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Geothermal Power Generation in Kamchatka, Russia

Dmitriy V. Kolesnikov[1], Aleksey A. Lyubin[1], Aleksandr N. Shulyupin[2]

[1] JSC "GEOTHERM", Koroleva str., 60, Petropavlovsk-Kamchatsky, Russia

[2] Far Eastern Mining Institute of RAS, Turgenev str., 51, Khabarovsk, Russia

E-mail address, ans714@mail.ru

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ABSTRACT

Complexities and possibilities of geothermal power generation in Kamchatka are considered. Conditions of Pauzhetskaya and Mutnovkaya geothermal power plants are analyzed. Promising geothermal fields are presented for the construction of new power plants.

1. INTRODUCTION

Kamchatka (Kamchatskiy Krai) is a region of the Russian Federation, located in the Far East. This region includes the Kamchatka peninsula and the surrounding territory. The power system of the region is isolated and consists of Central Power Hub that runs at 85% generating capacity, and many small technologically isolated power hubs. The total installed capacity of Kamchatka is 578 MW. Structure of the installed capacity of Kamchatka is shown in Figure 1. Consumption is dominated by domestic concerns and the non-productive sphere. Industry, agriculture, construction, transport and communications account for only 15%. Power consumption in all power hubs is characterized by pronounced seasonal and daily changes: winter load is approximately 1.5 times higher than summer, and daily load is about 1.5 times that of night.

More than 90% of the installed capacity of Russian geothermal power generation is located in Kamchatka. Kamchatka has three geothermal power plants: Pauzhetskaya power plant (14.5 MW), Verhne-Mutnovskaya power plant (12 MW) and Mutnovskaya power plant-1 (50 MW). About 20% of electric power in Kamchatka comes from geothermal sources, 60% from ordinary gas thermal power plants, 10% from hydro-power plants, and 10% from diesel engine stations. The state of existing geothermal power plants is examined and new possibilities for further development of regional geothermal power generation are explored in this paper.

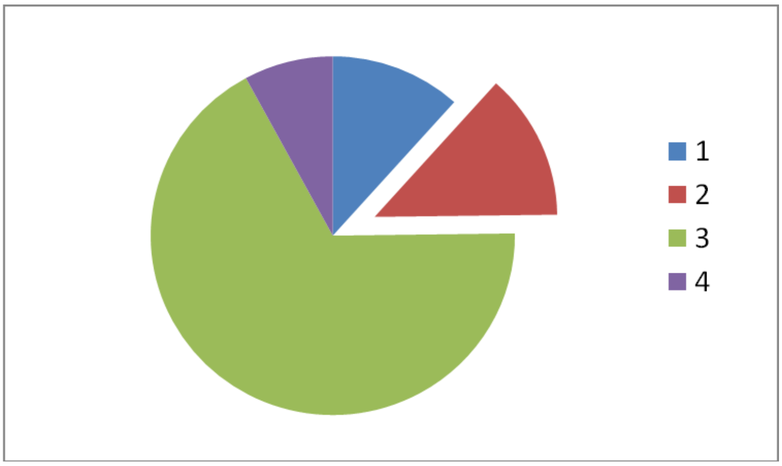

Figure 1: Structure of the installed capacity of Kamchatka. 1 – diesel engine stations, 2 – geothermal power plants (13.2%), 3 – gas ordinary thermal power plants, 4 – hydro-power stations.

2. OPERATING GEOTHERMAL POWER PLANTS

2.1 Pauzhetskaya power plant

Pauzhetskaya power plant is located in the South-western part of the Kamchatka peninsula, 30 km east of Ozernovskij settlement, located on the coast of the Okhotsk Sea. The power plant was put into operation in 1966. The power plant has two 6 MW turbines of direct cycle and 2.5 MW binary turbine. The first steam turbine is designed for an inlet pressure of 1.2 bars and a steam flowrate of 24.2 kg/s. The second steam turbine is designed for an inlet pressure of 2.2 bars and a steam flowrate of 25.8 kg/s. The binary turbine is designed for a separated water flowrate of 118 kg/s at 120^{o}C. Presently, one steam turbine is in operation, while the other steam turbine is a reserve.

The geothermal reservoir contains water with a temperature of about 190^{o}C. Proven steam resources of the Pauzhetska field are 35.5 kg/s (steam-water mixture – 424.5 kg/s) (Asaulova et al., 2009). This steam-water mixture is produced from 10 wells.

