Yamagawa Binary Power Station
Geothermal ORC plant in Japan

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Keywords

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ABSTRACT

Geothermal energy is recognized as one of the important renewable energy sources in Japan, however the current generating capacity is only about 0.2% of total electricity generation. After the Great East Japan Earthquake followed by the Fukushima nuclear power plant accident, Japan's government accelerated various deregulations and incentives to promote usage of renewable energy. Although there still are some difficulties to expand the geothermal energy development in Japan, large capacity geothermal resource developments are still ongoing, and recent developments are mainly small capacity such as 100kW class "Onsen (hot-spa)" power generation or 2,000-5,000 kW medium size power plants.

Under this circumstances, Fuji Electric Co., Ltd. (Fuji Electric) constructed two ORC power plants as the EPC contractor in 2017 and 2018. One is Takigami binary power plant (5050kW) which Idemitsu Oita Geothermal Co., Ltd. started commercial operation at Oita Japan in March 2017. Takigami power plant has a water cooling system and uses R245fa as the working fluid. (Asada & Yamada, 2017).

The other is Yamagawa binary power station (4990kW) which Kyuden Mirai Energy Co., Inc. started commercial operation at Kagoshima in February 2018. Yamagawa power station generates electricity using reinjection brine of the existing flash system geothermal power plant same as Takigami power plant. On the other hand, unlike Takigami power plant, Yamagawa power station has an air cooling system and uses n-pentane for the working fluid.

This paper introduces the overview of Yamagawa binary power station and its construction works.

1. Introduction

It is said that Japan has the world's third largest potential of geothermal resources. METI, Ministry of Economy, Trade and Industry, has been studying what issues need to be solved to promote more geothermal energy development and the result of the study was reported in 2009. Based on the report, METI started to promote incentives and deregulations. Such promotions were accelerated after the Great East Japan Earthquake in 2011 followed by the Fukushima nuclear power plant accident, and various incentives and deregulations were issued including a feed-in tariff (FIT). The tariff under Japan's FIT for a newly constructed geothermal energy is 26 yen/kWh for 15,000kW and larger capacity and 40 yen/kWh for less than 15,000kW. However the installed capacity of the geothermal power plants is just 530MW as of early 2017 and its generation is only about 0.2% of total electricity generation. Most of large capacity geothermal developments are still under exploration or construction stage, on the other hand, small and medium capacity geothermal power plants have been constructed already, utilizing the existing hot-spa hot water or newly drilled production wells. Especially, 37 units of small capacity ORC power generating system were installed from 2011 to 2017, ranging from 20kW to 440kW. Table 1 is the list of geothermal power plants constructed after the Great East Japan Earthquake until March 2017.

Table 1: Geothermal power plants constructed in Japan in 2011-2017

Location	Type	Capacity kW	Completion	Location	Type	Capacity kW	Completion
Oita	ORC	1x72	2013.01	Oita	ORC	1x125	2015.07
Oita	ORC	2x72	2014.01	Oita	ORC	3x20	2015.08
Oita	ORC	2x72	2014.01	Nagasaki	ORC	3x72	2015.09
Nagano	ORC	1x20	2014.04	Oita	ORC	1x20	2015.12
Hyogo	ORC	2x20	2014.04	Oita	ORC	1x125	2016.01
Oita	ORC	1x72	2014.07	Tochigi	ORC	1x20	2016.03
Kumamoto	ORC	3x20	2014.07	Oita	ORC	1x65	2016.04
Oita	ORC	4x125	2014.11	Oita	ORC	1x125	2016.07
Tottori	ORC	1x20	2015.01	Oita	ORC	1x125	2016.07
Oita	--	1x11	2015.02	Oita	ORC	1x72	2016.09
Kagoshima	ORC	1x1,580	2015.02	Hokkaido	ORC	1x125	2016.11
Oita	ORC	1x5,000	2015.06	Fukushima	ORC	1x440	2016.11
Oita	ORC	2x125	2015.06	Hokkaido	ORC	1x72	2017.03
Kumamoto	Flash	1x2,000	2015.06	Oita	ORC	1x5050	2017.03

2. FEATURES OF YAMAGAWA BINARY POWER STATION

The Yamagawa Binary Power Station is located at the Yamagawa Power Station which is the geothermal power plant operated by Kyushu Electric Power Co., Inc. in Ibusuki-City, Kagoshima of Kyushu area, and is operated by Kyuden Mirai Energy Company, Inc. (Kyuden Mirai). Figure 1 shows the location of Yamagawa Binary Power Station. The brine from the separator had been directly returned to the reinjection wells at the Yamagawa power station. The brine is more than 600 t/h (1.32 x 10^6 lb/h) at about 180 ^oC (356 ^oF). This power station

effectively utilizes the heat of this brine and generates power, without the need for new production wells. Kyuden Mirai and Fuji Electric signed an EPC Contract in June 2016. Construction was completed and commercial operation commenced on February, 2018. The rated and permitted maximum generator output is 4,990kW.

