

Hachijo-jima Geothermal Power Plant

Takashi Murakami

1. Introduction

Hachijo-jima Geothermal Power Plant, the first-ever geothermal power plant to be built on a remote island in Japan, was constructed in the Nakanogo district of Hachijo-jima. Hachijo-jima is an island located approximately 400km south of Tokyo, with a circumference of 58.9km and area of 65.9km². The island is gourd-shaped, and has two volcanic mountains, Miharayama (or Eastern Mountain, located in the south eastern part of the island) and Hachijo Fuji (or Western Mountain, located in the northwestern part).

In 1989, New Energy and Industrial Technology Development Organization (NEDO) selected the island as a site to survey for the promotion of geothermal development. A drilling survey confirmed the existence of promising geothermal resources in the southern part of the Eastern Mountain.

In 1992, The Tokyo Electric Power Co., Inc. started geothermal development on the site and performed production well drilling, blow-off tests, an environmental survey, and the basic planning and design for a power generation plant. After having completed various pre-construction procedures, The Tokyo Electric Power Co., Inc. started construction of the Hachijo-jima Geothermal Power Plant in June 1998. After trial runs, the plant began commercial operation on March 26, 1999 and continues its operation today.

This paper presents an overview of the Hachijo-jima Geothermal Power Plant.

2. Overview of the Project

Before the geothermal power plant was constructed, electric power was supplied only from diesel generator units, and demand for electricity was approximately 10,000kW at the maximum and 3,000kW at night.

This geothermal power plant has the capacity to supply 1/3 of the total electricity demand in the island. The plant was projected to serve as a stable power supply, and to reduce fuel cost and hence the cost of power generation compared to the existing diesel

Fig.1 Overview of Hachijo-jima Geothermal Power Plant



generator units.

In July 1998, Fuji Electric was awarded an order to supply a turnkey system for the project. Fuji Electric manufactured, procured, installed and commissioned all of the equipment and system, such as a turbine and generator rated at 3,300kW, a steam gathering system, a steam scrubbing system, and an H₂S abatement system.

Since only a short, 3-month installation period was scheduled, components of the plant were designed to be skid-mount type or package-mounted to the extent possible.

Since the steam contains high content of H₂S gas and H₂S gas emission is limited by local regulation, an H₂S gas abatement system was installed.

This plant also provides the hot water supplying system to neighbor facilities through plate-fin heat exchangers utilizing the hot water from the condenser.

Figure 1 shows an overview of Hachijo-jima Geothermal Power Plant.

3. Power Plant

3.1 Basic planning

The plant was planned with consideration for environmental preservation, cost effectiveness, reliability, maintainability, and in accordance with Tokyo metropolitan government regulations.

3.2 Heat cycle

Production wells are steam-dominated and are provided with a single flash cycle system because of the extremely low hot water content in the steam.

3.3 System configuration

Figure 2 shows the main piping diagram. Two-phase flows from the production wells, HT-1 and HT-2, are combined along their way to a steam separator. After being separated from hot water in the steam separator, the steam enters the turbine via the steam scrubbing system, expands in the turbine and then turns into condensate in the condenser. Hot water returns underground via a re-injection pump pit, re-injection pumps and a re-injection well.

With the exception of the two re-injection pump units, the two steam ejector units and some auxiliary machines, the plant is not provided with standby equipment.

3.4 Plant layout

Figure 3 shows the overall plant layout. There are

mountains to the north and east of the power plant, and private houses to the south and west. The plans called for machines and equipment to be installed in the eastern part of the plant.

4. Overview of Facilities and their Features

4.1 Steam gathering system

Geothermal fluid is fed as a two-phase flow to the steam separator. There, the fluid is separated into steam and hot water by centrifugal force. Lengths of the two-phase flow piping and steam piping are very short, approximately 30m from the master valve of the production well to the steam separator and approximately 70m from the steam separator to the steam turbine via the steam scrubbing system. Diameters of the pipes are designed to be larger than usual in order to reduce velocity to protect the sand erosion which will be caused by solid impurities and tiny rock.

