Wayang Windu Geothermal Power Plant

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1. Introduction

Throughout the world, development of geothermal power plants has been promoted to utilize clean and renewable energy with low carbon dioxide emissions. The country of Indonesia has the fifth largest development of geothermal energy, following the USA, Philippines, Italy and Mexico in the world.

In June 1997, Fuji Electric of Japan, together with a trading company, entered into an engineering, procurement and construction (EPC) contract with Magma Nusantara Limited (MNL) of Indonesia to supply equipment for the Wayang Windu Geothermal Power Plant (rated capacity : 110MW), including a power station and a steamfield above ground system (SAGS). As an independent power producer (IPP), MNL will operate the plant and sell electricity to Persahaan Listrik Negara (PLN) for 30 years.

The geothermal steam turbine manufactured at Fuji Electric's Kawasaki Factory, has the world's largest single casing capacity of 110MW with 27.4 inch long last-stage blades (LSB).

The plant was put into commercial operation in June 2000. One year after commencing operation, the turbine was disassembled, inspected and checked. Visual inspection revealed neither damage nor contamination. Thus far, plant operation has continued with no reported problem.

2. Overview of the Plant

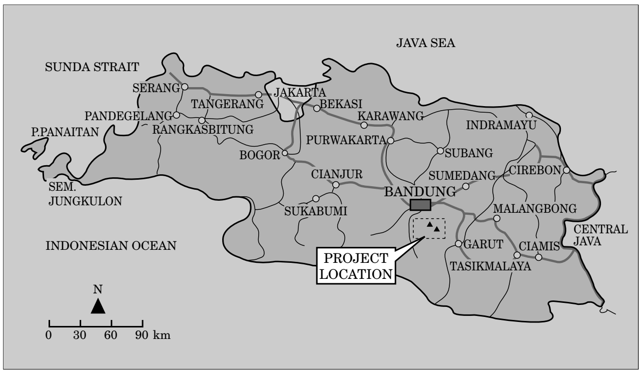
2.1 Plant location

Wayang Windu Geothermal Power Plant is located in Pangalengan approximately 40km south of Bandung, West Java in Indonesia, as shown in Fig. 1. The plant is named after nearby Mt. Wayang and Mt. Windu. A tea plantation surrounds the site and its altitude is approximately 1,700m above sea level.

2.2 Distinctive characteristics

Since the plant is an IPP project, low capital cost and reliable operation with high efficiency are essential from an economical point of view. The plant has several distinctive characteristics including large capacity turbine, two-phase fluid pipelines with central separators, and integrated pressure control designated to meet such requirements.

Fig.1 Project location



(1) Large capacity turbine

It is well known that larger capacity turbines are more efficient for geothermal as well as conventional power plants. The largest single casing capacity geothermal turbine of 110MW is utilized at this plant.

(2) Two-phase fluid pipelines

A mixture of steam and water from production wells is led to a central separator station as two-phase fluid. Use of smaller bore piping can reduce piping material and construction costs, comparing to the conventional steam flow piping

(3) Integrated pressure control system

Stable separator pressure is essential for maintaining steam quality. The integrated pressure control system uses turbine governor valves to maintain steam quality by varying pressure at the same time as controlling flow at the production wells. Consequently, the release of geothermal steam to the atmosphere can be minimized.

