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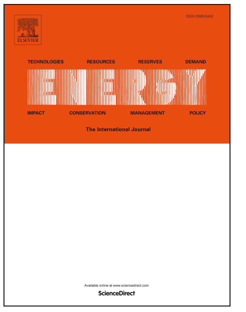

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Feasibility study of geothermal heat extraction from abandoned oil wells using a U-tube heat exchanger

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Abstract

The purpose of this study is to demonstrate the feasibility of using an abandoned oil well as a geothermal resource. A three-dimensional numerical model of a U-tube heat exchanger is simulated based upon the real field data of an abandoned oil well located in southern Iran. To assess and optimize the performance of the heat exchanger, the influences of mass flow rate, fluid inlet temperature, insulation length, and pipe diameter are analyzed. The simulation results indicate that the retrofitted well can be utilized for both electricity generation and direct applications. The great advantage of the proposed heat exchanger is that it can work steadily as a long-term geothermal production system. In a case with 288.16 K inlet temperature and 0.03 m/s inlet velocity, the outlet temperature reaches 324.73 K at the first year of operation and it declines to 324.13 K after 5 years.

Keywords: geothermal energy, numerical simulation, U-tube, heat exchanger, abandoned oil wells, heat transfer

1. Introduction

In view of rising energy demands, declining fossil energy sources and their adverse effects on the environment, the development and utilization of renewable energy resources is imperative for the near future. Geothermal energy is a promising alternative to fossil fuels due to the reliability, high availability [1], and most importantly being environmentally friendly [2]. These underground reservoirs of steam and hot water can be used for electricity production, direct usage and heat pump applications based upon the state of the extracted geothermal fluid and its temperature. The global electricity production in the geothermal power plants has increased from 1300 MW in 1975 to 10,715 MW in 2010 [3, 4] and it is expected to reach over 40 GW by 2035 [5]. Unfortunately, the application of geothermal systems has been restricted owing to the high cost of well drilling. There are about 20-30 million abandoned oil wells throughout the world [6]. Using these wells instead of drilling new geothermal wells is an economically viable solution which can decrease the capital cost of the geothermal projects by up to 50% [7]. Another significant reason for retrofitting the abandoned wells is the availability of geophysical well logs and geological studies on the existing wells. Furthermore, the problems of reinjection, corrosion and scaling can be eliminated given the fact that the circulating fluid is not in direct contact with the formation [8]. Researchers at the Leduc Energy Discovery Centre seek to extract heat from the abandoned wells in Alberta. They concluded that the cost to abandon a disused well could be up to $300,000 while converting it to geothermal and utilizing it for greenhouse operations could half that cost [9]. The abandoned oil wells are considered as a medium-to-low-temperature resource, which is a precious source of renewable energy [10].Hence, several researchers have focused on the exploitation of geothermal energy from abandoned oil wells (e.g. [6-8, 11-15]).

Kujawa et al. [11] assessed the possibility of extracting geothermal energy from an existing deep production well using a double pipe heat exchanger. The paper concluded that the fluid inlet temperature, flow rate and insulation on the inner pipe had a significant impact on the performance of the heat exchanger. Davis and Michaelides [12] proposed a numerical model of a double pipe heat exchanger retrofitted to an abandoned oil well. The effects of the down-hole temperature, injection pressure and flow rate of an organic working fluid were analyzed in this paper. Owing to the fact that the ground temperature was assumed constant with time, the calculated power output was overestimated. Bu et al. [7] developed a mathematical model describing the heat transfer between the well and the stratum, and concluded that the performance of the double pipe heat exchanger adapted to an abandoned oil well depends upon the fluid flow rate as well as geothermal gradient. Cheng et al. [13] performed a numerical simulation for an abandoned oil well with a depth of 6000 m. The results showed that the fluid outlet temperature gradually decreased with the system operating time and eventually approached stability. Furthermore, there was an optimal inlet velocity of fluid entering the injection well to maximize the net power for a specified geothermal heat source. Noorollahi et al. [14] investigated a 3D simulation of two abandoned oil wells based upon the real field data, and concluded that in addition to the mass flow rate and geothermal gradient, well casing geometry had a significant influence on the heat transfer in the wells and net