Part 8

RENEWABLE ENERGY SOURCES

8.1. Geothermal power plants (GPPs)

8.1.6. Overview of development of GPPs and heat supply systems as of 2014

M.P. Rogankov, E.E. Mikushevitch, V.M. Mikushevitch, Ecopolis ltd, Moscow, Russia

ABSTRACT

Geothermal sources of energy production are the matter of interest for a long time; however, due to different reasons, the main of which is their location close to natural geothermal sources, meanwhile they show comparatively small share of energy production in the whole balance of renewables. According to [1] capacities of all of renewables (without all hydro) in 2013 constituted 560 GW_e, and only 12 GW_e (or 2,1 %) refer to geothermal power plants (GPPs). Attractiveness of geothermal sources is substantiated by comparatively simple extraction or just availability of steam-and-water mixture or hot water, somewhat ready for further utilization for energy supply purpose.

Industrial use of geothermal hot water for the purpose of heat supply in the former USSR began in 1960's of the XX century. In 1988 its annual extraction constituted 60 mln m^3 [2]. The main regions of geothermal use in Russia are Kamchatka peninsula, Northern Caucasus, Krasnodar region. Some of hot water supply systems for small objects and settlements are in operation by the time being.

In 1967 Paratunskaya GPP on Kamchatka peninsula was built, being the first power plant with binary technology. This initiative gave a start to development of GPPs and at the time being some hundreds of binary units are in operation. GPPs were also developed. At Mutnovsky geofield in 1999 12 MW_e Verkhne-Mutnovskaya GPP was commissioned (comprising 3 units by 4 MW_e each), and in 2001 - 50 MW_e Mutnovskaya GPP (comprising 2 units by 25 MW_e each). Since 1993 3,6 MW_e Mendeleevskaya GPP on Kunashir Island is in operation (comprising module units Omega-500), the power plant is now under extension refurbishment to capacity of 7.4 MW_e.

In RF some more GPPs and heat supply systems are already designed and under design. In RF in case of the most optimistic scenario of geothermal energy use in the foreseen future it is possible to achieve 860-870 MW_e at GPPs and 850 MW_{th} at heat supply systems [2].

In the paper the authors used materials from the first version of section 8 "Renewables" of the Information Electronic Constantly Updated Open System "The Best Available and Perspective Nature Protection Technologies in the Russian Power Industry" (OIS BAT, http://osi.ecopower.ru), prepared by JSC ENIN [3] and more actual materials available later.

1. GEOTHERMAL POWER PLANTS WITH DIRECT CYCLE TECHOLOGIES

Brief description

In direct-cycle technologies with back-pressure and condensing-type turbines steam after separation of a water-steam mixture (received from a well) in a separator is directed to a turbine. Principle scheme is presented in Fig. 1 and Fig. 2.

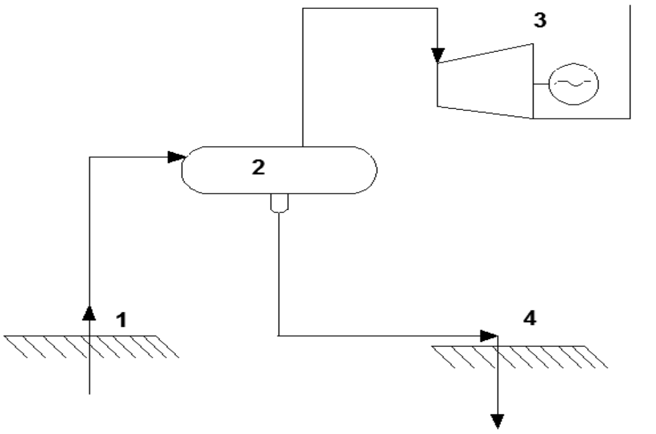

Fig.1. GPP with a back-pressure turbine
1 – steam-and-water mixture from a well; 2 – separator; 3 – turbine and generator; 4 – reinjection well

