poorer access. Careful consideration of not only the accessibility, but also the ability to secure manpower will be necessary.

3.3 Plant technology during testing

In Southern Sumatra, the largest power plant is the Taharan Thermal Power Plant (2×100 MW) to which Fuji Electric has delivered steam turbine generator equipment, and because the power grid infrastructure is fragile, even after receiving power, the commissioning was often affected by power grid trouble from outside the power plant.

After the Unit No. 1 was put into parallel operation for the first time, whenever power grid system trouble occurred, the power plant would be disconnected from the power grid so that it could continue to operate stably as island operation. At such a time, together with the geothermal supply system being operated by PGE, communication is established by exchanging necessary signals such as the signal to transition to independent operation within the plant, and the ability to implement a coordinated following operation, even in the case of abrupt load changes, was confirmed. In October 2012, the plant was handed over one week before the contractual taking over date. The commercial operation of the Ulubelu Geothermal Power Station has made a significant contribution to the stable power supply of Southern Sumatra (see Fig. 7).

Fig.7 Panoramic view of Ulubelu Geothermal Power Station

4. Postscript

This paper has discussed plant technology for thermal and geothermal power plants. Gas turbine combined cycle power generation and thermal power generation are environmentally-friendly power generation methods that have low CO_2 emissions, and technological improvements and improvement activities will be carried out worldwide in the future.

In the field of gas turbine combined cycle power generation, Fuji Electric will play the role of introducing the latest technology in the world to the domestic Japanese market, and in the field of geothermal power generation, we intend to share the latest optimization technology world-wide.

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