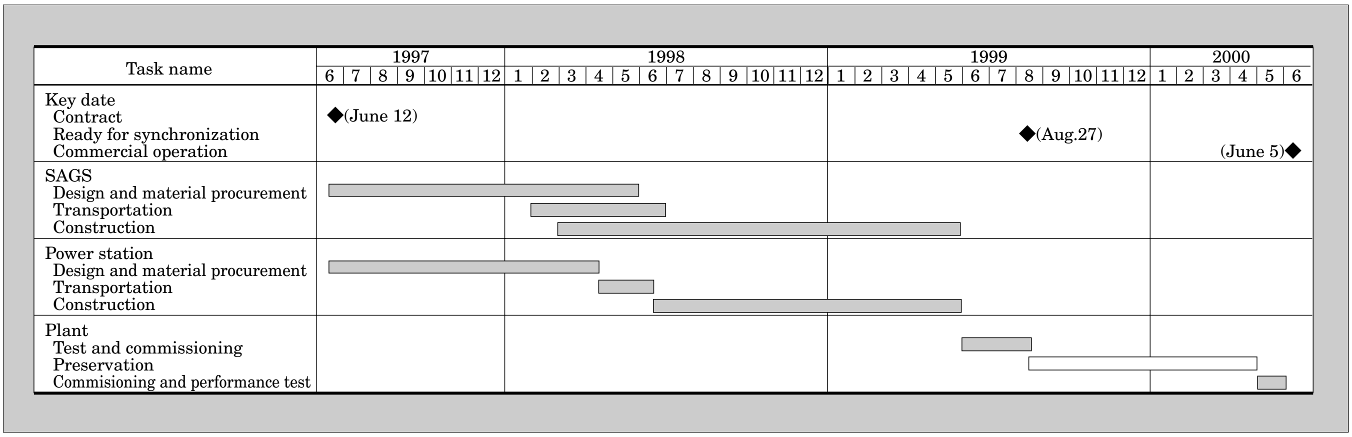
(4) Local architecture

In consideration of harmony with surrounding tea plantation, locally traditional roof and color are incorporated in the architectural design of the power plant.

3. Project Schedule

Figure 2 shows the project schedule, which includes

Fig.2 Project schedule



engineering, design, manufacturing, transportation, construction and commissioning. The contract began in June 1997 and the plant was ready for synchronization in August 1999. After 8 months preservation, the plant went online in June 2000.

3.1 Engineering, design and manufacturing

Critical equipment such as the turbine, generator and condenser were shipped from Fuji Electric's Kawasaki Factory 12 months after notice to proceed was given by MNL. Major auxiliary equipment such as hotwell pumps, the cooling tower, gas removal system, main transformer and distributed control system (DCS) were shipped from Japan, USA, Australia, Singapore, etc., 12 to 16 months after signing of the contract. SAGS piping materials designed by Kingston Morrison Limited (KML) were shipped in stages from Japan, USA, Korea, etc., 8 to 16 months after signing of the contract.

3.2 Construction and commissioning

Civil and construction work was delegated to local subcontractors. Proposals for that work were thoroughly evaluated in terms of technical, commercial and financial perspectives. Onsite work for power station started in June 1997.

SAGS onsite works started in December 1997. A local engineering company, which is a subsidiary of a New Zealand engineering company, has been hired for managing and supervising such subcontractors.

3.3 Preservation

Because the transmission line constructed by PLN was not completed in August 1999, the plant was put on preservation for 8 months.

Mechanical equipment such as the turbine and hotwell pump were disassembled and anti-corrosive measures were taken. Space heaters were put into operation for electrical equipment where necessary. Control and instrument equipment such as DCS and the monitoring system were operated normally.

SAGS pipelines were steam-capped at low pressure steam from production wells.

Fig.3 Power station overview

4. Power Station

Figure 3 shows an overview of the power station. The area is almost square, having 230m E-W and 210m N-S. Civil and architecture for Units No.1 and 2 and the power plant for Unit No.1 are completed at present.

The turbine is of the single flash and double flow type. The cooling water system is a closed circuit consisting of a direct contact condenser and wet cooling tower. The gas removal system is a hybrid system consisting of a steam ejector and vacuum pump.

Figure 4 shows a schematic diagram of the power station and Fig. 5 shows the power station layout after completion of Units 1 and 2.

4.1 Steam turbine

Major specifications are listed below.

Type : single cylinder, double flow and condensing type
Output : 110MW (MCR 115MW)
Inlet steam press. : 1.02MPa
Inlet steam temp. : 181°C
Exhaust press. : 0.012 MPa