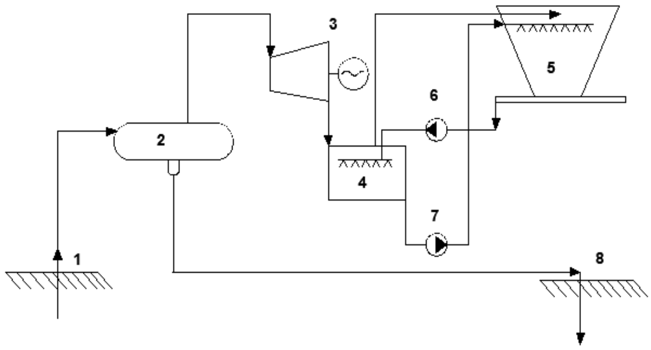

Рис.2. GPP with condensing-type turbine
1 – steam-and-water mixture from a well; 2 – separator; 3 – turbine and generator; 4 – mixing condenser; 5 – cooling tower; 6 – circulating pump; 7 – condensate pump; 8 - reinjection well

Types and capacities of power-generating equipment where it is recommended or possible to implement the technology under consideration

JSC "Kaluga Turbine Works" offers the unit-type turbine blocks, working with steam-and-water and low-temperature boiling working agents with capacity of 0,5…25,0 MW_e especially for GPPs of direct and binary cycle technologies: К-25-0,6, Tuman-2, GTS-700P и GTS-700V [4]. Turbines are manufactured small-sized and assembled for transportation in containers, as well as unique double-flow type. Turbine parameters:

- nominal electrical capacity — 1700...24650 kW_e;
- nominal thermal capacity — 0...2000 kW_{th};
- absolute pressure of dry saturated steam — 0,4...0,9 MPa;
- steam temperature — 151 °C;
- steam pressure after the turbine — 5,0...130 kPa.

Manufacturers of equipment

JSC "Kaluga Turbine Works" according to its own declaration is a monopolist of production of back-pressure turbines for GPPs in RF. Abroad they are manufactured in Japan, USA and Italy. Their capacity is not higher than 10 MW_e).

Range of applicability

Range of applicability of technologies with back-pressure and condensing-type turbines is substantiated by parameters of steam-and-water mixture (pressure, temperature and content of non-condensing gases in the gas matter), capacity of a geo-well, period of exhausting of potential of a geofield, parameters of a separator.

Technology application restrictions

Power units with back-pressure turbines are usually implemented at very high content of non-condensing gases in the gas matter (over 12…15 % by weight), the restriction is a situation when their output from the condenser becomes unprofitable from the point of view of energy consumption for auxiliaries and from economic point of view. In case of geological reasons the lifetime of a geofield is not enough for payback period for GPP with turbines of condensing type, then this niche can be opened for back-pressure turbines.

Advantages and disadvantages

Advantages:

- general advantages, characteristic for all of the renewables (elimination of pollutants except H_2S and some minor matters with steam-and-water mixture of the geofield, practically zero additional GHG emissions, organic fuel savings, diversification of energy sources, company's image increase aspects, etc.);
- specific capital investments per 1 kW of installed capacity together with well drilling (USD 1600…2000/kW for units with back-pressure turbines and USD 2000…2500/kW with condensing-type turbines) are comparable with the same parameter for coal-fired TPPs;
- all of the equipment can be manufactured by Russian producers;
- low operation costs and lower cost price of electricity as compared with traditional TPPs.

Disadvantages:

- specific capital investments per 1 kW of installed capacity together with well drilling for units with condensing-type turbines are higher than for gas-firing TPPs;
- substantial emissions of H_2S and micro emissions of other pollutants together with exhaust steam;
- necessary measures to prevent salt sediments.

References in RF

Power units of 3,6 MW_e with Omega-500 modules with back-pressure turbines are in operation at Mendeleevskaya GPP (Kunashir Island), being now under refurbishment with extension of capacity to 7,4 MW_e. Such units can be as well recommended as temporary power sources for self consumption and auxiliaries at construction sites of more powerful GPPs at geofields.

Two 25 MW_e power units with wet steam condensing type turbines are in operation at Mutnovskaya GPP. At Verkhne-Mutnovskaya GPP a small-scale condensing module "Tuman 4k" manufactured by JSC "Kaluga Turbine Works" is fully assembled in one unit.

Information on presence/absence of author's rights on the implemented technology, developers and/or legal owners of the technology

In the process of creation and improvement of GPP equipment some components and technologies were defended by author's rights (patents of JSC ENIN, JSC Nauka and other companies).

2. GPPS WITH BINARY CYCLE TECHNOLOGIES AND COMBINED ONES

Since in the Information System of the Moscow Power Engineering Institute "available" technologies in this subsection are presented, technologies of binary cycle and combined ones are described informatively since till now they are not introduced in industrial scale in RF. This material is based on the source [3].