Figure 4 shows an exterior view of the steam separator. Its specifications are as follows:

(1) Steam separator

Type: vertical cyclone, top-outlet type

Fig.2 Main piping diagram

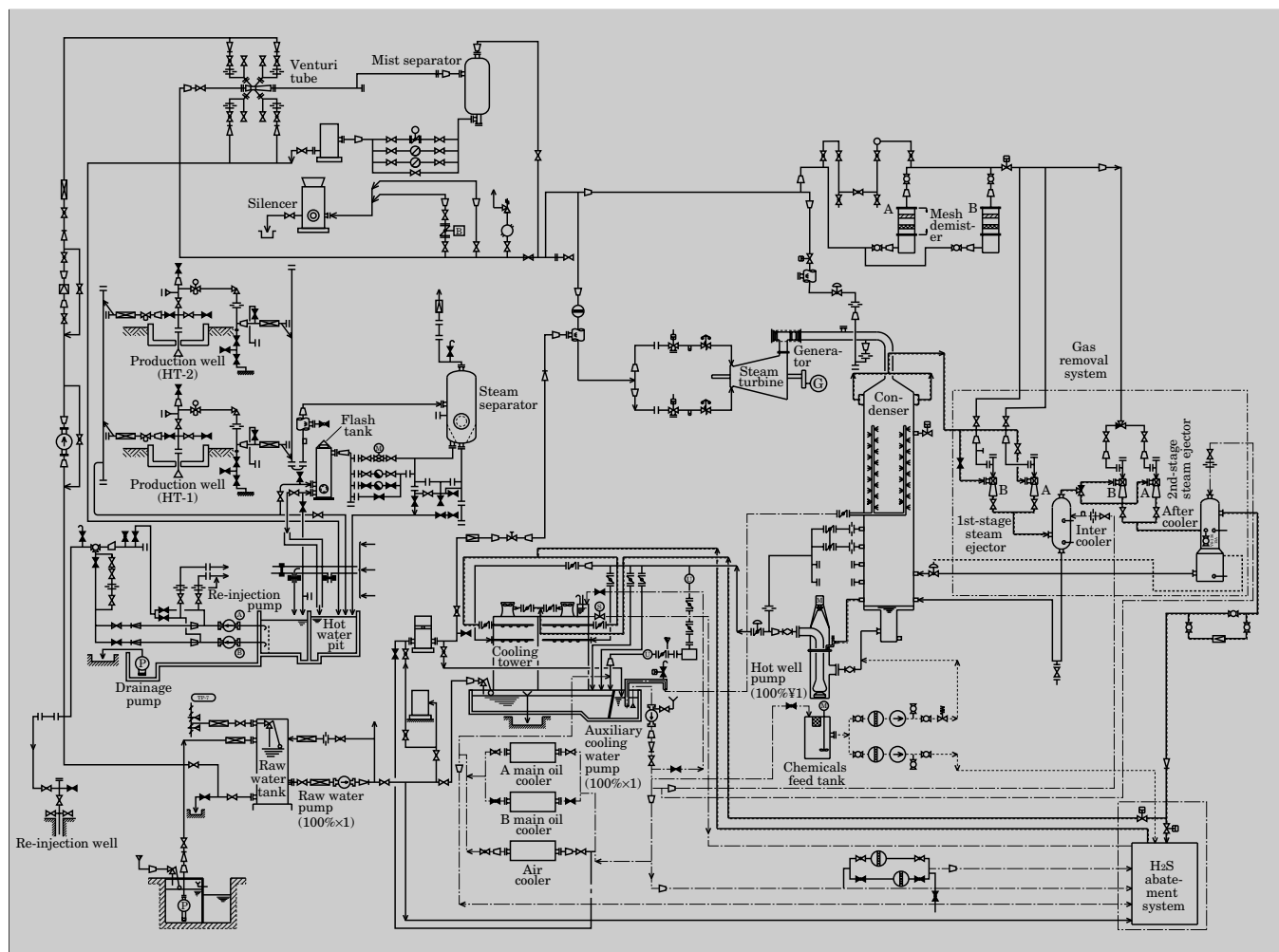


Fig.3 Overall plant layout