Fig.4 Power station schematic diagram

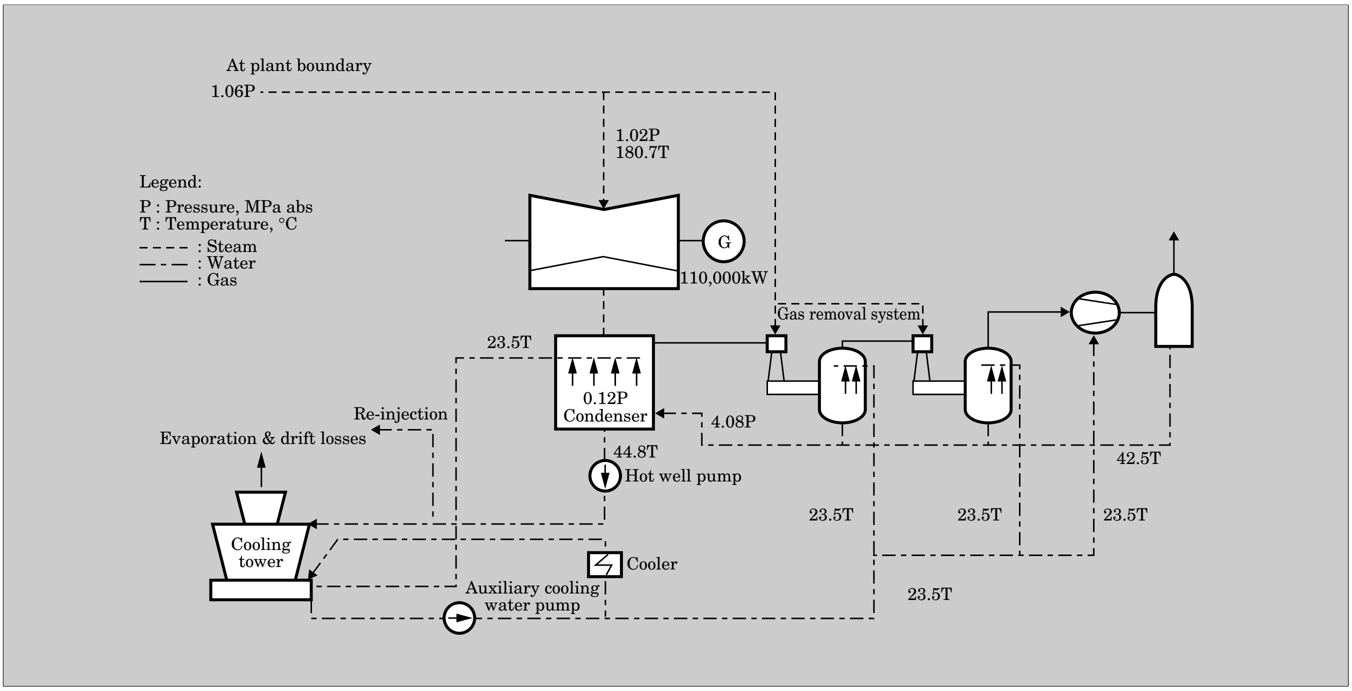
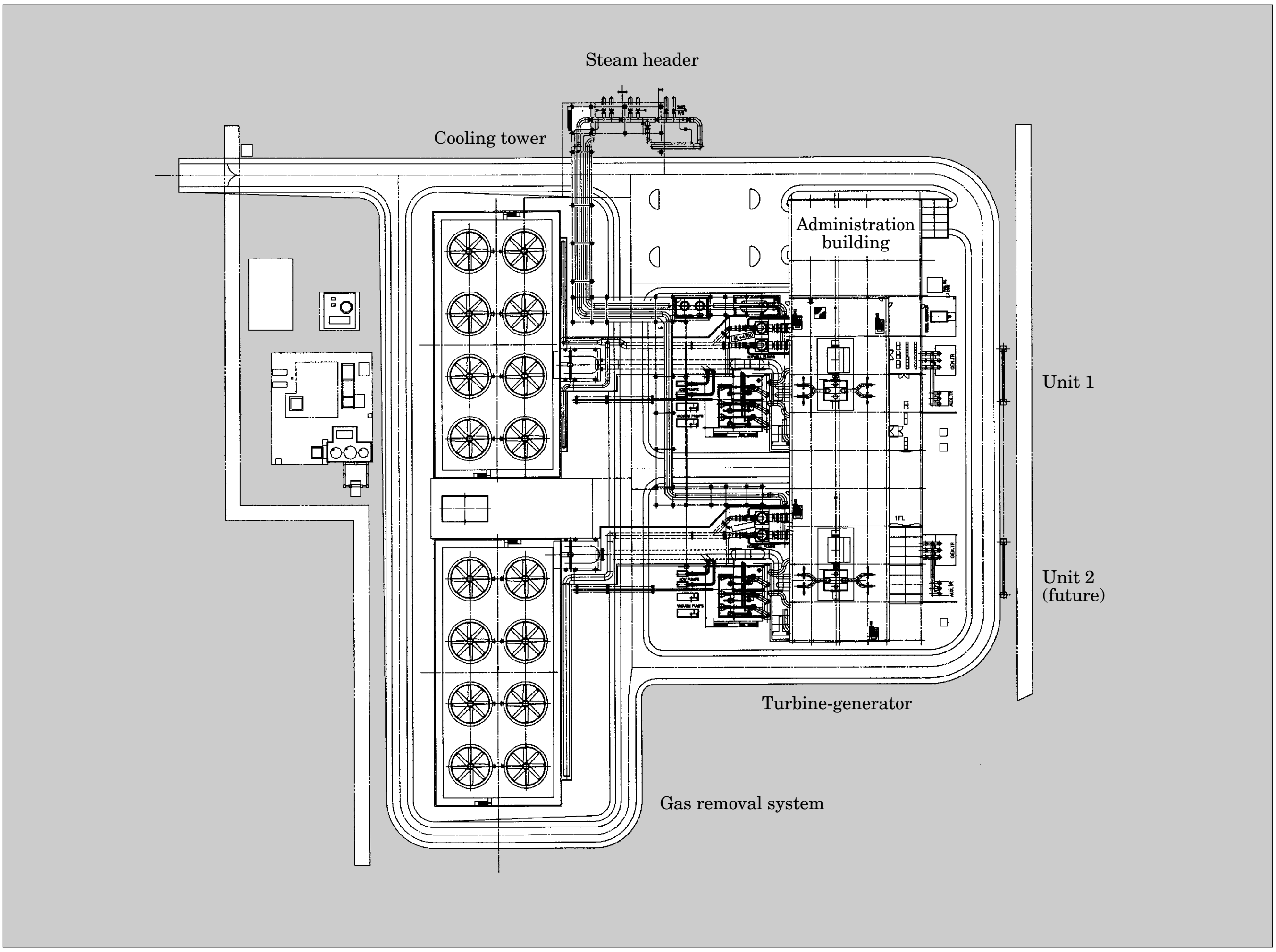