Binary cycle technology means introduction of 2 circuits: the first one - with the energy carrier from a geosource, the second one - with the energy carrier having the lower boiling temperature (Fig. 3).

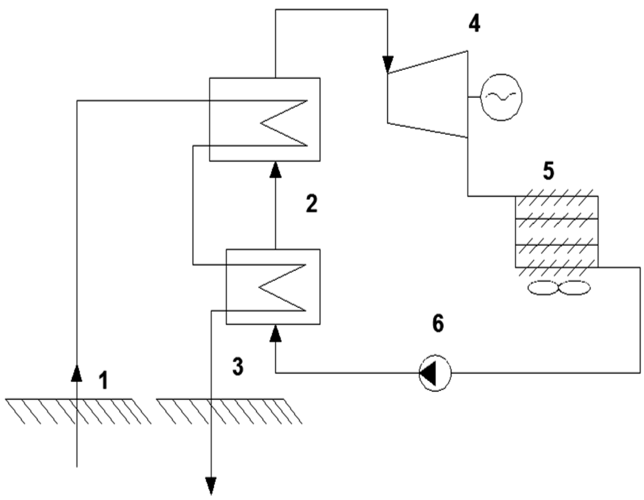

Fig. 3. Scheme of a binary GPP
1 – elevator well; 2 – heat exchanger-steam generator; 3 – reinjection well with a force-pump for saline; 4 – turbine; 5 – condenser; 6 – condensate pump

<u>Binary technology</u> makes it possible to escape such a threat as sediments of salts appearing while evaporation of geothermal brines in technologies with expanders. In the first circuit after cooling to the critical temperature defined by the absence of sediments of salts, the brine returns underground. To increase the amount of brine, the submerged pumps are sometimes used in the income well at the depth of 200 m and for the return pumping the forced pump are almost always used before the reinjection well (these modifications are not shown in Fig. 3). Coolants are used as a working substance (propane, butane, freon, and recently considered water-ammonia mixtures). Such a technology makes it possible to use dry steam in the turbine which is more efficient. The exhaust steam from the turbine is also dry (i.e. the turbine is a back-pressure type), and in some cases it becomes reasonable to utilize heat of that steam in a recuperative heat exchanger which is placed before the condenser*5* (not shown in Fig 3); the condensate is forwarded to the inlet of the steam generator.

The first in the world geothermal installation, using such a technology with freon-22 as a working substance, was tested in the middle of the XX century at Paratunsky geofield on the Kamchatka peninsula. At the time being serial production of 0,5…3 MW_e energy modules with low-temperature boiling working substances is made by company ORMAT (Israel). Total capacity of GPPs with such modules in many countries exceeds 350 MW_e. The cost of the module, manufactured by this company, is about USD 1000/kW_e of installed capacity. In our country JSC "Kirovsky Works" worked out the design of a 1,5 MW_e module on Freon 42b which does not impact the ozone layer. R&D in this field is under way.

Combined technology makes it possible to use the potential of water-and-steam mixture to a fuller extent. Each steam turbine is included both in the first and the second circuits. After the elevating well water-and-steam mixture is forwarded to a separator from where it goes to a back-pressure steam turbine. After this turbine steam goes to a condenser which performs a steam generator with low-temperature boiling working substance; then the steam is forwarded to the turbine of the second circuit. Thermal scheme provides utilization of condensate heat and of other flows. This technology is most effective at low ambient temperatures. As evaluated in [3], power production at Mutnovsky geofield with this combined technology will rise by 20 % as compared with GPP with condensing technology. JSC "Nauka" and JSC "ENIN" received a corresponding patent.

GPP with combined technology, produced by Israeli company ORMAT, is working on Phillippines and in Indonezia.

In RF it is envisaged to build the 4th unit with capacity of 6 MW_e at Verkhne-Mutnovskaya GPP.

3. SYSTEMS OF HEAT SUPPLY BASED ON GEOTHERMAL SOURCES

Brief description

Variety of local conditions for arranging this or that heat supply system, disposition of primary geothermal source and heat consumers, different parameters of geothermal water and its content, potential of primary geothermal sources, features of heat consumers and other conditions predetermine a number of options of heat and hot water supply systems and the choice of the principle scheme. In our country centralized heat supply systems, including long-distance are implemented for decades and the problem of heat supply system with geothermal sources is not much of scientific character but is more application engineering one.

