Indonesia has been promoting geothermal development as a measure to overcome its increasingly serious power shortage. Fuji Electric has long been committed to geothermal power generation, which has low CO₂ emissions and provides an eco-friendly and stable power supply independent of weather conditions. We possess a large number of technologies in this field. We emphasize the relationship with partners and work to shorten the construction period by applying various ideas and making efforts based on our experience and track record for promoting an engineering, procurement and construction (EPC) project. Units 5 and 6 at the Lahendong Geothermal Power Plant and Units 3 and 4 at the Ulubelu Geothermal Power Plant started commercial service up to 3 months ahead of the initial schedule, helping to improve the electricity situation in Indonesia.

2. Geothermal Power Generation in Indonesia

Indonesia is a key country in the Association of Southeast Asian Nations (ASEAN), abundantly endowed with natural resources and a labor force, and is expected to continue seeing significant growth also in the future.

Although the demand for electric power in Indonesia has tended to increase significantly in recent years, the power development plan has rather failed to keep up with the situation (see Fig. 2(1),(2)). The electrification ratio is still low at around 70% and power shortage is so serious that planned outages are performed. There are demands for the construction of new power generation projects, including shortening of work periods, as an engineering, procurement and construction (EPC) contractor. We have experience constructing a triple-flash geothermal power plant in New Zealand that has the largest capacity in the world. We have also obtained a good reputation for technologies specific to geothermal power plants, such as measures against silica precipitation and the selection of turbine blade material.

Indonesia has been promoting geothermal development as a measure to overcome its increasingly serious power shortage. Units 5 and 6 of Lahendong Geothermal Power Plant and Unit 3 of Ulubelu Geothermal Power Plant, to which Fuji Electric delivered major equipment, started commercial operation ahead of their initial schedules. The construction work for Unit 4 of Ulubelu Geothermal Power Plant has been continuing smoothly and we aim to complete it in April 2017.

This paper describes an overview of these geothermal power plants and our efforts toward shortening work periods.
plants as well as for the reinforcement of transmission networks.

On the other hand, the total capacity of the geothermal power generation facilities in Indonesia is the world’s third largest after the United States and the Philippines, and a power of about 1,340 MW was generated from geothermal energy as of 2015. Although the country’s geothermal resource potential is estimated to be 29,000 MW, which is the second largest in the world, the utilization ratio remains at around 5% (see Fig. 3).

Considering such background, the Ministry of Energy and Mineral Resources of Indonesia has set a goal of expanding the power supply from geothermal power plants and increasing the total electrical power capacity based on geothermal energy to 9,500 MW in the country.

By capitalizing on its expertise and experience in the geothermal power generation equipment field, Fuji Electric has delivered 3 generators and 16 units (turbine and generator) of geothermal power generation equipment in Indonesia. The total capacity of geothermal power generation equipment delivered by Fuji Electric has reached about 823 MW. In FY2014, Fuji Electric obtained an order for a project of 2 units, namely Units 5 and 6 of Lahendong Geothermal Power Plant and a project of 2 units, namely Units 3 and 4 of Ulubelu Geothermal Power Plant (see Fig. 4).

For both projects, Fuji Electric proposed high-quality and high-performance equipment in short delivery time, which were highly rated by the client; and we won the orders among increasingly fierce competition in the geothermal power generation market. While Unit 4 of Ulubelu Geothermal Power Plant is under construction, Units 5 and 6 of Lahendong Geothermal Power Plant and Unit 3 of Ulubelu Geothermal Power Plant have already started commercial operation up to 3 months ahead of the original project schedule.

The construction and commissioning of Unit 4 of Ulubelu Geothermal Power Plant are proceeding smoothly, and we aim to start commercial operation in April 2017.