Productive wells work with a constant flowrate. The total steam flowrate is 27.7 kg/s, wellhead pressure is 2.5-5.5 bars. The mixture is separated at the well head. Steam and water are transported separately by trunk pipelines.

The power plants work with variable power. Power is regulated by the discharge of steam from trunk pipelines in air. The steam flowrates of the turbines and discharge are not measured. Rough estimates of the discharged steam are about 50%.

The plant works as an isolated power hub. Users of electricity have increasing electricity requirements. The maximum total user requirement now is about 8 MW. Some users install their own diesel stations. The cost of the geothermal electricity for an average user is about 0.08 USD per kWh. This is 10 times less than that of diesel stations.

The station contains obsolete equipment, increasing the complexity of the operation. For example, the first steam turbine was manufactured in 1949. Both steam turbines have history prior to installation on the station. Furthermore, the most recent productive wells were drilled 35 years ago.

In addition, there is complexity associated with legislation. Laws require large payments for the discharge of harmful components contained in the waste water. It does not take into account the specificity of geothermal energy. For example, does not take into account the reduction of the natural sources in the time of the intensive selection of fluid.

Operation of the power plant shows the dependence of the quality and quantity of steam from the meteorological conditions. Heat losses in steam pipelines increase significantly in strong winds and rainfall. Some of the steam condenses, decreasing steam flowrate and dryness fraction. In these cases, the steam reserve is required to compensate for losses in order to meet the power demand.

There are claims to the well separators. Water level in separators is not regulated. In order to prevent the entry of water into the steam pipeline, operating mode is set with the skip of steam in water pipeline. This reduces flowrate in steam pipeline and, making it difficult appears to transport water through the pipeline.

Another significant concern was the reduction of maximum operating pressure at the wellhead. At some wells the maximum operating pressure decreased to values that excluded the possibility of connection to trunk pipeline. The main reason for wellhead pressure reducing is a pressure reduction at the bottom. In the past 30 years, bottom pressure was reduced by approximately 10 bars. Continuation of this trend will have a negative effect. Special studies have revealed the presence of a reserve to compensate for the steam loss in case a production well declines. This reserve is related to the optimization of the steam gathering system. Therefore, it is necessary to begin a drilling of new wells in the near future. It is necessary to develop new sites of the geothermal field.

2.2 Verhne-Mutnovskaya power plant

Verhne-Mutnovskaya power plant is located in 60 km to the southwest of the city of Petropavlovsk-Kamchatsky. The power plant was put into operation in 1999. The power plant has three identical direct cycle turbines of 4 MW each. Each turbine is rated at 8.3 bars inlet pressure and a steam flowrate of 8.4 kg/s. Another feature of the station is an air-cooled condenser.

The power plant is part of a single complex with Mutnovskaya power plant-1. These plants share the same geothermal field. This complex is involved in the Central Power Hub.

2.3 Mutnovskaya power plant-1

Mutnovskaya power plant-1 was put into operation in 2003. The plant has two identical direct cycle turbines of 25 MW each. Each turbine is rated at 6.1 bars inlet pressure and a steam flowrate of 44.5 kg/s.

The geothermal reservoir contains two-phase water . Temperature of reservoir is 250-300^oC. Proven steam resources of Mutnovskoe geothermal field are 172 kg/s. Fluid is extracted from 12 wells for a total steam flowrate of 156 kg/s. Wellhead pressures are 7-10 bars. Separation of the mixture is done at the plants. Steam-water mixture from wells is transported by individual and common pipelines. Separated water and waste heat are fed into the reinjection wells.

The decision about two-phase transportation was the result of administrative intrigues. Steam-water pipelines were built without hydraulic calculation until 2003. The optimal diameter of pipes sometimes was not determined. Some pipelines have created great pressure loss, some pipelines experience pulsations. Compensation of temperature extensions was implemented by curves in pipelines. Hydraulic calculations related to pipelines began in 2003 (Shulyupin, 2013). Old pipes were reconstructed and new ones were built. Bellows expansion joints were established and the non-functional local resistances were eliminated. At present, the total length of pipelines of steam-water mixture is more than 10 km. The longest pipeline has a length of 2.3 km.

The cost of electricity from the Kamchatka Central Power Hub's geothermal plants is 0.07 USD per kWh. This is several times lower than the cost of electricity from gas thermal power plants, which are the basis of the Central Power Hub. Gas plants have used mazut as fuel in the past. The mazut is delivered fuel, gas is extracted in Kamchatka. Replacement of the fuel is a strategic decision. Therefore, the use of gas is encouraged by the Government. Ordinary thermal plants have subsidies for gas buying.

