Geothermal Power Generation in China: Past and Future

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Keywords

Geothermal, power generation, capacity factor, resources superiority, barrier, China

ABSTRACT

Geothermal power generation has the highest capacity factor among renewable energy power generations. Considering investment cost, geothermal has highest investment benefit. China started geothermal power generation in 1970. It was the seventh country utilized geothermal electricity in the world. Since Yangbajain geothermal power plant completed total installed capacity of 24.18MW in 1991, there has been little in China. The barriers for Chinese geothermal power generation are due to longer exploration period, higher drilling risk, lack of demonstration projects and less favorable government policy. It is worth considering how to utilize the superiority of geothermal resources and accelerate the geothermal power generation in China.

1. Superiority of Geothermal Resources and Power Generation

Power generation is the most effective use of high temperature geothermal resources worldwide. It demonstrates the full potential of geothermal resources. It is a safe, stable and reliable resource when compared to other renewable energies. In the report from World Energy Council (WEC) to the United Nations, the capacity factor for geothermal power generation is the highest among all renewable energies [1](Fig.1).

Figure 1 shows a world average of capacity factors. However, Japanese made large units, such as single unit of 50MW, the capacity factor has reached 0.95. As an example, the Yangbajain geothermal power plant produces about 140 GWh of electricity annually with installed capacity of 24.18MW. Its capacity factor is 0.69 on average. Among 8 units in the plant, 7 of them are made in China. One 3.18MW unit is made in Japan. The domestic units need maintain once 2 times per year, but the Japanese unit requires maintenance once every 3 years only. It shows the higher efficiency for Japanese unit.

The investment cost of geothermal power generation is similar to hydraulic power (including relocation of residents) and wind power. It is cheaper than solar PV power. Therefore, there is a unique superiority for geothermal integrated investment benefit.

The global Mediterranean-Himalaya geothermal zone passes through Tibet and western Yunnan province in China. There are high temperature geothermal resources in this region. Liao[2] has identified 61 high temperature geothermal systems located in Yunnan-Tibet geothermal zone. The total reserved geothermal energy is 120 EJ ($E=10^{18}$). Its potential for geothermal power generation is 2,781 MW. In addition, there is potential of 3,036 MW from sub high temperature geothermal systems. Therefore the total potential of geothermal power generation is 5,781 MW in the region. The existing total of installed capacity of geothermal power generation is 27.28 MW in China. So the above potential is 213 times of existing installed capacity.

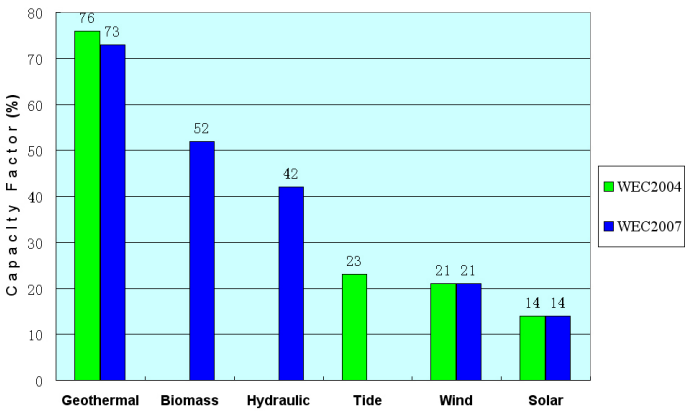

Figure 1. Comparison of capacity factors for renewable energy power.

2. Past Glory and Later Stagnation

The first geothermal power generation was in Italy in 1904. Projects in New Zealand (1958), US (1960), Japan (1966), previous Soviet Union (1966) and Mexico (1970) followed[3]. China implemented the first test unit of geothermal power generation successfully in 1970. At that time China was the 7th country

utilized geothermal electricity in the world. However, in the statistics of World Geothermal Congress 2010 China has been listed the 18th in terms of installed capacity in the world. The top 8 countries are US, Philippines, Indonesia, Mexico, Italy, New Zealand, Iceland and Japan.

Reviewing the past 40 years history, China shows a course from glory to stagnation. The history can be divided into 3 stages.