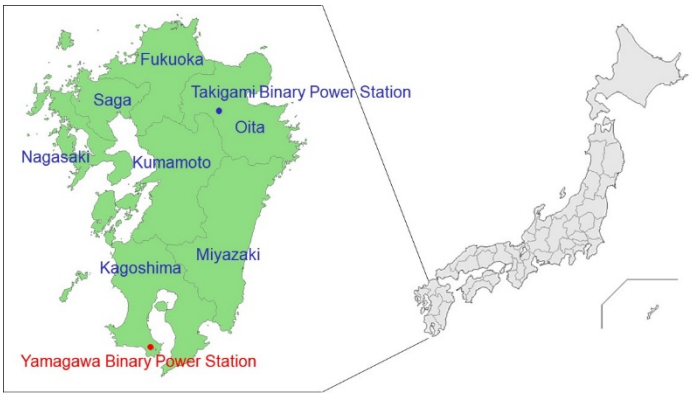

Figure 1: The location of Yamagawa Binary Power Station

2.1 Overview of Power Plant

Figure 2: Overview of the Yamagawa Binary Power Station

Figure 2 shows an overview of the Yamagawa Binary Power Station. Figure 3 shows a system flow. The brine branched from the reinjection line is changed to two phase fluid by the separator inlet valve and goes to the separator. The two phase fluid is separated brine and steam. After that the brine goes to the preheater and the steam goes to the evaporator. Normal pentane (n-pentane) is used as the working fluid. Because n-pentane is a flammable fluid, a fire-fighting system was supplied and a fire-fighting area was laid out around the binary system. n-pentane is pressurized by the pentane pumps and goes to the recuperator, the preheater and the evaporator. The n-pentane is heated by the preheater and vaporized by the evaporator. The vaporized n-pentane rotates the turbine. The type of condenser is air cooled condenser because cooling water is not available.