The main difficulty of exploitation of Mutnovskih plants are connected with bad meteorological and geographical conditions: strong winds, heavy precipitation, snow cover (Figure 2), rugged terrain. The plants are operated by two weeks shifts. Some complexity creates an accumulation of salts in wells, pipelines and other equipment.

Figure 2: Well box in snow cover.

Significant concern was the attempt to operate the plants in the mode of variable power. The cost of production on geothermal plants is lower than on gas power plants. Operation of wells with constant flowrate makes exploitation of geothermal plants in the variable power mode extremely inefficient, reduces capacity, and increases operating costs. Reducing of gas plant capacity reduces overall maintenance costs. Logic dictates that gas power plants should operate in variable power mode, while geothermal plants operate at constant capacity and deliver baseload electricity. However, bias toward the gas industry sometimes leads to illogical decisions.

3. PROSPECTIVE FIELDS

Kamchatka has a great potential for geothermal power development. There are many promising geothermal fields. There are opportunities to develop hydrothermal and hot dry rock resources. In the present paper projects that require complex solution of technological problems will not be considered. Only fields which have geological exploration showing potential for drilling productive wells are considered. The development of these fields does not require the development of novel technologies. This allows us to estimate the cost of their development.

3.1 New sites of Mutnovskoe geothermal field

The strategy of development of Mutnovskoe geothermal field involves the construction of the Mutnovskaya power plant-2 with capacity of 50 MW. The southern section of field has still preserved wells, which are suitable for the operation. Funding for preserved wells make it possible for expansion of the plant up to 25 MW by installing one turbine, similar to the existing Mutnovskaya power plant-1.

Technical state of Verhne-Mutnovskaya power plant is not very good. The actual inlet pressure in turbines is below the estimated. As a result the actual steam flowrate is more than 3 kg/s per MW. It is 1.5 times more than Mutnovskaya power plant-1. It is rational to replace the Verhne-Mutnovskaya power plant with one 25 MW turbine. Drilling of additional wells on the outskirts of exploited sites of the field will download the turbine completely. This will bring the total capacity of Mutnovskaya power plants up to 100 MW.

3.2 Bolshebannoe geothermal field

Bolshebannoe geothermal field is located in 40 km west from the Vilyuchinsk town. Detailed exploration was executed in 1961-1969. Operating resources were determined according to the total debits of productive wells at the end point of experimental-production well discharge when filtration regime in reservoir was stable. Minimum evaluation of renewable resources is the 220 kg/s of underground water at high pressure with an enthalpy of 662 kJ/kg. Static groundwater levels in wells are above the surface of the Earth at a height of 10.0-34.5 m.

This field is well known. It has a convenient location (proximity to users, affordable relief). Currently, however, the field is not used. Drilled wells are deleted. The main cause of loss of interest in the field is the accumulation of salts in wells that is associated with the chemical characteristics of liquid and gas composition. The accumulations were found in the top of the wells in the zone of two-phase flow.

As shown by Shulyupin and Chernev (2013), this field is well suited for use with suppressed boiling in wells. This method involves using deep pumps at high pressure. Hot water at a pressure above the boiling point enters the heat exchanger where the heat transfers to the binary heat-carrier. The lack of a transition phase keeps the chemical equilibrium and does not cause the selection processes of mineral components. Proven resources enable you to plan for the construction of the binary power plant with capacity of 14 MW. This plant can connect to Central Power Hub and effectively operate in the mode variable power, which is especially important for Central Power Hub.

3.3 Koshelevskoe geothermal field

Koshelevskoe geothermal field has interest in the longer term. The field is located 230 kilometers south-west of Petropavlovsk-Kamchatsky city. Currently, the closest power hub to the field is isolated from the Central Power Hub. There are no potential consumers to justify the start of construction of the power plant. Comparison of similar data indicates that the resources of Koshelevskoe geothermal field are not less resources of Mutnovskoe geothermal field. Therefore, a power plant could have a capacity of 100 MW.

4. CONCLUSION

Geothermal development in Kamchatka faces difficult conditions. Geothermal power plants have to compete with other forms of energy which are favored by bias. Part of the equipment of the geothermal power plants has a high degree of wear. This has a negative impact on development in the utilization of geothermal resources.

However, Kamchatka remains the leader of geothermal power generation in Russia and has good opportunities for development. The first development was linked to the possibility of the construction of new blocks in the Mutnovskoe geothermal field. In the longer term, there is potential for development of the Bolshebannoe and Koshelevskoe geothermal fields.

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