Some examples of such options are named below. When there is a substantial reserve of geothermal resources – it is an open and dependent type of geothermal hot water supply; when the resources are limited – it is an open type of geothermal hot water supply and heating from another source; when the temperature of geothermal water is higher than calculated for heating – it is series supply for heating and then on hot water supply; when the temperature of geothermal water is lower than calculated for heating – it is parallel or series supply for heating and hot water supply with additional peak heating from another source for heating; when primary geothermal resources are limited and the cost of geothermal hot water extraction and transportation is high – there are systems with additional peak heating and thermal pumps and combination of the hot water system with the air heating system; when there is an equal balance between a debit of geothermal water and hourly average consumption of hot water system – there are non-outlet systems. Dependent on chemical content and temperature of geothermal water these systems can be either one-circuit (without intermediate heat exchanger) or double circuit (with intermediate heat exchanger), open-type and closed-type, with dependent or independent connection of local heating system with heat networks.

Systems of geothermal heat supply comprise the following: water intake, located at geothermal field, primary heat network of geothermal water; secondary network with tap water unit of waste water outlet into an open water source or its pumping underground.

In order to protect the elements of a heating system from aggressive impact of thermal water, protective coating, special materials, plastic lining, corrosion inhibitors, anti-gyp treatment are implemented. To prevent sediments of suspended matters and sludge and for removal of gases the speed of hot water in the system should be not less than 2 m/sec. To utilize the thermal potential of geothermal water a complex use of heating systems is designed: for heating, for technological purposes, for hot water supply of greenhouses, swimming pools, public saunas, laundries, etc. Control of heat supply is conducted at the well, in peak boiler houses, pump stations, heat distribution units at the inlet to buildings. Daily unevenness of thermal water consumption for heat supply is equalized with the help of accumulating tanks. In geothermal systems of heat supply primarily heating appliances with ambient air control of heat emission are used.

Types and capacities of power-generating equipment where it is recommended or possible to implement the technology under consideration

Depends on consumers' demand of heat and hot water supply, the capability of geothermal source, the chosen principle scheme of heat supply, etc.

Equipment manufacturers

Many domestic producers of power-generating and auxiliary equipment.

Range of applicability

From heat and hot water supply of several buildings to big settlements, green houses, swimming pools, etc.

Restrictions on technology's implementation

Limited potential of a geothermal source, low temperature of geothermal water, high mineralization of geothermal water, far distance of a geothermal field from consumers.

Advantages and disadvantages

Advantages:

- general advantages, characteristic for all of the renewables (minimal emission of pollutants and GHG, organic fuel savings, diversification of energy sources, company's image increase aspects, etc.);
- low operational expenses.

Disadvantages:

- comparatively low enthalpy of heat carrier, decreasing capability of its transportation;
- dispersion and far distances of geothermal fields from consumers;
- decrease in the debit of the well at intensive use of the system and at no pumping of the used water underground;
- overgrowing of the well by salts and intensive scaling in the system when mineralization of geothermal water is high;
- intensive corrosion of metal, pipes and equipment because of saturation of geothermal wares with aggressive gases;
- harmful environmental impact caused by water discharge.

References in RF

In the former USSR large-scale use of geothermal water for the purposes of heat supply began in 1960's of the XX century. In 1988 annual output constituted 60 mln m^3 [2]. The main regions of geothermal water use were Northern Caucasus and Kamchatka peninsula and the main consumers were agricultural objects and settlements. In 1980's areas of green houses in Krasnodar region with geothermal heat was over 70 hectare. In Dagestan over 120 objects used heat from geothermal sources for heat and hot water supply of towns and settlements (for instance, Izerbash town with 25 thous. inhabitants). In 1969 on Kamchatka peninsula a heat supply system was created (Elizovo –settlement Paratunka - settlement Termalny); the system is based on direct use of geothermal heat. Reserve of geothermal water for operation of the system is 23.3 thous.m^3/day with the temperature of 77 ^oC.

REFERENCES

1. **Renewables** 2014 Global Status Report. REN21. Renewable Energy Policy Networks for the 21th Century. www.ren21.net/Portals.
2. **Перспективы развития** возобновляемых источников энергии в России. Программа Европейского Проекта TACIS для Российской Федерации. М., 2009. Изд. «Атмограф»
3. **В.А. Васильев, Б.В. Тарнижевский**. Раздел 8 «ВИЭ» в ОИС НДТ в энергетике России, 2011 (http://osi.ecopower.ru, версия 2011)
4. www.oaoktz.ru