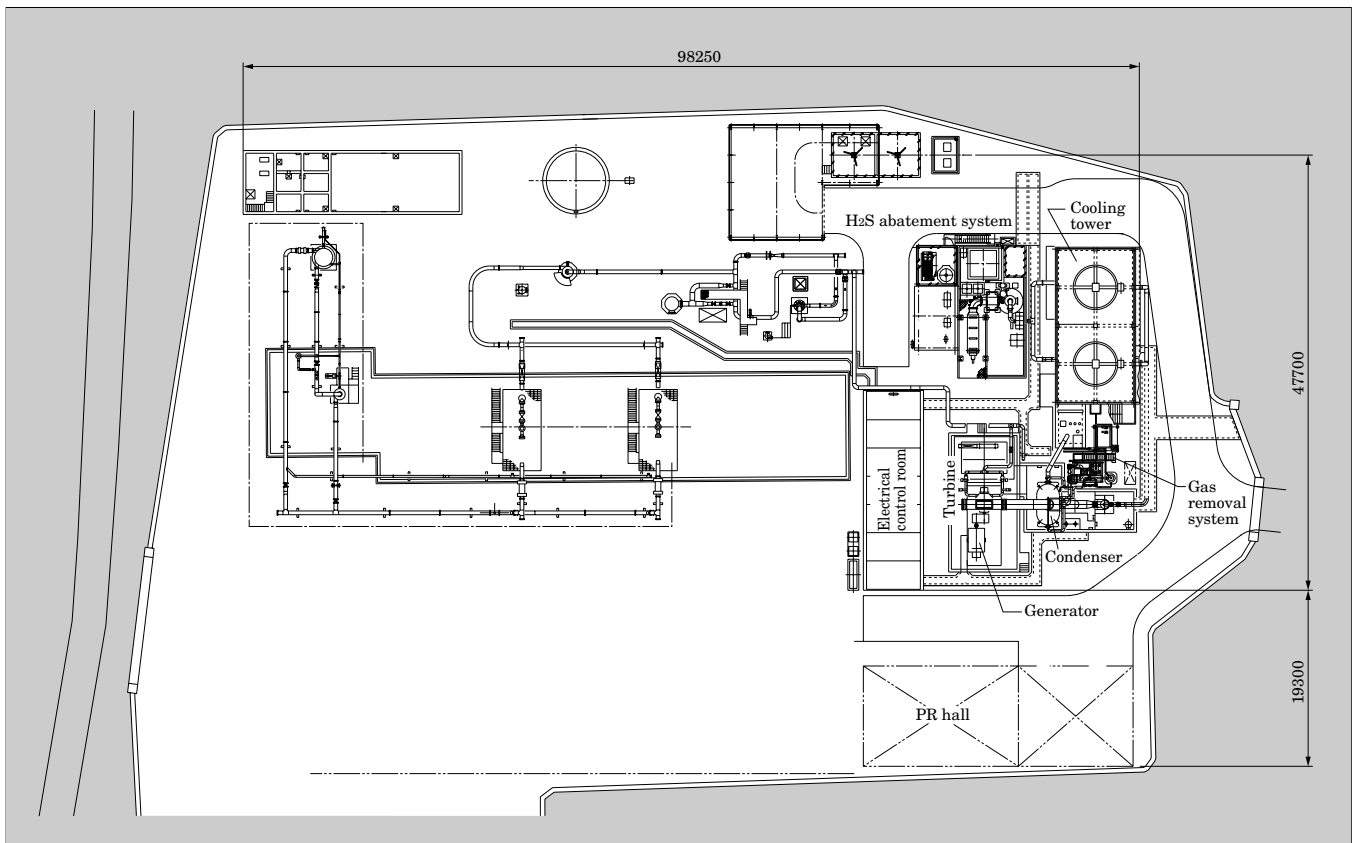


Fig.4 Exterior view of the separator



Number of units : 1
 Separated steam : 40t/h
 Separated hot water : 4t/h
 Design pressure : 1.07MPa
 Design temperature : 200°C
 Separation efficiency: 99.9%

