

61(4), pp. 272-275, 2017

<https://doi.org/10.3311/PPme.10546>

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RESEARCH ARTICLE

Received 26 January 2017; accepted after revision 24 August 2017

Abstract

Slovakia belongs to countries rich in geothermal energy resources with high productiveness. The use of geothermal energy (GE) is diverse, e.g. as source for centralized heating networks. The use of this alternative Energy Sources requires optimized exploitation of the energy potential. When using GE it is vital to design systems with cascade utilization of GE to increase the efficiency and have minimal impact on environment. When using GE we have not only take in account physical and chemical properties of geothermal water (GTW) reservoirs, but standards and regulations, as well as limitations given by the delivery points, which apply no matter what type of energy source we use – conventional or alternative.

Keywords

geothermal water, geothermal energy system, energetic balance

1 Introduction

Each and every GE resource has its individual parameters. They have to be identified and taken in account during the design of geothermal extraction system.

From an energetic point of view it is in first place the temperature at the wellhead and the yield. These determine the GE resource Usable Energy Potential Q' (heat rate) and the Usable Heat Energy Q (quantity of energy for a specific time period).

Furthermore, it is necessary to know the physical, chemical, biological, and bacteriological parameters of GTW. These parameters significantly determine the selection of Geothermal Energetic System (GES), as well as the material selection of pipes, armatures, pumps, technology equipment, etc. [1].

2 Conception of usage of geothermal energy

According to that proposed devices will serve in defined conditions which are limited by the regulations and technological norms, at the beginning of the customer proposal for example heating system we must synchronized proposal and calculation of this equipments with regulations and norm about attributes of heating source.

By the process of heat exchange from primary heating working medium – GTW to secondary heating working medium in form of heating water is running on the same physical laws and theories as by the usage of traditional heat resource. We should consider also the adverse conditions which will affect for example flow capacity of heat exchange area in the heat exchangers are stressed by incrustation and corrosion [3, 7].

The heating balance of energetic need must be calculated by the proposal of all devices exactly according to the instantaneous usage of heat when it is delivered to more customers. Balance of heat needs and energy we can execute by very easy form and to put into consumption curve. At the calculation we are proceeding from higher temperature level to the lowest.

After selected conception of complex usage of GE there will be proposal of block scheme of usage which is converted into a technological scheme after calculation. From that point the distribution of GTW is apparent from the source to the last capitation devices and removal of used waste GTW [2].

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3 Energetic balance

In order to optimally propose geothermal energetic system is needed to define possibility of heat source it means primary side GES. This part creates primary part of energy system which will be discussed in part 3.1. Secondary part of GES creates device which will be more specified in part 3.2.

3.1 Main energetic parameter of geothermal energy source

Basic parameters of geothermal energy source – geothermal drill are:

- drill head temperature t_o ,
- number of days in exploitation period n ,
- reference temperature of the cooled geothermal water t_r .

This parameters creates the edge conditions for estimation of usage effectiveness for this non traditional renewable source. By means of these predefined quantities we shall calculate the usable energy potential Q , usable heat energy E and usable mass of geothermal water M , per selected exploitation period n . Depending on this latter quantity, an algorithm of daily, weekly, monthly, seasonal or permanent utilization of the heat source [5]. The usable energy potential Q (kW) is calculated from the formula, as in Eq. (1):

$$Q = v \cdot \rho \cdot c_v \cdot (t_o - t_r) \quad (1)$$

The usable heat energy E (MWh) is calculated from the formula, as in Eq. (2):

$$E = \frac{24 \cdot Q \cdot n}{1000} \quad (2)$$

The usable mass of geothermal water M (m³) is calculated from the formula, as in Eq. (3):

$$M = \frac{24 \cdot n \cdot m_o}{1000} \cdot 3600 \quad (3)$$

where:

- v – specific capacity of geothermal water (m³/s),
- ρ – specific density (kg/m³),
- c_v – specific calorific content of geothermal water (kJ/(kg K)),
- t_o – the temperature of geothermal water at the drill head (°C),
- t_r – reference temperature of cooled geothermal water equal $t_r = +15$ °C,
- n – number of days in exploitation period (-),
- m_o – geothermal source output expressed in (l/s).

3.2 Delivery points

Under the meaning of delivery points we mean technological equipment which are assigned for usage of energy of renewable sources directly or indirectly as it was written above. Between delivery points we include [6, 16]: heating of buildings, ventilation and AC, preparation of hot water, agriculture [4], recreational purposes and technologies.

4 Block scheme of geothermal energetic system

Following the features of geothermal source, suitable delivery point will be proposed as shown on Fig. 1 depicting block schema (need of completion parameters needed – flow and temperature). At the same time, we assume consistent multi-usage and application of numerous heat exchangers arranged consecutively [8, 9].