3. Units 5 and 6 of Lahendong Geothermal Power Plant

3.1 Project overview

Units 5 and 6 of Lahendong Geothermal Power Plant were constructed in the mountains about 800 m above sea level in Talikuran village, Tompaso District, Minahasa Province on Sulawesi Island, which is an
island located at almost the center of Indonesia. The place is about an hour and 20 minutes by car from Manado, the capital city of North Sulawesi Province located at the north end of Sulawesi Island. The generation capacity is 40 MW at the sending end as net electric power output (20 MW × 2 units). In the nearby village of Lahendong, existing Units II to IV of Lahendong Geothermal Power Plant have been operating commercially. All of these units were delivered by Fuji Electric (see Fig. 5).

This project was ordered by PT Pertamina Geothermal Energy on December 1, 2014 as an EPC contract including civil engineering and installation, with Sumitomo Corporation specified as a prime contractor. Fuji Electric closed a contract with Sumitomo Corporation to deliver the major equipment of the power plant including geothermal steam turbines and generators that constitute the main part and condensers. A steam-above-ground system (SAGS) and some other equipment were delivered by PT Rekayasa Industri, a leading engineering company in Indonesia.

Figure 6 shows a panoramic view of Units 5 and 6 of Lahendong Geothermal Power Plant and Fig. 7 is the external appearance of the turbine and generator of Unit 5.

### 3.2 Project characteristics

This project employs axial exhaust flow turbines that have low exhaust loss. The condensers are a compact direct-contact type with built-in gas cooling zones. In order to shorten the construction period, the turbines and generators are designed and manufactured in the skid-mount style*1 and shipped from Japan.

The ratio of noncondensable gas components to the geothermal steam is 1% (weight %). For gas extraction equipment used to extract this noncondensable gas component from the condenser, we adopted a hybrid system of a steam ejector and a vacuum pump. The gas extraction equipment consists of 3 units in total: 2 units operating at 50% capacity (regular use) and one unit operating at 50% capacity (backup). The cooling tower has a tower body structure made of FRP and consists of 3 cells. The hotwell pumps are designed as 2 units operating at 50% capacity. This power generation equipment is provided with a run-back function to lower the output setting instantaneously when one hotwell pump stops and operate by limiting the amount of cooling water sent to the condenser to 50%.

The distributed control system (DCS) includes automatic turbine activation equipment so that the plant can be started automatically with the push of a button from opening the main steam stop valve to 100% rated output.

Table 1 shows the major specifications of the turbine and generator.

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*1: Skid-mount style: A style of unit in which a steam turbine and a generator are provided as a package. Since the equipment can be shipped, transported and installed as a package, on-site assembly is unnecessary, and this greatly contributes to shortening the construction period on the site.
4. Units 3 and 4 of Ulubelu Geothermal Power Plant

4.1 Project overview

Units 3 and 4 of Ulubelu Geothermal Power Plant are constructed about 800 m above sea level in the mountains in Ulubelu District, Tanggamus Regency, Lampung Province at the south end of Sumatra Island. The generation capacity is 110 MW at the sending end as net electric power output (55 MW × 2 units). They are located next to existing Units 1 and 2 of Ulubelu Geothermal Power Plant which uses equipment delivered by Fuji Electric and started operation in 2012 (see Fig. 8).

Sumatra Island is expected to have the largest geothermal resource potential in Indonesia, and Ulubelu is an area where geothermal development was started ahead of other areas in the island.

Fuji Electric has been promoting the project in cooperation with Sumitomo Corporation and PT Rekayasa Industri. Unit 3 of Ulubelu Geothermal Power Plant already started commercial operation in July 2016 and Unit 4 is being constructed with the aim of completion in April 2017. The electric power generated in this station is supplied to the Lampung area via the Indonesian government-owned electric power company, (PT. PLN), and it is making a great contribution toward eliminating the chronic power shortage in the area.

Figure 9 shows a panoramic view of Units 3 and 4 of Ulubelu Geothermal Power Plant and Fig. 10 shows the external appearance of the turbine and generator of Unit 3.

Units 3 and 4 of Ulubelu Geothermal Power Plant are positioned as one of the renewable energy development projects promoted by the Indonesian government under a presidential decree. The project is funded by a loan from the World Bank and has been attracting a lot of attention in Indonesia.