2.1 Glory in 1970s

The first geothermal power station is located in Dengwo Village of Fengshun County, Guangdong province in China. It started geothermal power generation on December 12th, 1970. At that time Prof. J. S. Lee, the former Minister of the Ministry of Geology sent a telegram to express congratulations. The test station used flash technology for 92°C geothermal water to run 72kW generator, upgraded later to 300kW. This is a low temperature for geothermal power generation by flash. Following this success, six similar stations of low-medium temperature geothermal power generation where created in 1970s. They are listed in Table 1 briefly[4].

Table 1. Low-medium temperature geothermal power stations constructed in 1970s in China.

Location			Installed Capacity (kW)	Geothermal Temp. (°C)
Village	County	Province		
Dengwo	Fengshun	Guangdong	300	92
Huitang	Ningxiang	Hunan	300	98
Houhaoyao	Huailai	Hebei	200	87
Tangdongquan	Zhaoyuan	Shandong	300	98
Xiongyue	Gaixian	Liaoning	200	90
Reshui	Xiangzhou	Guangxi	200	79
Wentang	Yichun	Jiangxi	100	67

In addition, 1 MW test unit of high temperature geothermal power generation started successfully to operate in Yangbajain, Tibet in October 1977.

2.2 Growth in 1980s

The Yangbajain geothermal power plant completed its full installation capacity of 25.18 MW in 1991. With the original 1MW test unit there are 8 units installed in south and north plants respectively. The south plant completed 10MW installation in 1985. It increased 3 units with each 3MW capacity progressively. Then the north plant installed 3.18 MW Japanese unit in 1986. And followed up 4 units of 3MW each. The 7 domestic units were made in Qingdao Jieneng Steam Turbine Company. During the ten years delivery, the Qingdao Company addressed comments from the user to improve its design and products progressively. But unfortunately, 5MW new design wasn't available. Yangbajain geothermal power plant provides electricity to the Central Tibet grid for power supply to Lhasa. The plant provided Lhasa with 50% average and 60% at winter power supply in the 1980s.

In addition, two of 1MW flash units for geothermal power generation were installed in 1983 in Langju plant in Ali region of west Tibet. It produced only for a short period in the mid 1980s. Its output reduced to 400kW for intermittent running. And then stopped due to insufficient steam yield.

2.3 Stagnate in 1990s

With aid from United Nations, an Ormat 1MW organic Rankin cycle binary unit was installed in Nagqu geothermal power plant in Tibet in 1993. It produced for a short period in the 1990s. Due to heavy scaling problem it stopped in 1999.

Even though the Yangbajain geothermal power plant has been running well since completing full installed capacity of 24.18MW (its 1MW test unit retired) as showing in Fig.2, geothermal power generation had little progress in the 1990s.

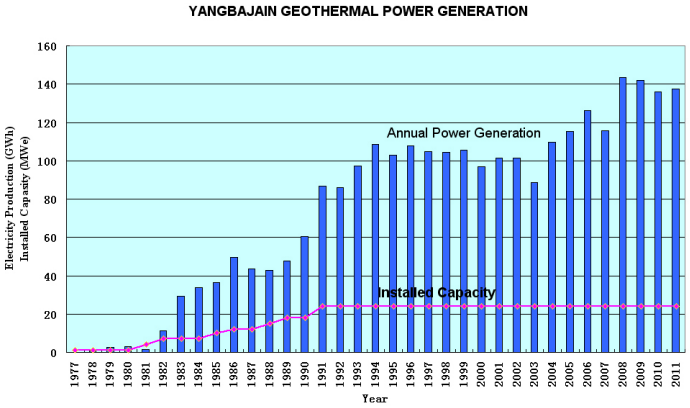

Figure 2. History of production in Yangbajain geothermal power plant.

2.4 Progress in Recent Years

After Stagnation for many years, a few private companies started to take part in geothermal power generation projects. The national owned enterprises, such as China Longyuan Power Group Corp. Ltd. and China Guodian Corporation, also contributed.