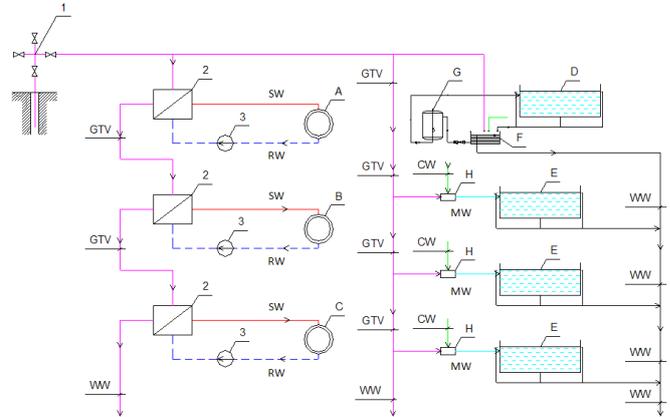


Fig. 1 Scheme of geothermal energetic system

1 – head of geothermal well, 2 – heat exchanger, 3 – pump of hot water, H – mixing point of water, GTV – pipe of geothermal water, SW – supply water of heating system, RW – return water of heating system, CW – cold water, MW – mixed water, WW – wasted water, A – Heating system, B – Low temperature heating system, C – Preparation of hot water, D – Recirculation swimming pool, E – Flow-through pool, F – Balancing reservoir, G – filter

At the delivery point, the quantity of used energy (kW) will be calculated by the formula, as in Eq. (4):

$$Q = m_o \cdot c_v \cdot (t_1 - t_2) \quad (4)$$

where:

$(t_1 - t_2)$ – temperature difference of supply and return water (K).

According to Eq. (4) we will calculate also the need of heat for the other delivery points. By entering of required period (day, week, month, summer period) we will calculate the need of energy for individual delivery points and the need of energy (MWh) for entered period; following the formula, as in Eq. (5) [10, 11]:

$$E = \frac{24 \cdot Q \cdot n}{1000} \quad (5)$$

In the recuperative heat exchanger, the heat (kW) is being transferred from the primary cooling medium – geothermal water through heat exchange areas to secondary cooling medium, as shown on Fig. 2.

These actions could be described by the following formulas, as in Eq. (6) [12, 13]:

$$Q_{GTV} = c_{GTV} \cdot m_o \cdot (t_0 - t_{01}) \quad (6)$$

where:

c_{GTV} – specific calorific content of geothermal water (kJ/(kg K)),

t_0 – the temperature of geothermal water at the head of geothermal well (°C),
 t_{01} – the temperature of geothermal water entering the heat exchange in (°C).

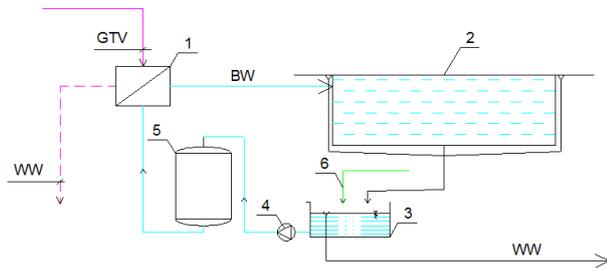


Fig. 2 Heat transfer in the recuperative heat exchanger

1 – heat exchanger, 2 – flow-through pool, 3 – balancing reservoir,
 4 – circulating pump, 5 – sand filter, 6 – adding fresh water,
 GTV – geothermal water, BW – pool water, WW – wasted water

The quantity of heat (kW) which is transferred to secondary cooling medium, such as the pool water, can be formulate as follows Eq. (7) [14]:

$$Q_s = c_v \cdot m_1 \cdot (t_1 - t_2) \quad (7)$$

where:

c_v – specific heat of cooling medium of heating water (kJ/(kg·K)),
 m_1 – mass flow of cooling medium – heating water entering the heat exchange (kg/s),
 t_1 – temperature of cooling medium – heating water at the heat exchanger output (°C),
 t_2 – temperature of cooling medium – heating water entering the heat exchange (°C).

In the recuperative heat exchanger, on the primary side, the geothermal water will drop of temperature, and on the secondary side, the temperature of cooling medium will increase. Thus, the cooling medium will be warmed for the heating system from its lower temperature t_2 to the desired temperature for supplying of the heating system. According to the heat source features, it is possible to operate in this manner number of heat exchangers consecutively (Fig. 1).

5 Efficiency evaluation of geothermal energy

For the calculation of quantity GTW and elective heat slope on the delivery point are calculated energetic balances and as a result we have useful respectively useless wasted capacity of energy where we are coming from theoretical useful quantity of energy E_{total} (MWh) for all delivery points, as in Eq. (8) [1]:

$$E_{total} = \frac{M_{total}}{3600} \cdot c_v \cdot (t_0 - t_r) \quad (8)$$

where:

M_{total} – the geothermal water volume for the all off-take point (m³/s),
 t_0 – the temperature of geothermal water at the head of geothermal well in (°C),
 t_r – reference temperature of cooled geothermal water equal $t_r = +15$ °C (this is a required temperature of waste water).

