Fuji Electric's Geothermal Power Plants

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1. Introduction

In recent years, many geothermal power plants have been put into commercial operation in Japan and the Philippines. In the Philippines, geothermal power plants of about 600MW are being developed in Leyte. Indonesia is also planning to construct geothermal plants of about 1,000MW within the next 10 years. In the US, however, the construction of geothermal power plants has decreased very much.

Fuji Electric constructed the Palimpinon II geothermal power plants consisting of four 20MW units in the Philippines in 1995, and is currently constructing the Malitbog Power Plant with three 77.5MW units also in the Philippines and three 59.5MW geothermal turbine generators for the Salak Geothermal Power Plant in Indonesia. Geothermal power plants had been constructed by electric utility companies in Asia before, however recent developers are constructing these plants under BOT (Build, Operate and Transfer) or BOO (Build, Operate and Own) schemes. This paper introduces recent geothermal power plant construction under these conditions.

Table 1 Geotharmal power plants in the Philippines[1]

Region	Plant name	No. of units	Unit capacity (MW)	Total capacity (MW)	Commissioned
Mak-Ban	Bulalo	6	55	330	1979-1984
	Bulalo *	3	5.2	15.7	1994
	Bulalo	4	20	80	1995
Tiwi	Tiwi	6	55	330	1979-1982
Bacon-Manito	Palayan	2	55	110	1993 / 1994
	Cawayan	1	20	20	1994
	Botong	1	20	20	1995
Mt Labo	Labo	1	20	20	1998
	Labo	2	50	100	2000
Leyte	Tongonan I	3	37.5	112.5	1983
	Upper Mahiao *		118	118	1996
	Malitbog	3	77.5	232.5	1996 / 1997
	Mahanagdong	3	60	180	1997
	Alto Peak	1	77.5	77.5	1997
	Tongonan I	1	14	14	1997
	S. Sambaloran	1	12	12	1997
	Mahanagdong	3	6	18	1997
Southern Negros	Palimpinon I	3	37.5	112.5	1983
	Palimpinon II	2	20	40	1994
	Palimpinon II	2	20	40	1995
Northern Negros	N. Negros I	1	40	40	2000
Mindanao	Matingao	1	50	50	1997
	Sandawa	1	70	70	1998
Total	–	–	–	2,142.7	–

Note: The asterisked plants are binary cycle plants.

2. Current Status of Geothermal Power Development

Geothermal power plant constructions in the US is very sluggish at present, however many geothermal power plants are being constructed or planned in Asia.

In the Philippines, the construction program of 20MW class units, including Palimpinon II (4 × 20MW), by the National Power Corporation (NPC) is completed. Currently, the Philippine National Oil Company (PNOC) is proceeding with the development in Leyte. NPC offered full turnkey contracts to the manufacturers, but PNOC requires BOT contracts with the developers, In these BOT contracts, the plants are constructed and operated by a developer, and then transferred to PNOC after 10 years.

In Indonesia, geothermal power plants were constructed through contracts with PLN. Future development contracts will be either BOT or BOO. Various US developers are targeting the Asian geothermal power plant market.

3. Geothermal Power Plants in the Philippines

The capacity of the geothermal power plants installed in the Philippines is about 1,000MW. This is the second largest geothermal country in the world next to the United States. The capacity in the Philippines will be about 2,000MW by the year 2000 as shown in Table 1.

3.1 Palimpinon II Geothermal Power Plant

The Palimpinon II Geothermal Power Plant consists of the Nasuji Power Plant and Okoy-5 Power Plant, both of which have one 20MW unit, and the Sogongon Power Plant having two 20MW units. The Nasuji Power Plant and Okoy-5 Power Plant were put into commercial operation in February and December 1994 respectively. Unit 1 and 2 of the Sogongon Power Plant were put into commercial operation in February and May 1995.

The turbines and the generators are assembled at the factory, delivered to the site, and then installed on a flat foundation at the ground floor level. This configuration saves both construction and installation costs. The electrical and control rooms are located in a module house.

Figure 1 shows an overview of the Nasuji Power Plant.

