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An optimisation model of geothermal-energy conversion

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Abstract

A mathematical model of the behaviour of a geothermal-energy source, based on the theoretical water well of different quality parameters has been presented. Heat energy magnification produced by the well by increasing the stream of pumping water is analysed. Optimisation analyses are conducted assuming different types of source: constant or dynamic parameters. The technical optimisation model maximises the net power of the source, which is the difference between the heat source power and the power of pumping. The optimisation model maximises the value of heat energy produced by the source minus the value of the electrical energy used for pumping. The technical and economic optimisation gives different results because the unit cost of heat energy is lower than that of electrical energy.

Keywords: Geothermal energy; Optimisation; Conversion

1. Introduction

According to its origin, *geothermal heat energy* can be divided into two categories:

accumulated solar energy and *internal Earth's heat energy*.

The solar radiation energy is accumulated in the Earth's surface, causing the ground temperature to increase. As a result, we observe temperature changes of the shallow—up to ~14 m—ground solid matter and water, the average ground temperature varies seasonally. The geothermal energy can be used as warmth or coolness for the subsequent usage in heaters and radiators respectively.

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We can *exploit geothermal energy* sources by harnessing the thermal waters using vertical wells. We differentiate two basic *technologies*:

1. *Open water-circulation*;
2. *Closed water-circulation* /pumping water into *injection well*/:
   - with energy accumulation (changing flow direction)
   - without energy storage (constant flow direction).

In this article, the author discusses only the technology of open circulation. We assume that the geothermal well is characterised by stable parameters which represent *quality* and *volume*/*capacity*/ of the source.

The following parameters are used for the geothermal-water outflow characterisation:

v—water outflow capacity (m^3/s)
T—water temperature (K)
T_0—surrounding temperature (K).

Assuming the temperature and the source volume as being constant, we notice that the quality and capacity of the source are also unchangeable (provided the environment conditions remain constant).

The heat power of a geothermal resource is defined as:

$$P = kv(T - T_0)$$

The level of heat power of the source varies in time as a function of the surrounding temperature.

The maximal heat power of a geothermal resource is equal to:

$$P_{\max} = kv(T - T_{0\min})$$

The useful thermal source capacity is that part of the source power, which can be productively used. In principle, any technology is characterised by a border temperature T_g, which determines the capacity and possibility of the source usage (Fig. 1).

$$P_{\max} = kv\big(T - T_g\big) = kv\Delta T$$

The energy outflow is a very important characteristic of the geothermal source. We assume the heat-capacity parameters of the latter remain constant without any

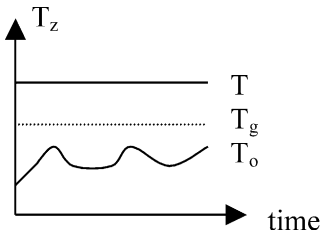

Fig. 1. Variations of surrounding temperature T_0 with time.