(1) The Sino-Italy cooperation project "Study on Tibetan energy sustainability and development strategy" completed in 2006 proposed geothermal development for power generation as supplement a power supply especially for winter electric shortages. At that time a private company from Zhejiang province intended to invest geothermal power generation in Tibet. The Tibetan Government, its Development and Reform Committee and electric power department supported the project. But due to no subsidy for grid price the project did not proceed.

(2) Since 2007 a private Jiangxi Huadian Electric Power Co., Ltd. has started a small project and some progress. A 1MW screw expander unit was installed in Yangbajain. It is the company designed product. Initially it intended to use waste discharge of 80°C and 50,000 m^3/d from existing Yangbajain geothermal power plant. But it didn't have success. Then it used a part of high temperature geothermal fluid from well ZK4001 to complete its test. A total 2 unit of 1MW screw expander were installed and operated in Yangbajain in 2009 and 2010 respectively. Then a 400kW unit of screw expander was installed in Yangyi geothermal field by using previous exploration well in 2011.

(3) In addition, a 400kW binary screw expander unit was installed in nationally owned North China Oil Field Corporation in 2011. It used 3 oil production wells in Liubei field. The wells yield about 2% of oil and 98% of hot water in total flow rate of 2,880 m^3/d at temperature 110°C[5]. The 400kW unit has been running well. Output used for infield supply.

3. Barriers for Geothermal Power Generation in China

Drawing conclusions from the past 40 years development, analyzing the factors restricted geothermal power generation in China, the barriers and suggests are 4 aspects as below.

3.1 Longer Period for Geothermal Resources Exploration

According to the national guidelines of "Geological Exploration Standard of Geothermal Resources", reconnaissance, detailed survey and exploration step by step will expense for several years. Fortunately, the new issued "Standard" in 2010 had permitted a simplified process.

3.2 Risk for Geothermal Well Drilling

High temperature geothermal resources reserved in fractured reservoir make for higher risk in well drilling. Professional team will have ability to reduce such difficulty. It should be better if we have "risk fund" to help such project.

3.3 Demonstration of Resource Management

Hot spring resorts have been a growing business in China because it is seen as a realitively safe investment. Yangbajain project, production wells drilled in center of manifestation area for geothermal power generation depleted the boiling springs and hot lake features. A demonstration of good resource management is needed to reduce such negative effects. As a comparison, Wairakei geothermal power plant has run for 54 years, but the geothermal manifestations nearby are still active. Therefore we need demonstration project to show the benefit from geothermal power generation without negative impacts.

3.4 Privilege Policy is Not Enough

Geothermal power generation as with other renewable energies needs higher initial or upfront investment. And has a longer recovery period. So it is necessary to have subsidy for new project. Solar PV has policy for subsidy of grid price as 1.15 CNY/kWh. Winds electricity and biomass electricity have also subsidy 0.53 CNY/kWh. But there is no subsidy for geothermal electricity. European countries have geothermal electricity subsidies up to 2 times conventional grid price. This has promoted development.

4. Decision Makers Are Still Thinking About …

If we invest 1,000 million CNY (about 159 million USD) for power generation, geothermal will produce 240 GWh/yr; while solar PV will produce 18 GWh/yr only. A 1 MW solar PV plant installed in Yangbajain in 2011, the project is close to the best of geothermal resources but didn't use it.

We need also consider the technology selection for geothermal power generator. There are flash, binary and full-flow methods can be chosen. What is suitable for us? It needs demonstration by practice. Unfortunately, the new test of screw-expander (Full-flow) unit completed a report. We could not say what the best is.

China was the 7th country for geothermal power generation in the world. There are 24 countries with geothermal electricity worldwide now. The world's geothermal power generation has been progressing during past 30 more years. But China has had stagnated growth. We need strengthen international cooperation to learn advanced experience from the World.

Acknowledgement

Author would like to express his thanks to Senior Engineer Yong Jiang, the Chief Engineer of Yangbajain Geothermal Power Plant, and Dr. Kewen Li, the professor of China University of Geosciences (Beijing), for providing concerned data. And thanks to Dr. C. Monis, Technical Committee of 2012 GRC Annual Meeting, for kind help for reviewing my paper.

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