4.2 Steam scrubbing system

Steam from the steam separator contains a fine mist of sprayed-off hot water. The power plant is provided with a steam scrubbing system to trap the mist and to improve steam quality.

The system consists of a venturi tube, which injects water into the main steam and mixes and collides the injected water drops with mist, and a mist separator, which separates such mist from steam and drainage after water injection.

Figures 5 and 6 show an exterior view of the venturi tube and mist separator. Their specifications are as follows:

- (1) Venturi tube
 - Steam : 40t/h
 - Number of nozzles: 4 × 50A (A: nominal diameter)
 - Injection water : 3.7t/h
- (2) Mist separator
 - Type: vertical cyclone, top-outlet type
 - Number of units : 1
 - Separated steam : 40t/h
 - Separated hot water: 4t/h
 - Design pressure : 1.07MPa
 - Design temperature : 200°C

4.3 Turbine and auxiliary equipment

A high-speed turbine is adopted based on the results of an assessment to optimize steam conditions,

Fig.5 Exterior view of the venturi tube



Fig.6 Exterior view of the mist separator



plant efficiency and cost of the turbine and its related equipment.

Upward exhaust and skid-mount construction are employed in consideration of the short installation period. In the skid-mount construction, a reduction gear assembly and a generator are mounted on a common bed.

The turbine and generator were installed with an outdoor cover.

A drum-type rotor, reaction-type blading, high pressure blades with an integral shroud and free-standing low pressure blades, all standard features of Fuji Electric's geothermal turbines are utilized. In addition, the turbine includes a skid-mount type oil console with a main oil tank, an oil pump and lubricating oil filters mounted on the skid.

Figure 7 shows a cross-sectional view of the

Fig.7 Cross-sectional view of the turbine

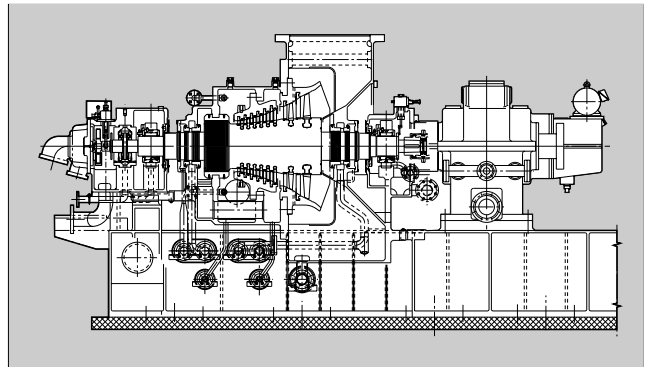


Fig.8 Exterior view of the condenser



turbine. Its main specifications are as follows.

Type: single cylinder, single flow, top exhaust
condensing, high-speed turbine

Output: 3,300kW

Steam conditions

Pressure: 0.79MPa

Temperature: 170°C

Exhaust pressure : 143kPa

Gas content in steam: 2.7% (wt%)

Revolution speed : 7,266 r/min

Number of stages : 8

4.4 Condenser and gas removal system

A spray-jet, direct-contact-type condenser is employed. Fuji Electric has supplied many condensers of this type, which have reliable operational experiences.

To resist corrosion by the geothermal fluid, stainless-clad steel is used for the shell and stainless steel is used for all internal components.

