GIVING FULL PLAY TO GEOTHERMAL IN RENEWABLE ENERGY DEVELOPMENT IN TIBET, CHINA

Keyan ZHENG[1]
[1]Geothermal China Energy Society, 20 Da Hui Si Road, Beijing 100081, China
E-mail: kyzheng@public3.bta.net.cn

ABSTRACT

There are various abundant renewable energy resources in Tibet. They can satisfy the local demand of power generation. Hydropower can bear the main part of power generation. But small flow rate at winter could not ensure a full load generation. However, high temperature geothermal resources can generate a full load electric power there. It can make up for the deficiency of hydropower especially in winter. Geothermal space heating either transporting waste hot water from Yangbajain geothermal power plant or using ground source heat pump, has ability to supply winter space heating for the whole buildings in Lhasa.

Keywords: renewable energy, geothermal, power generation, space heating, Tibet

1. INTRODUCTION

Tibet is located at the southwestern border area of China. Due to historical and geographical reason, local economy has not yet reached the inland average level. There is a lack of conventional energy resources in Tibet. And the energy utilization is in low level. There are 42% of populations without electric power supplying. Tibet Autonomous Region has planned to change this backwardness. How to raise the energy utilization in Tibet? It is proposed that fully utilize abundant local renewable energy, to create a biggest demonstration of renewable energy use. This will keep a natural ecological and environmental superiority. However, the abundant geothermal resources will have a full play in renewable energy development in Tibet.

2. DEMONSTRATION OF RENEWABLE ENERGY IN TIBET

There are 2.63 million people residing on vast land of 1.22 million km^2 in Tibet. Historical and geographical reason made local economy did not reach the inland average level. Energy supplying and utilization are the first problem. There are abundant renewable energy resources in Tibet as following:

Hydroelectric resources: There are very rich hydroelectric resources in Tibet. It occupies 29.7% of total hydroelectric resources in the country. Most of them have not yet been developed at present.
Geothermal resources: High temperature geothermal resources distributed in Tibet and west Yunnan province on the mainland of China. Yangbajain geothermal power plant has run for nearly 30 years.
Solar energy resources: There is the best condition of solar energy resources in Tibet if compared to whole of China. Lhasa has another name and has been called "the solar city".
Wind energy resources: There are good wind energy resources in Tibet. It is better in western Tibet.
Firewood resources: It distributed mainly at northeastern Tibet.
Dung resources: This is the main fuel in Tibet. It is used for cooking and heating popularly, especially in pasture areas in northern and western Tibet.

Due to above resources background, electric power as secondary energy sources in Tibet is hydropower mainly and geothermal power in secondary position, with few photovoltaic and wind power systems (GCES, 2006).

Hydraulic power generation: There is no unified electric grid in Tibet. Lhasa grid is the biggest grid called the Central Tibet grid. Its electric power comes from the Yamzho Yumco Hydropower Plant mainly. This is the biggest hydropower plant in Tibet. It has had an installed capacity of 90 MW, but plans an increase to 112.5 MW, and a second stage plan is being considered. The total installed capacity for hydropower in Tibet is 433.22 MW. It occupies 87.8% of installed capacity in Tibet.
Oil-burning electric power generation: There is small scale oil-burning electric power plants in Lhasa and Rikaze cities with total installed capacity of 25.6 MW in Tibet. It occupies 5.2% of total installed capacity in Tibet.
Geothermal power generation: There were 25.18 MW installed capacity in Yangbajain geothermal power plant, but it runs 24.18 MW after retiring the 1 MW test unit. There are another 2 MW installed in Langju of Arli, with 1 MW running now. And another 1 MW installed capacity in Nagqu has stopped due to scaling problem. So at present the

total installed capacity of geothermal power is 25.18 MW. It occupies 5.1% of total installed capacity in Tibet. However, total geothermal electricity occupies 9.9% of Tibetan electricity.
Photovoltaic and wind electricity: There is a total installed capacity of 9 MW in Tibet. It occupies 1.8% of total capacity.

Tibetan electricity has not been able to satisfy local electric demand at present. There are 4,850 villages, 0.21 million families and 1.1 million people without power supply.
Based on such basement, in order to change local economic backwardness, energy development will still emphasize the renewable energy resources, to create a biggest demonstration of renewable energy in the world.

3. GEOTHERMAL NECESSARY SUPPLEMENT FOR HYDROPOWER

There have been near 30 years experience for geothermal power generation in Tibet. Hydropower got strong growth in recent years. However, history and status can demonstrate that hydropower was the main part of electric power in Tibet, but geothermal is a very important supplement.