Fig.5 Power station layout



Number of stages : 2 (flows) × 8
Length of LSB : 697 mm (27.4 inch)
Bearing span : 5,800mm
Speed : 3,000 r/min

Figure 6 shows a cross section of the turbine.

(1) High efficiency LP blade

Advanced LP blades are employed in the last three stages, which are designed using the fully three-dimensional (3-D) flow calculation method. The last stationary blades are angled in the radial direction to reduce losses at the root area. The airfoils near the tip of the LSB form the so called convergent-divergent channel that minimizes the shock wave losses. By employing these advanced LP blades, efficiency at the LP blades can be improved by 3%.

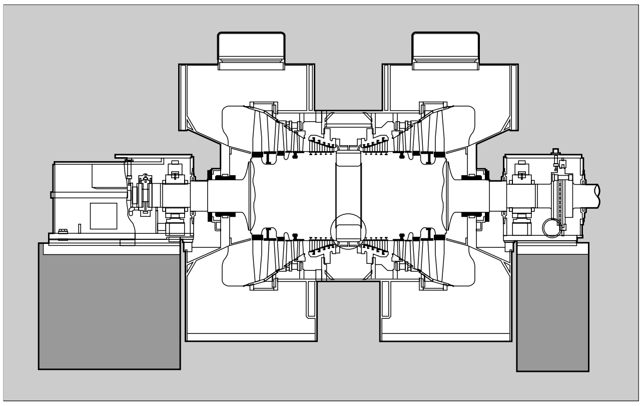
(2) Reaction blade

The turbine blades of Fuji Electric's geothermal steam turbines are all reaction type blades. Blades in the first through fifth stages are integral shroud blades, each of which is machined from one piece of material. These blades are assembled in the rotor and/or the stationary blade holders so that the shroud and root have compression stress on each surface that contacts the adjoining blades at both sides. With this type of assembly, high vibration damping due to dry friction will be produced, but no gaps will form between the adjoining blades under any operational conditions . The moving blades of the sixth stage have a integral shroud with zigzag contour that assures good damping.

(3) Casing

The turbine casing has a single shell construction and is composed of two blocks in the axial direction, i.e. the front and rear parts. The upper half of the casing is shipped as one block, bolted at the vertical joint flange of the front and rear parts assembled with the upper half of stationary holder and/or stationary blade rings, so as to decrease the work at job site. The lower half is also designed as one block in the factory. The casing is directly supported by foundation at both sides of the exhaust. The bearing pedestals are independent from the casing and directly fixed on the foundation. This construction secures the vibration stability of the turbine rotor.