Figure 8 shows an exterior view of the condenser. Specifications of the condenser and gas removal system are as follows:

(1) Condenser

Type: spray jet, direct-contact low-level type

Internal pressure: 133kPa (4 in. Hg)

Cooling water : 1,032m³/h

Cooling water temperature: 33.2°C

- (2) Non-condensable gas removal system
 - Type: 2 × 100% 2-stage steam ejector
 - Number of units: 2 (including one standby unit)
 - Capacity : 1,181kg/h
 - Driving steam
 - Pressure : 0.71MPa
 - Flow rate: 3.9 t/h

4.5 H₂S abatement system

The content of H₂S gas in the plant's geothermal steam is very high. To comply with the maximum permissible emission of 10ppm specified by the Tokyo metropolitan government, dilution of the exhaust gas only with exhaust air from the cooling tower would require an extremely large cooling tower and impractical. Thus, an H₂S abatement system was introduced. In introducing the system, a flue gas desulfurization method was selected based on consideration of the particular circumstances for an island, raw material cost and maintainability. In this method, H₂S gas is mixed with LPG, combusted, converted into SO_x and then desulfurized with injected magnesium hydroxide. The H₂S abatement system consists of combustion equipment which combusts the H₂S gas, a desulfurizer which produces harmless magnesium sulfate by sprinkling magnesium hydroxide on the generated SO_x, and a sludge processing unit to remove suspended solid (SS) content from the powdered magnesium hydroxide raw material.

Figure 9 shows an exterior view of the H₂S abatement system. Its main specifications are as follows.

- (1) Combustion equipment
 - (a) Combustion furnace
 - Type: fixed horizontal, cylindrical combustion furnace
 - Number of units : 1
 - Design pressure : 108.7kPa
 - Design temperature: 1,200°C

- (b) Combustion air blower
 - Type: centrifugal type
 - Number of units: 1
 - Capacity : 3,000 Nm³/h × 170.0kPa
 - Motor output : 11kW
 - (c) LPG supply equipment
 - Type: LPG cylinder (50kg)
 - Number of cylinders: 18 (9 × 2 lines)
 - Supply pressure : 116 to 121kPa
 - (2) Desulfurizer
 - (a) Absorber
 - Type: vertical, cylindrical filling type
 - Number of units: 1
 - Dimensions : 800mm × 2,000mm (diameter × height)
 - (b) Oxidation air blower
 - Type: root type
 - Number of units: 1
 - Capacity : 1,140 Nm³/h × 150kPa
 - Motor output : 30kW
 - (3) Sludge processing equipment
 - (a) Filter press
 - Type: hydraulic automatic clamping type
 - Number of units: 1
 - Capacity : 300 liter

4.6 Cooling water system

Cooling water is fed to the condenser by the pressure difference and elevation difference (head) between the cooling tower cold water basin and the condenser.

After being mixed with cooling water, geothermal steam turns into condensate, and is fed to the cooling tower by a hot well pump. After being cooled at the cooling tower it returns to the cooling tower cold water basin and is again fed to the condenser.

To reduce the noise generated by the splashing of water droplets, the body of the cooling tower is made of concrete. In addition, to prevent ventilation noise from disturbing the local community, the cooling tower employs a single suction type ventilation system in which air intake vents are provided only on the east side of the cooling tower at a considerable distance from private houses.

The height of the cooling tower is limited to within 13m by environmental regulation.

Figures 10 and 11 show exterior views of the hot well pump and cooling tower, respectively. Their main specifications are as follows:

- (1) Hot well pump
 - Type: vertical mixed flow type
 - Number of units: 1
 - Capacity : 1,300t/h
 - Total head : 23m
 - Motor output : 110kW
- (2) Cooling tower
 - Type: induced draft, counter flow, single suction type
 - Number of units: 1

Fig.9 Exterior view of the H₂S abatement system



Fig.10 Exterior view of the hot well pump



Fig.11 Exterior view of the cooling tower



Water quantity : 1,262m³/h
 Inlet water temperature : 46.6°C
 Outlet water temperature : 33.2°C
 Design wet-bulb temperature: 21°C
 Fan: 2 × 55kW

5. Electric and Control Systems

5.1 Electric system

Figure 12 shows a single line diagram. Electric power generated in the geothermal power plant is supplied to the transmission line of the diesel power station. Even if a failure should occur on the transmission line, the electric system is designed so that isolated operation can be performed by disconnecting the circuit breaker for transmission and instead using in-house auxiliary power.