3.1 Yangbajain Geothermal Power Plant:

High temperature geothermal resources used for power generation started in Yangbajain geothermal field. The Yangbajain Geothermal Power Plant is called the bright pearl on the world's roof. It played a key role until middle of the 1990s for solving the electricity shortage in Lhasa city. The Tibetan Geothermal Geological Team was founded and started geothermal well drilling in 1976. They completed the first artesian geothermal well in Yangbajain Geothermal Field in 1977. The first 1 MW test unit was installed and run successfully at that time. Then the power plant was expanded until in 1991 it reached the highest installed capacity of 25.18 MW (1 + 3 × 3 MW in south plant and then 4 × 3 + 3.18 MW in north plant).

3.2 Investment Analysis of Geothermal Power Plant:

Total investment covers two parts including well drilling as underground part and power plant construction as surface part.
Geothermal exploration and production well drilling in shallow reservoir in Yangbajain Geothermal Field expanded to 30 million *yuan*. Deep production wells have been drilled, but have not been used yet. Power plant construction including workshop, steam turbine and generator, wellhead equipment and pipeline, electricity transporting facilities etc. expanded to 192.91 million *yuan*. Therefore, the total investment is equivalent to 8,852.7 *yuan* per kW (TGGT, 2000). As comparison, the average hydropower construction fee in Tibet is 11,980 *yuan* per kW. While the photovoltaic power station is more than 0.1 million *yuan* per kW. So geothermal power is very attractive economically (TGGT, 2000).

3.3 Operation Status of Geothermal Power:

All generation units in Yangbajain geothermal power plant have run for 15 to 25 years. These equipments have become old. The yield of the geothermal wells has decreased. Initial wellhead temperature 160-180°C has decreased to about 120°C. The existing installed capacity 24.18 MW can run a load of 18.5 MW. So its real output is about 75% efficiency. But they run 4,400 to 6,240 hours per year at present. The annual production is 109.73 GWh in 2004 and 115.44 in 2005. They created new records continuously for this plant. Yangbajain geothermal power plant has generated a total of 18,800 GWh electricity (Fig.1) (GCES, 2006).

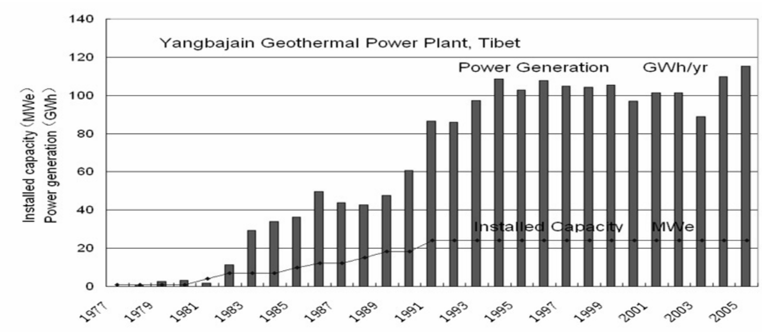

Figure 1 Yangbajain power plant capacity and generation

3.4 Necessary Supplement for Hydropower

There is abundant hydropower resources in Tibet, because huge land areas and less population. Due to less precipitation (438 mm in Lhasa), river gets recharge from melted mountain snow. So flow rate in winter is very limited. Local people need more heating and electricity in winter. But it is no possible from hydropower. So geothermal power is very important supplement there. Geothermal installed capacity is about one fifth of total capacity in Lhasa. However the geothermal electricity is 25% and 40% of total Lhasa usage in summer and winter respectively. It shows the significant function for geothermal power.

Before the completion of Yamzho Yumco Hydropower Plant, geothermal power generation satisfied 50 % electrical demand in Lhasa, and specially 60 % in winter.

3.5 Geothermal Power Generation Prospects

Yangbajain geothermal power plant has been using the shallow reservoir only. Deep exploration had carried out and new deep production wells have been drilled. The National Committee of Mineral Resources Reserves approved its reserves in 1997: exploitable fluid 300 t/h with steam 37 t/h in which, its potential of power generation is 12.5 MW. In addition, another Yangyi geothermal field has been explored already. It is located 55 km south of Yangbajain. The National Committee of Mineral Resources Reserves approved its reserves in 1991: 30 MW potential of power generation. All these are potential reserves.

4. GEOTHERMAL & GEO-TEMPERATURE WINTER SPACE HEATING

It is necessary for winter space heating in Lhasa, the capital city of Tibet. But there is no heating facility basically in Lhasa before. At present, only about 10% of buildings installed heating system. Considering a scheme for winter space heating with saving energy, high efficiency and environment protection purpose, geothermal could play an important role.

4.1 Feasibility of Geothermal Space Heating

Yangbajain geothermal power plant discharges waste thermal water from steam in 80^{o}C and 50,000 m^{3} per day. The most of the water has been discharging into local Zangbu River. This wastes heat energy and pollutes the river by high contents of fluoride and boron etc. chemical compositions. However, the waste thermal water can be used for winter space heating in Lhasa of 90 km away (GCES, 2006). This needs to solve corrosion problem, reduce temperature loss, avoid high pressure in pipeline and avoid environment pollution.

