Fuji's Activities in Geothermal Power Generation

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1. Introduction

Geothermal power generation was first experienced in Italy in 1904 as a water-binary cycle system that used a reciprocating steam engine, very different from the flash cycle systems of today. In 1923, also in Italy, a system which introduces geothermal steam directly into a steam turbine was tested for the first time.

Since then, this system has become the major means of geothermal power generation. Many geothermal power plants which use flash cycles (natural steam, single flash or double flash) have been built in countries where geothermal resources are abundant such as New Zealand, the Philippines, the USA and Japan. According to presentations at the World Geothermal Congress of May, 2000 in Beppu and Morioka, Japan, the total capacity of geothermal power plants in the world is about 8,000MW at present. Of that number, Fuji Electric has supplied equipment that produces about 1,700MW in total.

2. Current Status

Features of geothermal power generation, that it is clean and recyclable, are widely known. Since there is no combustion of fossil fuels which emit carbon dioxide and nitrous or sulphurous oxides, geothermal power generation contributes to the conservation of the environment. Geothermal steam was originally rain water which penetrated deep underground and then was heated by magma. After being separated from steam, hot water is also returned from wells to the earth. This completes a natural recycling system. Although geothermal energy cannot be transported like a fossil fuel, it is actively being developed in countries where geothermal resources are abundant. Figure 1 shows geothermal zones throughout the world and the capacity of geothermal unit installed by Fuji Electric. Table 1 shows the capacity of countries in both 1995 and 2000, and a forecast for 2005. As you can see from this table, the development of geothermal power generation is particularly active in those countries which have no petroleum resources such as the Philippines, New Zealand and Italy. In the USA which has the largest installation of geothermal power plants in the world, and at the same time is a major oil producing country, geothermal power generation is recognized as an economical and environmentally benign means of power generation, and geothermal resources are abundantly distributed in the western states, especially in California. Although Indonesia is blessed with fossil fuels such as oil and natural gas, it is aggressive in the development of geothermal resources. All geothermal energy development plans in Indonesia have been suspended ever since the economical crisis, however, those plans will be revived soon. If present development plans are realized, Indonesia will become one of the largest geothermal power generation countries in the world as shown in Table 1.

In the Philippines and Indonesia, geothermal power plants used to be built by national utilities such as NPC (the Philippines) and PLN (Indonesia). However, it is becoming more popular to build a plant under BOT (build, operate and transfer) type contract where a foreign developer and the national utility sign an ECA (energy conversion agreement) or PPA (power purchase agreement). This system helps accelerate the construction of power plants by attracting foreign developers, particularly American developers who have vast domestic experiences. In this system, either a governmental body such as PNOC-EDC (the Philippines) or PERTAMINA (Indonesia) develops and maintain geothermal fields to supply steam and developers build power plants, or a private developer does everything from drilling wells and constructing pipelines to building the power plant. In either case, the main tendency is for the developer to enter into an EPC (engineering, procurement and construction) type contract with a supplier, where the supplier is solely responsible for completion of the power plant. In order to receive financing from monetary institutions, it is essential to have a single responsible entity as the main contractor rather than having multiple contractors.

Fuji Electric, a leading manufacturer of geothermal steam turbines, recognizing the needs of geothermal developers, has become increasingly focussed