3.2 Malitbog Geothermal Power Plant

In 1992, the PNOC announced it was accepting BOT bids for several geothermal power plants in Leyte. As a result, the Visayas Geothermal Power Company (VGPC, subsidiary of CalEnergy Company, USA) was contracted to construct and operate three sets of 77.5MW units in the Malitbog area, and Fuji Electric

Fig.1 Overview of Nasuji Power Plant

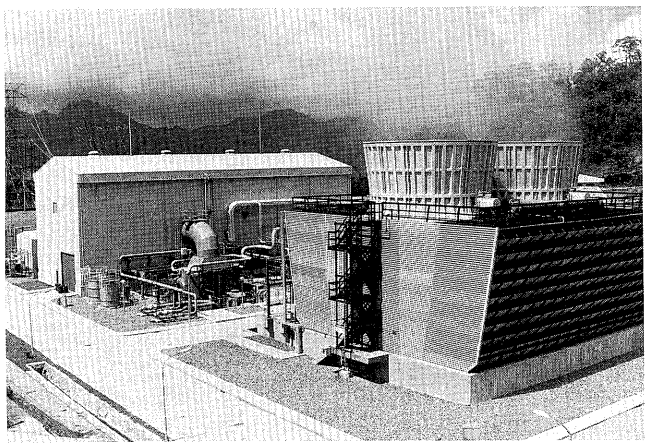


Fig.2 77.5MW geotharmal steam turbine for Maltibog Power Plant

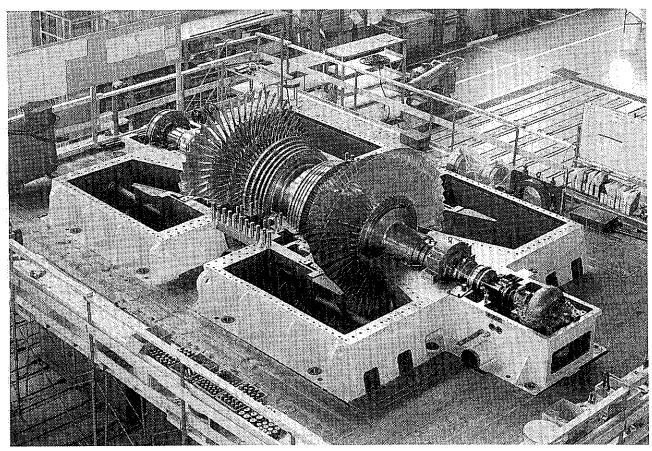


Table 2 H_2S abatement system

System	Application	Efficiency	Chemicals	Problems
Burner / scrubber	Condensation	50%	–	Low efficiency
Iron Catalyst	Condensation	50%	Fe sulfate	Sludge disposal material corrosion
Stretford	Gas	78 to 92%	Na carbonate Na ammonium polyvanadate ADA	Construction cost Sludge disposal
Stretford & Peroxide	Gas & condensation	99%	Na ammonium polyvanadate ADA & peroxide	Construction cost Sludge disposal
Chelate - Iron	Gas	78 to 92%	Chelate-Iron	Condenser
DOW process	Steam	96%	Oxygen peroxide	Sludge disposal
EIC process	Steam	95 to 99%	Cu sulfate	Sludge disposal

Table 3 Overseas procurement for Malitbog Powe Plant

Mechanical equipment	Steam turbines	by Fuji
	Condenser	by Fuji
	Pipings	USA
	Demister	USA
	H_2S abatement system	USA
	Gas extraction system	USA
	Cooling tower	USA
	Overhead crane	Singapore
	Hotwell pumps	Japan
	Auxiliary cooling water pumps	USA
	GRS cooling water pumps	USA
	Air compressors	USA
	Machine shop equipment	USA
	Chemical dosing system	USA
	Fire pumps	USA
	Fire fighting system	USA
	Air conditioning system	USA
	Superstructure	Malaysia
Electrical equipment	Generators	by Fuji
	AVR	by Fuji
	Step-up transformers	Brazil
	Power transformers	USA
	Interlock relay cubicle	USA
	13.8kV switchgear	USA
	LV switchgear	USA
	Supervisory panels	USA
	Bus ducts	USA
	Battery and charger	USA
	UPS	USA
	Instruments	USA etc.
	Control panels	USA
	Control valves	USA
	DCS	USA
	Diesel generator	USA
Civil engineering and construction	Civil design	Japan
	Civil construction	Philippines
	Inland transportation	Philippines
	Cables etc.	USA etc.
	Electro-mechanical construction	Philippines

received a full turnkey contract including construction and civil engineering work.