(1) Thermal Water Corrosion Problem

Solving the corrosion problem needs a large scale heat exchange station. The waste thermal water just passes through heat exchanger of titanium material, then reinject into Yangbajain shallow reservoir. So only the heated clean water was transferred to Lhasa.

(2) Pipeline Temperature Loss

Following the experience from Iceland, we'll use the same pipeline and insulated material of polyurethane foam. Our flow rate is very similar with Iceland. Assuming we would have a 20% discount, so we'll get 6^{o}C temperature loss.

(3) Avoiding High Pressure in Pipeline

There is an elevation difference of 600 meters between Yangbajain and Lhasa. So it will accumulate 60 atmosphere pressures. We can divide the total pipeline into 15 sections. Use simultaneous computer controlling system. If leaking or plugging occurred at someone section, the simultaneous control can protect a safe operation.

(4) Avoiding Environment Pollution

The original geothermal water has been reinjected after passing the heat exchanger. So it will not have any pollution problem.

(5) Potential of Space Heating

Waste thermal water will lose 5^{o}C when passing through heat exchanger. Piping transferring will lose 6^{o}C. So the thermal water at Lhasa end will be in 69^{o}C. We use heating index of 60 W/m^{2}. Therefore, when the thermal water decreased temperature into 35^{o}C, the total thermal energy can supply a heating area of 1.37 million m^{2}. It is 35% of total Lhasa building area.

We can further use GSHP to reduce the water temperature into 15^{o}C. So we can solve space heating for additional 1.09 million m^{2}. It will cover 60% of total building area in Lhasa. When we develop Yangbajain deep reservoir, we'll get more separated thermal water, which we can use for heating more buildings.

4.2 Feasibility of Ground Source Heat Pump

GSHP has great and continuous growth in recent 10 more years in the world. Its COP can reach 3-4 and does not cause environment pollution. So GSHP can form the best option for winter space heating (GCES, 2006).

(1) For Open System GSHP
There are rich groundwater resources especially along the Lhasa River basin. Lhasa city is mainly located on the Lhasa River basin. We can drill wells in 30-50 m depth to get rich groundwater. We can use 5°C temperature difference. A shallow well drilled on Lhasa River flood plain and bench can get production rate of 80 m^3/h. For total building area of 3.91 million m^2 in Lhasa, for heating index 60 W/m^2, the total heat load is 234.66 MWt. It needs a total flow rate of 40,354 m^3/h. We need drill 504 production wells and other 504 reinjection wells. For Lhasa constructed 51 km^2 urban area, we use 60% of the land. Then the space among wells will be 174 m. This density is no problem for flood pain and bench. There will be no interference among wells.
(2) For Close System GSHP
Usually we drill heat exchange hole keeping a space of 5 m. It means per 25 m^2 drill one hole. The depth of hole is 200 m. We use 7°C temperature difference. The thermal conductivity for soil and rock is 2.1 W/m.°C usually for the area without anomaly. So this hole with a U-type circulation pipe will be able to collect about 5.6 kWt thermal power. It can serve near 100 m^2 building area. This means 25 m^2 land area can satisfy a thermal demand of 100 m^2 building area, or say, 1 m^2 land area can satisfy a thermal demand of 4 m^2 building area. It is never problem for the application of close system GSHP.

4.3 Cost Estimation
By calculation, the heating cost for transporting waste thermal water from Yangbajain to Lhasa, including heat exchanger station, main pipeline, distribution pipeline and indoor facilities, for heating 1.37 million m^2 is about 326 *yuan*/m^2; while for heating 2.46 million m^2 is 305 *yuan*/m^2. The cost of investment for GSHP in inland cities is 220-300 *yuan*/m^2, considering high transport fee and lower efficiency, the cost in Tibet will be 330-400 *yuan*/m^2.

Above investment costs are basically equivalent to oil boiler or gas boiler. However, their running cost is much less than conventional energy sources (Table 1).

Table 1 Comparison of Heating Cost

(*yuan*/m^2)	Cost of investment	Running cost
Geothermal heating	326	19.6
Geothermal + HP	305	21.0
GSHP	330-400	22.4
Oil boiler	346	52.4
Gas boiler	400	35.8
Coal boiler	130	22.7

* One USD exchanges about 8 *yuan*.

5. CONCLUSIONS
There is a lack of conventional energy resources in Tibet, China. Existing power generation and future growth all rely on renewable energy resources. Hydropower is the main source of electricity in Tibet. It has great potential. But its limitation is serious inadequacy of water flow in winter. Geothermal power generation can make up for the deficiency of hydropower especially in winter. Geothermal can also give play to strong points in space heating in winter, either transporting waste thermal water from Yangbajain or using ground source heat pump.

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