Fig.1 Worldwide geothermal zones and power plants supplied by Fuji Electric

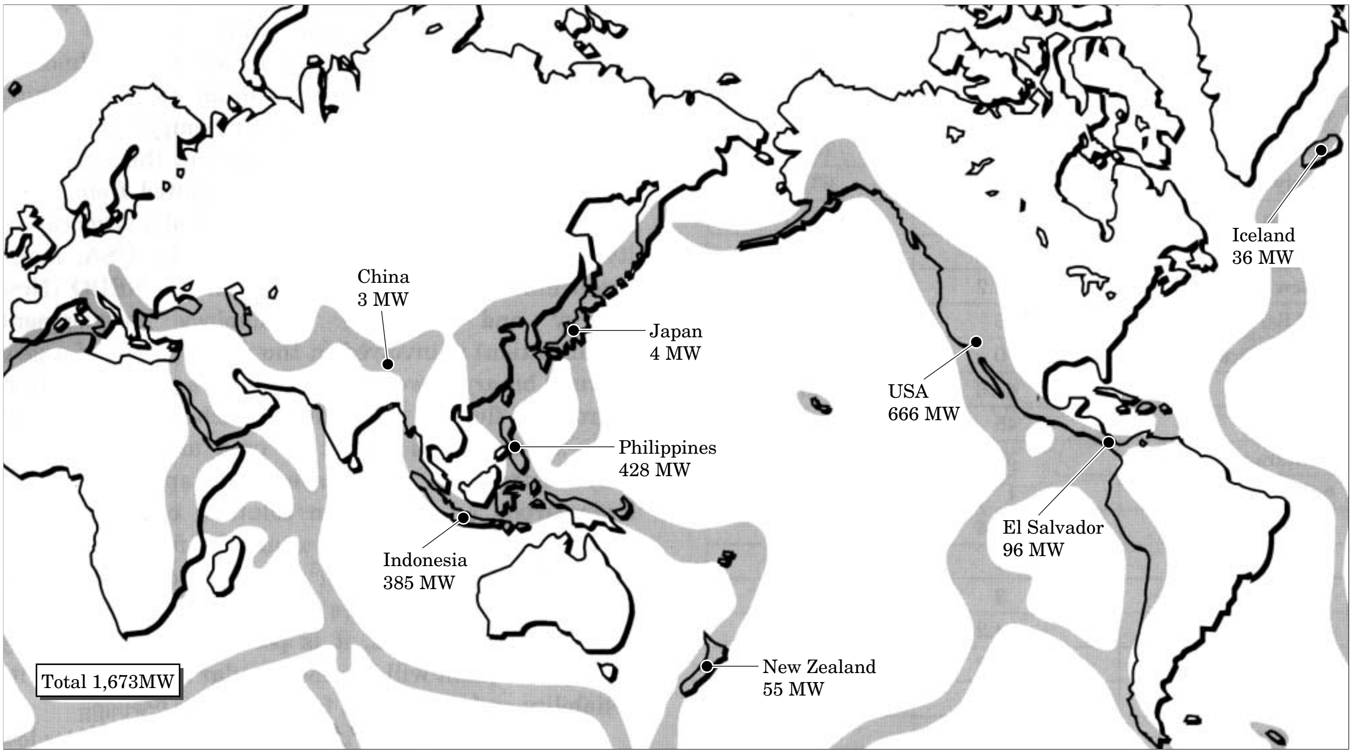

Table 1 Worldwide capacity of geothermal power plants (Source : IGA NEWS, July to September 2000)

Countries	Capacity (MW)		
	Year 1995	Year 2000	Year 2005 (forecast)
* USA	2,817	2,228	2,376
* Philippines	1,227	1,909	2,637
Mexico	753	755	1,080
Italy	632	785	946
* Japan	414	547	567
* Indonesia	310	589	1,987
* New Zealand	286	437	437
* El Salvador	105	161	200
Nicaragua	70	70	145
Costa Rica	55	142	161
* Iceland	50	170	170
Kenya	45	45	173
* China	29	29	NA
Turkey	20	20	250
Russia	11	23	125
Portugal	5	16	45
France	4	4	20
Argentina	0.7	0	NA
Thailand	0.3	0.3	0.3
Australia	0.2	0.2	NA
Ethiopia	0	9	9
Guatemala	0	33	33
Total	6,833	7,974	11,398

Note : * shows the countries where Fuji Electric supplied geothermal power plants.