Fig.6 Turbine cross section



(4) Corrosion protection

The turbine uses reaction blades and therefore the turbine rotor has a drum type construction. Due to the flat configuration, stress concentration and deposition of corrosive components are eliminated and the possibility of stress corrosion cracking (SCC) is avoided. Because the rotor has the longest LSB for geothermal use, its maximum diameter is quite large and stresses on the blade groove are large. To reduce the maximum stress on the blade groove, the newly designed low stress groove is employed.

(5) Erosion protection

Stellite shields are brazed to the L-0 and L-1 moving blades on the tip to protect against erosion by water droplets. Also to reduce the erosion by water droplets, drainage is provided at the inlet chamber, fifth stage outlet, and inter-stage of LP-blade row, whereby water droplets will be discharged to the condenser.

(6) Scale protection

A blade wash system is provided as another countermeasure against scaling. This blade wash system washes the turbine blades during normal operation by injecting condensate water.

4.2 Generator

The air cooled turbogenerator for this plant is the largest capacity unit developed by Fuji Electric for geothermal power plants.

(1) Major specifications are as follows:

Type : three-phase horizontal cylindrical revolving field total-enclosed type synchronous generator.
Ventilation : self-ventilation
Cooling : totally enclosed water-to-air cooled (TEWAC)

(2) Rating

Output : 137,500kVA
Voltage : 13.8kV
Power factor : 0.8 (lag)
Frequency : 50Hz
Number of phases : 3
Speed : 3,000r/min
Insulation class : F
Excitation : brushless excitation

5. Steamfield Above Ground System (SAGS)

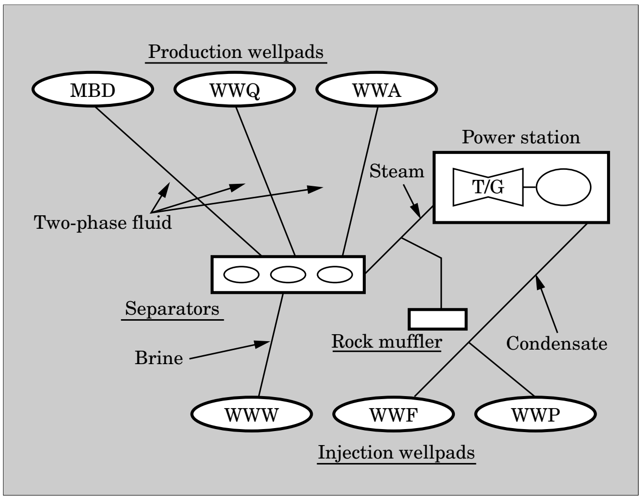
Steamfield above ground system (SAGS) is the generic name for facilities other than the power station in a geothermal power plant, such as the steam pipeline, brine/condensate pipeline, separator, scrubber, rock muffler, etc.

Figure 7 shows a schematic diagram of SAGS.

5.1 Production and injection wells

The production and injection wells were developed

Fig.7 SAGS schematic diagram



by MNL prior to commencement of the work for the power station and SAGS. There are three production wellpads and three brine/condensate injection wellpads. Each production wellpad has three or four wells ranging from 1,800m to 2,500m.

The altitude of the production wellpads is approx. 1,850m above see water level (aswl), being higher than that of the power station by 150m. On the other hand, the altitude of the injection wellpads is approx. 1,500m aswl, being lower than the power station by 200m.

Figure 8 shows a production wellpad (WWQ).

5.2 Pipeline

Geothermal steam and fluid from production wells are piped downhill to the separators as two-phase fluid. Pipelines from each wellpad to the separators are made of carbon steel with a 36-inch nominal bore. The distance between the wellpads and separators is approx. 4km. The steam pipeline from the separators to the power station has a 40-inch nominal bore and is approximately 1km long. The brine pipeline from the separators to the injection wellpads has a 30-inch nominal bore and approximately 8km long. The condensate pipeline from the cooling water piping to the injection wellpad has a 28-inch nominal bore and is approximately 9km long.

The necessary pipe loops are provided on those pipelines to absorb thermal expansion.

5.3 Separator, scrubber and rock muffler

Three cyclone type separators are used to separate steam from the two-phase fluid that comes from production wells. Steam is fed to the power station while brine is fed to the injection wells.