To protect the generator, digital duplex protective relays are employed for redundancy.

Figure 13 shows an exterior view of the generator. The electric system's main specifications are as follows:

- (1) Generator
 - Type: horizontal cylindrical, air cooled type
 - Capacity: 3,660kVA
 - Voltage : 6.9kV
 - Power factor : 0.93, leading
 - Revolution speed: 1,500 r/min
 - Frequency : 50Hz
 - Excitation : brushless type
- (2) House transformer
 - Type: molded type
 - Capacity: 600kVA
 - Voltage : R6.9-F6.6-F6.3kV/460V

5.2 Instrumentation and control systems

Plant starting and stopping is performed at the electrical control room of the plant.

After the system is brought up to a steady condition, all necessary monitoring and control of the voltage or load are performed by the ITV at the remote central control room of the diesel power station about 12km far from this plant.

In parallel operation, turbine is usually operated under power control as base load using turbine bypass system, which controls constantly turbine inlet steam pressure by releasing the surplus steams to the condenser.

A hydraulic blow down control valve is provided downstream from the steam separator. This valve rapidly discharges steam when the turbine trips, and also serves as a backup in case of malfunction of the turbine bypass control valve.

A digital governor named "TGR", which has necessary functions such as turbine automatic start up, power control, inlet steam pressure control, load limiting, and AVR, operates this plant.

TGR consists of the digital voltage source, I/O devices and has redundancy. Generator protection relays also have redundancy.

Electrical and control panels are installed in the packaged type electrical and control room.

5.3 Package-type electrical control room

The electrical control room is a compact package-type housing, comprised of seven modules.

As the countermeasures against H₂S gas corrosion to the electrical and instrumentation equipment in the packaged type electrical and control room, H₂S gas absorption filter is installed at air intake of air conditioner.

In addition, the corrosion protection measures such as tin plating, epoxy coating, and special greases are taken to the electrical and instrumentation apparatus.

Figure 14 shows a view of the package-type electrical control room.