(1) Geothermal steam turbine

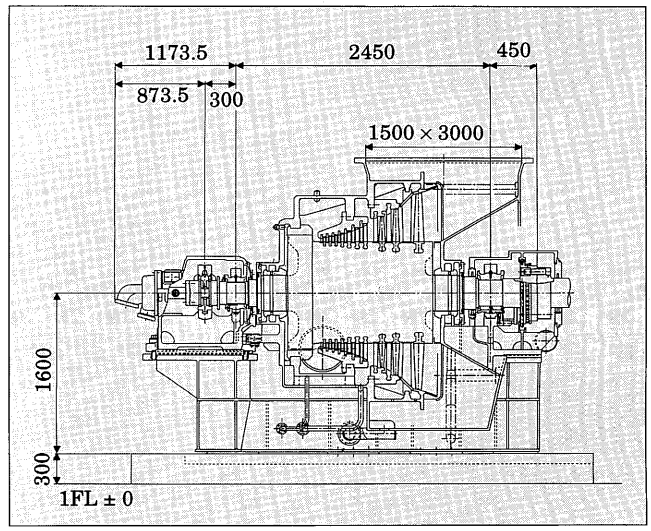
The geothermal steam turbines employed in the Malitbog Power Plant are of the single cylinder dual exhaust condensing type. Their rated output of 77.5MW is the largest in the world for a single casing geothermal turbine. The 26 inch blade employed in the last stage of the turbines is the longest class blade used in geothermal service. Figure 2 shows the turbine assembled at Fuji Electric's Kawasaki Factory. A 26 inch last stage blade was also employed in the 60.5MW turbine at the Dixie Valley Geothermal Power Plant and in eight 30MW turbines for Coso built in 1989. The

Table 4 Geotharmal power plants in Indonesia[2]

Region	Plant name	No. of units	Unit capacity (MW)	Total capacity (MW)	Commissioned
Java	Kamojang	1	30	30	1983
	Kamojang	2	55	110	1987
	Gunung Salak	2	55	110	1994
	Darajat	1	55	55	1994
	Gunung Salak	3	55	165	1997
	Darajat	1	55	55	
	Dien	3	20 / 55	95	
	Patuha	1	40	40	
	Karaha	1	55	55	
	Wayang Windu	4	55	220	
	Candi Kuning	1	60	60	
	Kamojang	3	26	80	
Sumatera	Ulubelu	2	20	40	
	Lumt Balai	2	20	40	
	Sibayak	1	22	20	
Sulawesi	Lahendong	1	20	20	
Total	–	–	–	1,197	–

Note: The asterisked plants are binary cycle plants.

Fig.3 Cross section of 20MW geotharmal steam turbine for 50Hz



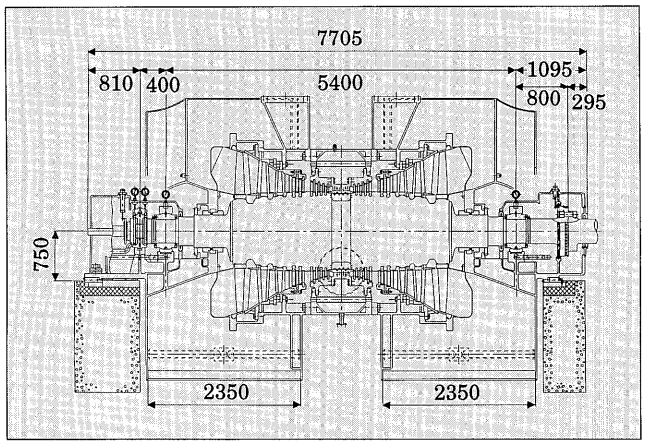
dimensions of the turbine casing for Malitbog is sized down, since they will be installed in a mountainous area.