The usefully utilized quantity of geothermal energy E_{iu} (MWh) can be calculated from the formula, as in Eq. (9):

$$E_{1,iu} = \frac{M_{total}}{3600} \cdot c_v \cdot (t_0 - t_{01}) \quad (9)$$

Wasted quantity of geothermal energy E_{iw} (MWh) can be calculated from the formula, as in Eq. (10):

$$E_{1,iw} = \frac{M_{total}}{3600} \cdot c_v \cdot (t_{01} - t_r) \quad (10)$$

At the same time, the following equation applies:

$$E_{total} = E_{iu} + E_{iw} \quad (11)$$

where:

E_{iu} – usefully utilized quantity of geothermal energy (MWh),
 E_{iw} – wasted quantity of GE (MWh).

If the temperature of outgoing, cooled GTW from heat exchanger higher than 30 °C, we need to think for another useful usage for example for preparation of hot water or for preparation technological water for the swimming pools, fish farm or for another technology – melting of snow etc. [15].

Usefulness of geothermal energy is evaluated on the base of processed energy analyses effectiveness non-traditional renewable heat source. Mathematically is the usefulness of geothermal energy as a ratio (%) usefully used heat by the total theoretical used heat, as in Eq. (12):

$$\mu = \frac{\sum E_u}{E_{total}} \cdot 100 \quad (12)$$

where:

$\sum E_u$ – sum of utilization of used energy by the delivery points for the tracking time period; $\sum E_u = E_1 + E_2 + E_3 + E_4$ (MWh),
 E_{total} – maximum theoretical used quantity of energy by the delivery points (MWh).

Practical sample of immediate utilization usefulness geothermal energy is shown in Fig. 3 as a graphical view. The vertical axis of the graph represents temperature of geothermal water in °C and horizontal axis of the graph represents current water flow in l/s.

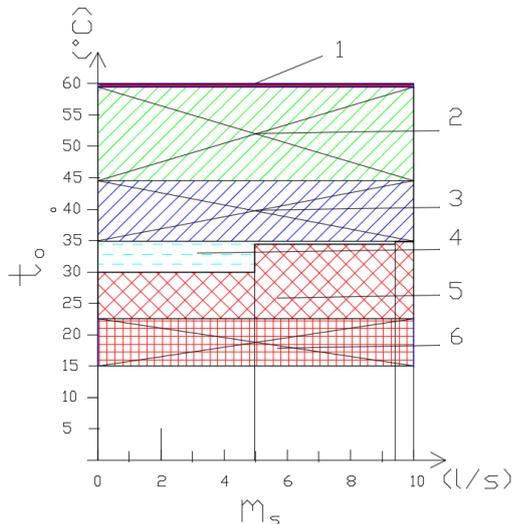


Fig. 3 Graphical evaluation of utilization geothermal energy in GES[1,2]

1 – E_{o1} heat loss in piping, 2 – E_1 hot water heating system, 3 – E_2 low temperature heated system, 4 – E_3 flow pool filled up with diluted, 5 – E_{o2} waste heat from pool, 6 – E_{o3} non used energy – waste

6 Conclusion

The GE energetic efficiency assessment done at delivery points shall consider few approved facts and recommendations listed as following:

1. Basic parameters are given by the GE resource – the temperature at the wellhead, the yield, and GTW parameters.
2. The use of GE shall be designed to cover the “base energy consumption” (preparation of WW, heating system, ventilation and AC, and/or technology). Energy consumption peaks shall be covered by supplementary resource (natural or biomass gas).
3. Balance of heat shall be calculated for all objects which will be the subject to heat supply (this includes heat consumption and energy demand calculations). Consequently the technical design of heating network shall be created. Parameters as heating capacity and heat slope for heat exchanger shall be determined. [16].
4. Measuring points for monitoring flow volume and temperature profile shall be determined. Suitable monitoring and controlling system shall be determined as well to cover the energy consumption in real time and will regulate the heating network based on pre-set setups.
5. Monitoring and controlling system shall achieve the best possible degree of GE use by analyzing available data.
6. The application of monitoring and controlling system shall help to achieve considerate use of GTW reservoirs and like this extend its lifespan.
7. Used GTW shall be disposed with least negative impact to the environment.

The use of GE lowers the use of other energy resources such as coal and natural gas. Like this the exhalants produced by burning classical energy resources are reduced.

Acknowledgement

This work was supported by the Slovak Research and Development Agency under the Contract No. DS-2016-0030, and by the Ministry of Education, Science, Research and Sport under VEGA Grant 1/0807/17.

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