Fig.12 Single line diagram

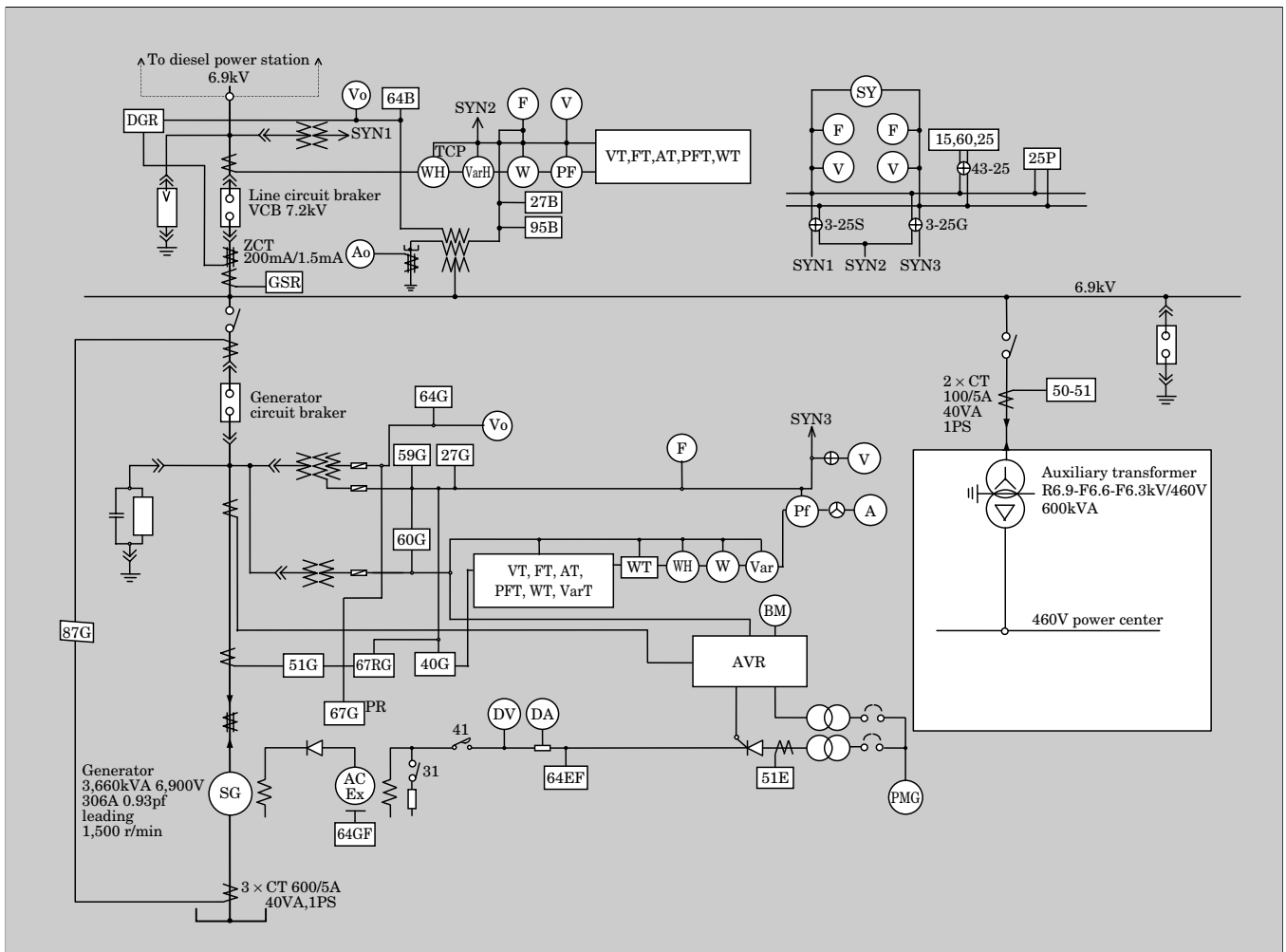


Fig.13 Exterior view of the generator

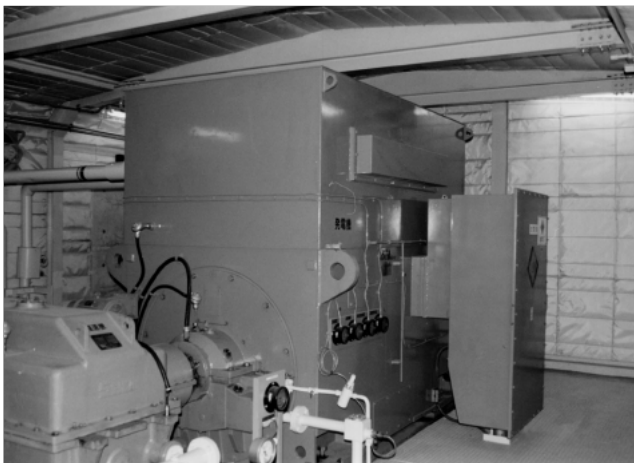


Fig.14 View of the package-type electrical control room



6. Conclusion

This paper has presented an overview of Hachijo-jima Geothermal Power Plant. At present, the power

plant is playing an important role in supplying base power in Hachijo-jima.

It is hoped that this paper will provide useful information for future similar geothermal power plants.



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