Two corrugate type scrubbers are provided just in front of the power station to eliminate further moisture.

Surplus steam is released to the atmosphere through vent valves. Two rock mufflers are provided near the separator station to reduce the noise level of

Fig.8 Production wellpad (WWQ)

released steam.

Figure 9 shows an overview of SAGS.

6. Power Generation

Since the commencement of commercial operation in June 2000, the plant has been operating stably as a base load power supply for the West Java region. In consideration of recent power demand, the plant is controlled to generate 110MW of power during the daytime and 105MW during the nighttime by the PLN load dispatch center in Bandung.

Figure 10 shows the monthly power generation since June 2000.

7. Other Issues

7.1 Environmental protection

A tea plantation and villages surround the plant. During the construction and commissioning periods, storm water discharge, soil disposal, dust, and water quality have been controlled to ensure minimal environmental impact. Periodical monitoring reports in accordance with AMDAL (Indonesian environmental regulation) were submitted to the government office every 3 months.

7.2 Weather

The period from May through October is usually the dry season. Civil works such as excavation, concrete pouring and backfilling were planned to take place during the dry season. However, there was no dry season in 1998 due to the so called “La Nina phenomenon” which was a consequence of “El Nino phenomenon” in 1997. The progress of civil and structural works was significantly affected. Unanticipated environmental protection works were implemented accordingly.

7.3 Economic crisis in Indonesia

In Indonesia as well as other Southeast Asian countries, an economic crisis occurred in 1998. The difficulty that local subcontractors had in raising funds

Fig.9 Bird's-eye view of SAGS

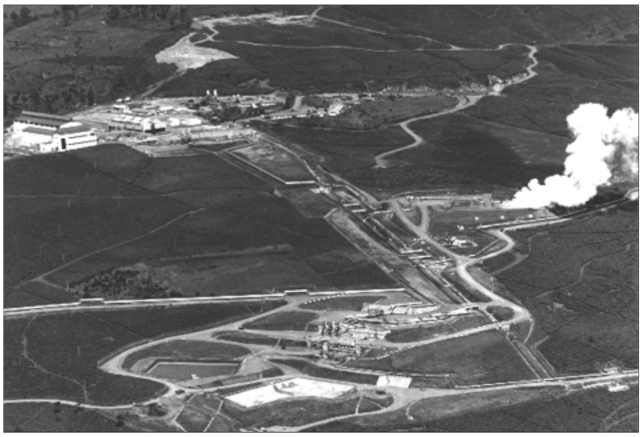
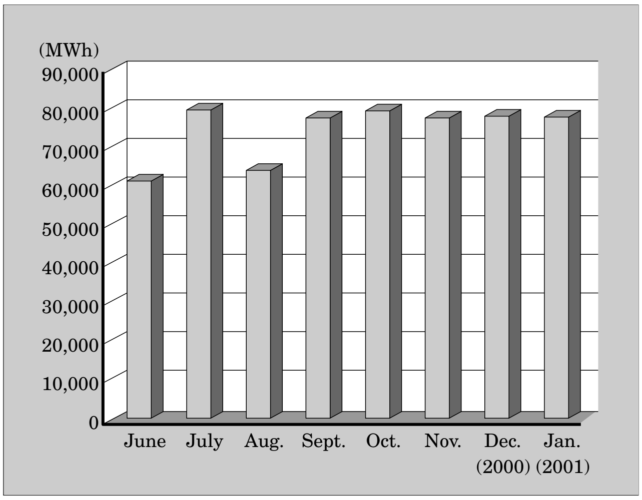


Fig.10 Monthly power generation



resulted in the delay of work progress. Local subcontractors faced difficulty in purchasing materials from foreign countries because foreign companies did not accept letters of credit issued by Indonesian banks.

As a countermeasure, we offered improved terms of payment to the subcontractors so as to assist in solving their finance problem and we purchased necessary materials from foreign companies and supplied them to the subcontractors.

8. Conclusion

The world's largest capacity geothermal turbine was manufactured at Fuji Electric's Kawasaki Factory in Japan, based on extensive experience in both the geothermal and conventional power generation businesses.

The Wayang Windu Geothermal Power Plant unit No.1 has been successfully completed in cooperation with MNL and local subcontractors. We sincerely hope that the electricity generated at this plant will contribute to the development and improvement of life for local people in this area.

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