toward total plant engineering. In the recent construction of Malitbog Geothermal Project in Leyte, Philippines, Fuji Electric (along with a trading company as the main contractor) worked on the project to provide a full turnkey solution, including construction, civil engineering work, manufacturing, procurement, installation and commissioning of the plant which consists of three 77.5MW units. In this case, the only data supplied to Fuji Electric was given were the steam conditions at the plant boundary, the site meteorology, and the customer's required net plant output. Fuji started the engineering work by determining the design wet bulb temperature, which has a large influence on the plant economy and performance. Then, design conditions were determined for the main equipment and each sub-system. The ultimate goal of plant engineering is to realize a geothermal power plant which is reliable, highly efficient, economical, and at the same time has a minimum influence on the environment.

More recently in 1999, Fuji Electric provided equipment to the Wayang Windu Geothermal Power Plant located in West Java, Indonesia also under an EPC contract. The power plant is equipped with a 110MW geothermal steam turbine, the world's largest single casing turbine for geothermal service.

Another recent example, in contrast to Wayang Windu in terms of its size, is the Hachijo-jima Geothermal Power Plant also inaugurated in 1999. The power plant, whose output is 3.3MW replaced distributed diesel power plants in Hachijo-jima island which is a remote volcanic island in eastern Japan about 300km from Tokyo.

3. Technological Aspects

3.1 Large capacity geothermal steam turbines

In the latter half of the 1980's, several large scale 110 to 150MW capacity units consisting of two 55MW class turbines coupled in tandem, were constructed in the Geysers area of northern California to lower the cost per kWh of generating power. These large units can certainly help reduce the plant construction cost per kilowatt, but they run the risk of causing a shortage of steam to generate the rated capacity. In fact, the last 150MW unit was manufactured and delivered in 1989 but never installed because of the shortage of resources. A large unit is especially unsuited for an IPP (independent power producer), which sometimes rely on only a single unit for revenue, use of a large capacity unit is inappropriate because of possible shut downs of the total power plant due to scheduled maintenance or trouble. Therefore, if the developer has enough steam to support 150MW, it is wiser to install three 50MW units or two 75MW units to increase the flexibility of plant operation.

3.2 Packaged type geothermal steam turbines

On the other hand, there are increasing demands to shorten the period of site work. Responding to this demand, Fuji Electric has standardized so-called skid mounted type turbines and has delivered several of them. To minimize the onsite installation work, steam turbines and generators in the 20 to 40MW range are completely pre-assembled on separate beds at Fuji Electric's Kawasaki Factory prior to shipment. For smaller units, it is possible to assemble both the turbine and the generator on one common bed. However a skid mounted configuration is impossible for larger units such as the ones manufactured for the Philippines and Indonesia due to transportation restrictions, Fuji's design aims to reduce the number of assembled blocks per shipment in order to shorten the installation period. Since most geothermal sites are in remote mountainous areas, and the majority of available labor cannot always be expected to be well experienced, reducing the number of blocks in the shipment becomes even more important from the point of view of both the site schedule management and the preservation of reliability.

3.3 Titanium alloy last-stage blades

Geothermal steam contains hydrogen sulphide, and in such an environment, the internal stress of turbine parts such as blades and rotor should be within the appropriate limit value for each material to avoid cracking due to stress and corrosion. The maximum centrifugal force is exerted at the base of the low pressure blade in the last stage. For this reason the length of the stainless steel blade of the last stage is limited to 26 inches at 60Hz (nominal) or 30 inches at 50Hz. However, since the enthalpy of geothermal steam is low, the turbine exhaust loss cannot be ignored as a portion of the heat drop across the turbine. By using longer last-stage blades, costs can be lowered by reducing the exhaust loss or by implementing a single flow design rather than a dual flow design for the same steam flow. A last-stage blade longer than current limit must be made of a titanium alloy which is lighter than stainless steel and has excellent erosion- and corrosion-resistant characteristics. Fuji Electric has successfully tested long titanium alloy blades and is prepared to supply turbines that use such blades. The physical dimensions of turbines will inevitably increase as longer blades are employed. While contrary to the concept of above mentioned skid mounted design, this technology may be used in the near future for a very big geothermal field if enough steam to support multiple 100MW class units is confirmed.

