Method for selecting geothermal energy extraction technologies using nomograms

K F Gabdrakhmanova, G R Izmaylova, P A Larin and L S Kuleshova

Ufa State Petroleum Technological University, Branch of the University in the City of Oktyabrsky, 54a, Devonskaya St., Oktyabrsky, Republic of Bashkortostan, 452607, Russian Federation

E-mail: klara47@mail.ru

Abstract. The article analyzes the efficiency of geothermal energy extraction method. Different regions of the Russian Federation were analyzed. Available geothermal energy extraction technologies using nomograms were analyzed. The nomograms describe the dynamics of outlet changes in temperatures and the amount of energy produced at various coefficients of thermal conductivity and heat capacity of rocks. The nomograms used for selection of suitable geothermal energy production technologies depending on geological and physical conditions were developed. Based on geological and physical characteristics of the bottomhole formation zone, such well parameters as the radii of the casing and the tubing and coolant velocity, outlet temperatures and thermal capacity of the well were calculated. The more efficient technology was selected.

1. Introduction

Since the last quarter of the 20th century, mankind has been studying the use of geothermal energy [1] for various purposes, mainly for its conversion into electrical energy. Among renewable resources, the focus is on geothermal energy, because it is considered a reliable source of energy due to its independence on seasonal, climatic and geographical conditions. In recent years, new technologies based on geological field data have appeared. The problem of utilization of geothermal energy is an important issue [2-5]. The reserves of the geothermal energy are enormous and inexhaustible. Only about 4% of the subsoil heat is being used [5]. Based on the results of the field research in various regions, it is possible to develop a method for selecting geothermal energy extraction technology and identify resource attractiveness of these wells.

There are various technologies for using geothermal energy depending on the well bottom temperature:

1) The dry steam technology. In regions with a high geothermal gradient of the earth, i.e., with a high reservoir temperature (which is more than 240 °C), this technology can be used. In Russia, it can be used in Kamchatka Peninsula, Stavropol Krai. This technology is used in the United States, Italy, Indonesia, and Japan [3]. Sub-soil steam is transported to a steam turbine which converts thermal steam energy into mechanical energy which is further converted into electrical energy. In [4], it is said that this technology produces 22% of global energy in geothermal stations.

2) Single-stage multistage technologies used at lower temperatures (less than 100 °C) [5].

3) The binary cycle is used at 80°C [5].
4) For temperatures of less than 80°C, researchers develop technologies for more efficient use of geothermal energy [2].

The researchers do not develop generalized methods for selecting technologies according to geological and geophysical parameters of the regions. The authors suggest using nomograms as diagnostic and prognostic tools for selecting well operation technologies.

2. Materials and methods

The results of geological field research of wells in the regions of the Russian Federation were used [7]. The characteristics that are fundamental for selection of technologies (a temperature gradient, an injection rate, a bottomhole depth, coefficients of thermal conductivity and heat capacity of the formation, outlet liquid temperature) were identified. Consequently, the nomograms have to describe various values of the main geological and field characteristics – a temperature gradient, a well depth, and a thermal conductivity coefficient.

3. The method for using nomograms

For a specific well with known geological and geophysical parameters (bottomhole temperature, bottomhole depth, thermal conductivity coefficients of the formation), outlet temperature of the coolant and thermal capacity of the well are determined using the nomograms. According to the data obtained, the geothermal energy extraction technology is selected.

For example, Figure 1 shows the wells located in a region with a geothermal gradient G = 0.2°C/m. This geothermal gradient does not allow for conversion of existing geothermal energy into electrical energy using the existing technologies. Figure 2 shows the outlet temperature of the coolant. At a depth of 3000 m a coolant has a temperature of 50°C. Under these conditions, low-boiling liquids (e.g., freon), can be used as a coolant. Figure 3 shows wells with different depths. The geothermal gradient is 0.04°C/m. This region is characterized by a rather high formation temperature; therefore, energy generation at geothermal stations is economically profitable [8] using the above described existing technologies. Moreover, it is possible to use water as a coolant even during the cold season.

Production of the extracted thermal energy depends on the geothermal gradient, depth of the well and the injection rate of the coolant [6]. For the nomograms below, the following initial data were used: injection rate v = 0.05 m/s, pipe radii - R1 = 0.1 m, R2 = 0.15 m, ambient temperature Tm = 15°C, initial temperature of the thermal transfer T0 = 15°C. Water with known thermal properties was used as a thermal transfer [9-11].

Using the similar technology, nomograms can be constructed for different regions characterized by wide limits of geothermal gradients and geological and geophysical characteristics.
Figure 1. Nomogram for determining output thermal transfer liquid temperature at various depths of the wells $\lambda=1\ W/(m\cdot K)$, $G=0,02^\circ C/m$

Figure 2. Nomogram for determining output thermal transfer liquid temperature at various depths of the wells $\lambda=1\ W/(m\cdot K)$, $G=0,03^\circ C/m$
4. Conclusion
The original approach described in this article helps predict the energy potential of wells located in various territories.

A method for constructing nomograms was developed. It differs from the well-known methods as it helps select wells and reduce the volume of field research.

References
[1] Kaya T and Kahraman C 2010 Multicriteria renewable energy planning using an integrated fuzzy VIKOR & AHP methodology: the case of Istanbul Energy 35(6) 2517–27
[2] Burton J and Hubacek K 2007 Is small beautiful? A multi-criteria assessment of smallscale energy technology applications in local governments Energ. Policy 35(12) 6402–12
[3] Bertani R 2016 Geothermal power generation in the world 2010–2014 update report Geothermics 60 31–43
[4] DiPippo R 2015 Geothermal power plants: evolution and performance assessments Geothermics 53 291–307
[5] Chamorro A, García-Cuesta C R, Mondéjar J L and Pérez-Madrazo M E 2014 Enhanced geothermal systems in Europe: an estimation and comparison of the technical and sustainable potentials Energy 65 250–263
[6] Gabdrakhmanova K F, Izmailova G R, Larin P A, Vasilyeva E R, Madjidov M A and Marupov S R 2015 Nomogram method as means for resource potential efficiency predicative aid of geothermal energy J. Phys. Conf. Ser. 1015(3) 032036
[7] Akhmetov R T and Mukhametshin V V 2018 Estimation of displacement coefficient with due account for hydrophobization of reservoir using geophysical data of wells IOP C. Ser.: Earth Env. 194(6) 062001
[8] Batalov D A, Mukhametshin V V, Dubinskiy G S and Andreev V E 2018 Laboratory grounding of waterproofing sealant based on acrylic polymers IOP C. Ser.: Earth Env. 194(4) 042003
[9] Tyncherov K T, Mukhametshin V Sh, Paderin M G, Selivanova M V, Shokurov I V and Almukhametova E M 2018 Thermoacoustic inductor for heavy oil extraction IOP Conf. Ser.: Mat. Sci. 327(4) 042111
[10] Ibragimov N G, Fattakhov I G, Kuleshova L S, Kadyrov R R, Sakhapova A K and Khamidullina E R 2011 New dedicated software determines water production behavior Oil industry [in Russian – Neftyanoye Khozyaystvo] 7 48–49
[11] Gabdrakhmanova K F, Izmaylova G R and Larin P A 2018 The way of using geothermal resources for generating electric energy in wells at a late stage of operation *IOP C. Ser.: Earth Env.* **194**(8) 082012