(2) Hydrogen sulphide abatement system

Hydrogen sulphide (H_2S) gas abatement systems have been installed at geothermal power plants in the US because of restrictions on the emission of H_2S gas. Outside the US, there were no specific regulations to restrict the emission of H_2S gas, but recently such regulations are being issued in some countries. The Philippines has begun to limit the emission of H_2S gas from newly installed geothermal power plants.

There are various types of H_2S gas abatement systems, as shown in Table 2. A modified chelate-iron sys-

Fig.4 Cross section of 59.5MW geotharmal steam turbine for Salak Power Plant



tem is employed at the Malitbog Power Plant.

(3) Overseas procurement

Various materials, equipment or systems, which Fuji Electric does not manufacture, have to be procured from outside to construct a power plant. Procurement of such items from outside Japan is required to avoid the risk of fluctuating currency exchange rates and to maintain the project budget under the current yen valuation. The overseas procurement ration for Malitbog Power Plant is about 85% of the procured items, and is about 50% of the project budget. Table 3 shows major equipment and their source countries.

4. Geothermal Power Generation Equipment in Indonesia

Though the capacity of geothermal power plants in Indonesia is about 300MW today, the construction of many additional geothermal power plants is scheduled as shown in Table 4. Fuji Electric is well experienced in supplying geothermal units to 60 Hz areas such as the US and the Philippines, and is ready to manufacture a 50 Hz series of units based on such experience and new technologies. Figure 3 shows a cross section of the 50 Hz version of the standardized 20MW class geothermal steam turbine. This turbine is assembled on a skid at the factory, similar to the 20MW turbine for Palimpinon II. The dimensions are minimized considering it will be transported to a mountainous site in Indonesia.

In addition, the design of a 50Hz model of the 55MW class geothermal steam turbine is also completed. These will be used in three 59.5MW units for the Salak Geothermal Power Plant. The Salak Geothermal Power Plant is located in southwestern Jakarta in Java, Indonesia. The plant will be constructed under a BOT scheme by UGI (Unocal Geothermal Indonesia).

Figure 4 shows the turbine section. The plant cycle is single flash, but will be changed to double flash if the resource conditions change. The turbine is designed to allow double flash operation without any modifications on the turbine casing. LP steam inlet flanges are mounted on the turbine casing so that LP steam piping can be easily connected to the turbine even after the installation work. A digital triplicate electro-hydraulic governor is employed.

Table 5 Operational experiance of existing units

Year	Palimpinon I			Del Ranch	Elmore	Leathers
	Unit 1	Unit 2	Unit 3			
1989	99.43%	99.11%	97.84%	98.76%	–	–
1990	99.03%	99.52%	99.58%	96.99%	96.51%	96.64%
1991	99.71%	99.87%	99.39%	100.0%	96.71%	97.56%
1992	99.25%	99.69%	99.33%	96.72%	95.59%	96.74%
1993	99.60%	99.15%	99.64%	100.0%	98.15%	93.59%

5. Operational Experiences of the Installed Units

Every geothermal steam turbine generator supplied by Fuji Electric has operated very smoothly and shown high reliability. Table 5 shows the availability factor of the units.

6. Conclusion

The major characteristics of geothermal energy are: 1) that it is suitable for protecting the atmospheric environment, 2) it is recyclable energy and 3) pure domestic energy. This energy will be developed further in countries where geothermal resources exist. Fuji Electric will participate in such future development by continuing to supply geothermal power generating units with high reliability in accordance with customer needs to utilize geothermal energy effectively.

References

(1) Javellana, S.P.: Country Update on Philippine Geothermal Development and Operations. World Geothermal Congress 1995.

(2) Radja, V. T.: The Role of Geothermal Energy in the Context of the Future Electric Power Supply in Indonesia. World Geothermal Congress 1995.