4.2 Project characteristics

A hot water high temperature liquid-dominated geothermal resource (2-phase fluid), which consists mainly of liquid water underground, is collected from multiple production wells to the production well pads through transport pipelines and then separated into steam and geothermal brine by a steam separator. The steam is sent to the power plant after its pressure

![Fig.8 Location of Ulubelu Geothermal Power Plant](image)

![Fig.9 Panoramic view of Units 3 and 4 of Ulubelu Geothermal Power Plant](image)

![Fig.10 Turbine and generator of Unit 3 of Ulubelu Geothermal Power Plant](image)

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### Table 1: Major specifications of turbine and generator of Units 5 and 6 of Lahendong Geothermal Power Plant

<table>
<thead>
<tr>
<th>Item</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Turbine</strong></td>
<td></td>
</tr>
<tr>
<td>Type</td>
<td>Single-cylinder, single-flow, axial exhaust, reactionary condensing turbine</td>
</tr>
<tr>
<td>Sending end output</td>
<td>20,000 kW</td>
</tr>
<tr>
<td>Inlet pressure</td>
<td>8.0 bar (absolute pressure)</td>
</tr>
<tr>
<td>Inlet temperature</td>
<td>170.2 °C</td>
</tr>
<tr>
<td>Condenser vacuum</td>
<td>0.075 bar (absolute pressure)</td>
</tr>
<tr>
<td><strong>Generator</strong></td>
<td></td>
</tr>
<tr>
<td>Type</td>
<td>Air-cooled turbo generator</td>
</tr>
<tr>
<td>Capacity</td>
<td>25,300 kVA</td>
</tr>
<tr>
<td>Voltage, frequency</td>
<td>11 kV, 50 Hz</td>
</tr>
<tr>
<td>Power-factor</td>
<td>0.85 (lagging)</td>
</tr>
</tbody>
</table>
and flow are regulated, and the geothermal brine is returned to the underground through a reinjection well. The total length of these transport pipelines reaches 30 km or longer. The separated steam is controlled to a constant pressure by the vent equipment located in the power plant. After the steam scrubber of the power plant removes moisture from it, the steam is sent to the steam turbine.

The major equipment of the power plant includes reactionary condensing steam turbines with downward exhaust, totally enclosed air-cooled generators, direct contact condensers, large electric motors and turbine generator control devices. These were manufactured by Fuji Electric and the steam separators, steam scrubber, electrical equipment, FRP pipes and cables were procured in Indonesia.

The overall layout of the power plant was restricted by the site area and terrain. We made a plan to arrange Unit 3 and Unit 4 east and west and placed the cooling tower on the hill in the north, the turbine building and electrical room in the center, and the switching station in the south.

Table 2 shows the major specifications of the turbine and generator.

### Table 2 Major specifications of turbine and generator of Units 3 and 4 of Ulubelu Geothermal Power Plant

<table>
<thead>
<tr>
<th>Item</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Turbine</strong></td>
<td></td>
</tr>
<tr>
<td>Type</td>
<td>Single-cylinder, double-flow, downward exhaust, reactionary condensing turbine</td>
</tr>
<tr>
<td>Sending end output</td>
<td>55,000 kW</td>
</tr>
<tr>
<td>Inlet pressure</td>
<td>7.6 bar (absolute pressure)</td>
</tr>
<tr>
<td>Inlet temperature</td>
<td>168.0°C</td>
</tr>
<tr>
<td>Condenser vacuum</td>
<td>0.08 bar (absolute pressure)</td>
</tr>
<tr>
<td><strong>Generator</strong></td>
<td></td>
</tr>
<tr>
<td>Type</td>
<td>Air-cooled turbo generator</td>
</tr>
<tr>
<td>Capacity</td>
<td>70,000 kVA</td>
</tr>
<tr>
<td>Voltage, frequency</td>
<td>11 kV, 50 Hz</td>
</tr>
<tr>
<td>Power factor</td>
<td>0.85 (lagging)</td>
</tr>
</tbody>
</table>

5. Points to Note on Implementation of Geothermal Power Generation Project

5.1 Cooperation with partners

As the consortium leader, Sumitomo Corporation assumed the role primarily in general commercial affairs, insurance service and shipping operations, conducted coordination and negotiations with PT Pertamina Geothermal Energy, and supported PT Rekayasa Industri and Fuji Electric.