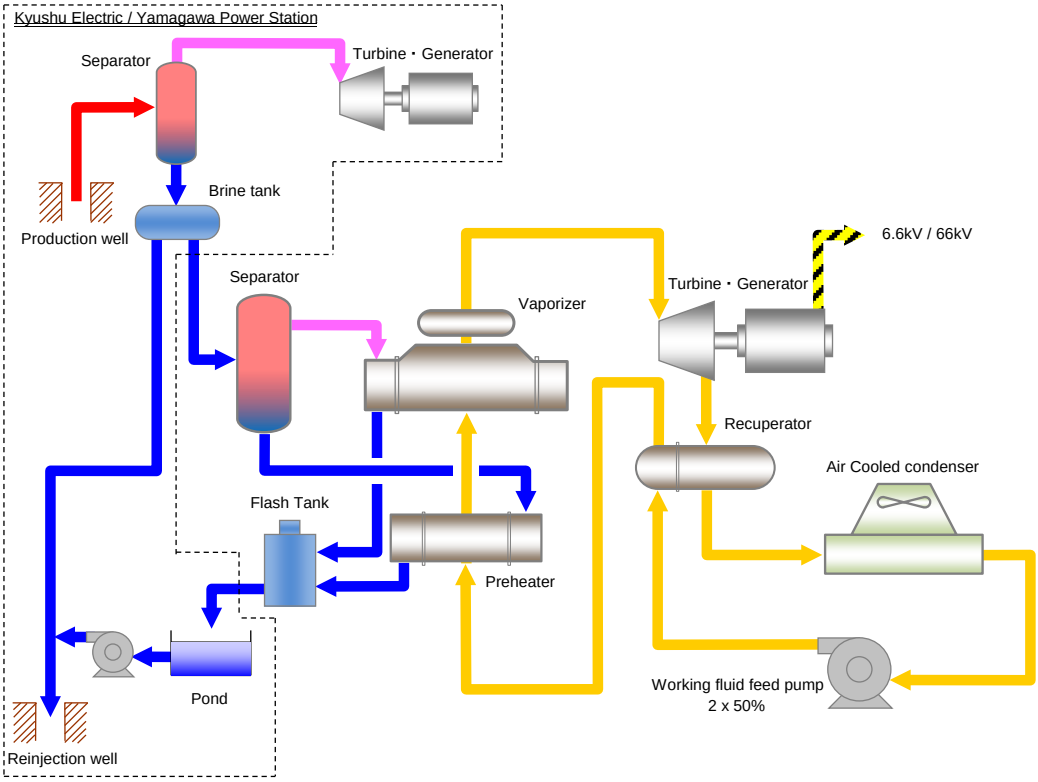

Figure 3: System flow of the Yamagawa Binary Power Station

2.2 Features of each equipment

(1) Turbine & Generator

The turbine and generator were designed and manufactured by Fuji Electric. The turbine uses reaction blades and basically a similar design to Fuji Electric's geothermal steam turbines. The main difference is the shaft seal type; Fuji Electric's ORC turbine uses double mechanical seals, while the geothermal steam turbines use a steam seal. The turbine rotation speed is 1,800 min^{-1}

which is half of Fuji Electric's standard geothermal steam turbines. Table 2 shows the specifications of the ORC turbine and Figure 4 shows the ORC turbine and generator.

Table 2: Specification of Yamagawa ORC turbine

Rated inlet vapor pressure	820 kPaG (119 psiG)
Rated inlet vapor temperature	122 ^{o}C (252 ^{o}F)
Rated generator output	4,990 kW
Maximum generator output	4,990 kW
Rotating speed	1,800 min^{-1}

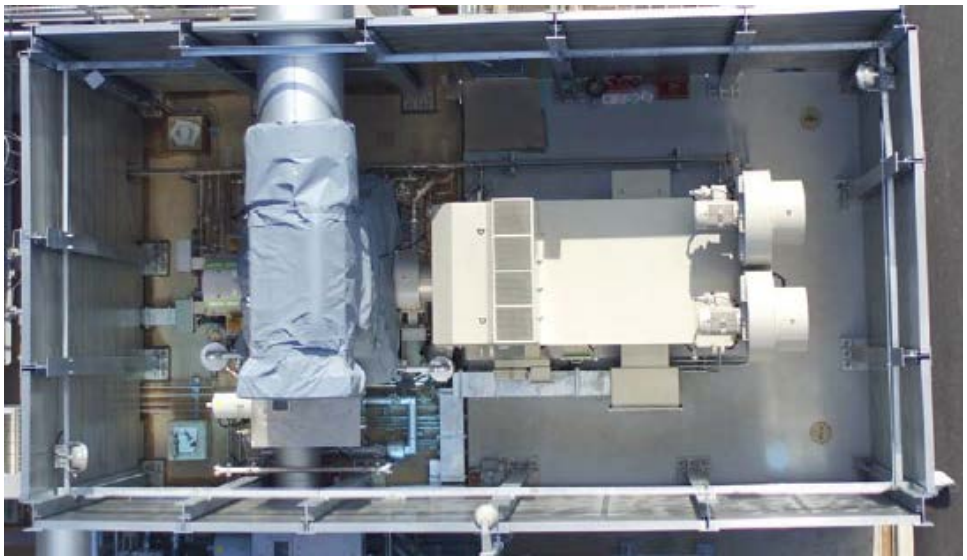

Figure 4: Top view of ORC turbine and Generator

(2) Heat exchangers

The heating system consists of one preheater and one evaporator. The material of tubes for all of these heat exchangers is super duplex stainless steel, considering composition in brine which has high chloride ion. The cooling system consists of one recuperator and air cooled condenser. The fan blades and motors are low noise type considering surrounding environment. The condensed n-pentane is extracted by the pentane pumps and pumped to the preheater. Figure 5 shows the heat exchangers.

Figure 5: Heat Exchangers

2.3 Site construction works and commissioning works

Construction of the electro-mechanical works commenced in May 2017. All components of the equipment are installed outdoors except for the electrical and control system. The Kagoshima area is located in typhoon street. Typhoons came four times to the power station area during the construction period. Measures to prevent scattering and upset were carried out each time. The site-testing works and commissioning commenced in December, 2017. All commissioning works and the performance test were completed in February, 2018 and the commercial operation commenced.

3. CONCLUSIONS

Fuji Electric completed Yamagawa ORC system which has air cooling system and uses n-pentane for working fluid, following Takigami ORC system which has water-cooled system and uses R245fa. Both ORC system, Yamagawa and Takigami, continue to operate stably since start commercial operation.

Fuji Electric will reflect the findings obtained from these plants in the future plant design and will provide total solution for geothermal power generation industry both flash and ORC system.

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