3.4 Utilization of low temperature geothermal resources

Most geothermal power generation is in the form of a flash cycle that introduces steam, separated from geothermal brine, directly into a steam turbine. To use low temperature geothermal resources for power generation, binary cycle technology employs a suitable thermal medium as the working fluid according to the hot water temperature. This technology has been utilized mainly in the USA. The capacity of a single binary unit is limited from several hundred kW to 4MW maximum. To build a large capacity plant such as a 40MW plant in the USA, many small units are combined. In Japan, NEDO (New Energy and Industrial Technology Development Organization) is involving in the development of a geothermal binary power plant. One problem is that a group of fluorine compounds, which were often used as the working fluid, can no longer be used anymore because they destroy the ozone layer. The application of a hydrocarbon or ammonium solution, or discovery of a new thermal medium is very important for further development of binary cycle power plants. Since medium and low temperature resources are more common than high temperature resources, it is possible that the binary cycle power plants will become popular in Japan once their reliability and economical feasibility are proven.

Other technologies that utilize medium and low temperature geothermal resources for power generation are the total flow turbine and the low pressure flash cycle. The total flow turbine directly intakes geothermal brine, which is either hot water or a mixture of steam and hot water. Fuji Electric designed and manufactured a small scale total flow turbine and carried out a series of factory tests and an onsite test of approximately 1,000 hours using a geothermal fluid. One possible application of the total flow turbine is to utilize hot water from the separator for power generation, before the hot water is re-injected to compensate for plant parasitic loads.

The low pressure flash cycle is similar to an open cycle OTEC (ocean thermal energy conversion). It simply generates low pressure steam by flashing hot water, and guides that steam into the steam turbine. This method does not require the development of new technology because the turbine is an application of the low pressure part of the existing dual flash steam turbine. The characteristic features of this system are that no special working fluid is necessary and that the plant parasitic load is small compared to a binary cycle.

3.5 New technologies

There have been several proposals to use heat from magma or volcanoes directly for power generation, and some basic research has been carried out. The hot dry rock (HDR) technology is probably the most advanced new technologies under development for geothermal power generation. In Japan both NEDO and the CRIEPI are working on HDR projects and have succeeded in retrieving injected water as steam. The next step will be improvement of the percentage and temperature of retrieval. An HDR power plant must be a closed cycle so that the flow of injected water can be reduced. One possibility to solve this problem is to employ a dry type cooling tower instead of the commonly used wet type. The application of a binary power plant is another possibility.

4. Conclusion

This year, the total installed capacity of geothermal power generation in Japan is 580MW, and some additional developments are planned. The Philippines increased their capacity during the 5 years from 1995 to 2000 by 680MW, which includes the construction work of geothermal power plants in Leyte and Mindanao, and still has further development plans. In such Central American countries as El Salvador and Costa Rica, several new geothermal projects,each being 50 to 60MW in size, were completed in late 1990s. Indonesia once had many plans for large capacity geothermal power plants, but these have been suspended ever since the country's economy crisis. However the already signed BOT or BOO (build, operate and own) contracts are still valid, and these projects are expected to resume soon. In addition to these big projects, installations of small wellhead units in remote communities which will allow more people to access to electricity are another possibility as a local energy source in a country like Indonesia.

Coping with the continuously increasing demand for energy while striving for harmony with the global environment is a serious issue for the entire world.

Geothermal power generation, however small a percentage of the total energy output, can be a major source of power in regions or communities where geothermal resources exist. Fuji Electric, through the construction of geothermal power plants based upon its many proven global technologies, as well as new technologies, will contribute to solving the global energy problem.

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