PT Rekayasa Industri has been the sole operator serving the on-site portion by handling the SAGS, electrical equipment and site construction. It also took the initiative to ensure compliance with Indonesian laws and regulations and coordinate with local communities.

Sumitomo Corporation, PT Rekayasa Industri and Fuji Electric have been working together in many order negotiations and project implementations in the construction of geothermal power generation facilities in Indonesia for over 10 years and have developed an ideal partnership bringing a synergy effect.

5.2 Improvement of client satisfaction

Fuji Electric designs equipment by considering the life cycle with the emphasis on operation and maintainability. In terms of improving client satisfaction, we optimized the layout of the power plants based on maintenance and management, considered the accessibility to the equipment, and reflected the requests from the client regarding operability and other factors as much as possible in both the engineering stage and site construction stage.

5.3 Shorter project delivery

In recent years, the construction period for geothermal power plants has become shorter than that of the past cases. For Unit 5 of Lahendong Geothermal Power Plant, the client requested a work period of 22 months. This is one month shorter than the period of 23 months requested for Unit 5 of Kamojang Geothermal Power Plant, which is a power plant of the same scale also delivered by Fuji Electric and which is already in commercial operation. The contracted work period for Unit 3 of Ulubelu Geothermal Power Plant was 23 months. The client requested a 5-month reduction from the 28 months taken for constructing Unit 1 of Ulubelu Geothermal Power Plant, which is already in commercial operation in the area. Fuji Electric met these requests for work period shortening by planning the arrangement of gas extraction equipment by itself to optimize overall layout and downsize the power plant. It also designed the turbine, generator and chemical equipment as a package to reduce the amount of materials required for site construction.

In the initial stage of the project, we coordinated the construction and commissioning processes in detail with PT Rekayasa Industri. During the construction of the project, we planned the delivery of equipment and materials according to the processes agreed on with PT Rekayasa Industri to prevent any delay in the site construction. In the engineering stage, it is important to exchange engineering data smoothly. We set the deadline for this exchange with PT Rekayasa Industri in advance and followed the schedule to promptly accomplish the equipment specifications and a detailed design of civil engineering and construction. We actively had meetings with PT Pertamina Geothermal Energy in both Indonesia and Japan to determine the design principles and solve pending issues.

These activities have led to the promotion of core engineering in the initial stage of the project, making it possible to deliver equipment and carry out construction in accordance with the plan.

As a result, Unit 5 and Unit 6 of Lahendong Geo-
Units 5 and 6 at Lahendong Geothermal Power Plant and Unit 3 of Ulubelu Geothermal Power Plant started commercial operation about one month, 3 months and 3 weeks ahead of the initially planned schedules respectively. The construction work for Unit 4 of Ulubelu Geothermal Power Plant has been progressing smoothly.

6. Postscript

This paper described Units 5 and 6 of Lahendong Geothermal Power Plant and Units 3 and 4 of Ulubelu Geothermal Power Plant.

Constructing geothermal power plants in Indonesia in the future is expected to become more difficult due to geographical conditions and environmental considerations. Fuji Electric aims to contribute in both aspects of the environment and energy by making the most of its experience and achievements.

Furthermore, by utilizing our expertise based on a number of achievements, we are determined to promote further development of geothermal power generation as a renewable energy source that generates fewer CO₂ emissions, is environmentally friendly and ensures stable power supply independent of the weather conditions.

In closing, we should mention the considerable cooperation we received from our client, PT Pertamina Geothermal Energy, and Sumitomo Corporation and PT Rekayasa Industri in the construction of these geothermal power plants. We would like to express our deep appreciation for their cooperation.

References
Fuji Electric
Innovating Energy Technology

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