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HYDRAULIC FRACTURING IN SYSTEMS OF GEOTHERMAL ENERGY UTILIZATION (EGS, HDR)

1. INTRODUCTION

Hot dry rock geothermal system (HDR) allows to use the heat from impermeable rock formations – igneous, metamorphic and claystones. The terms of heat exctract in this system, are not particularly conditioned by the geological structures.

The idea of utilization of such system is based on forced and closed water circulation in a natural and permeable geological reservoir or in a reservoir, where the fracture zone was created artificially by for example hydraulic fracturing treatment. In this system, water is injected by a well to heated rocks with high rate of hydraulic conductivity. By using the second wll hot stem is extracted on the surface. There are designs of treatments using the energy of nuclear blast to create the fracture zone and to crush hot, deep granite rocks, to provide connection between two wells.

In case of HDR systems, designs can be free from the problems of colmatation and corrosion by mineralized groundwater. As working fluid in closed circulation (without leakoff) can be used water, methanol or another fluids with good heat exchange parameters, which is particularly important with rapid circulation.

An interesting example of HDR system application is project designed for the city Soultz in France (Fig. 1).

The existing well GPK-1 of a depth 2000 m reaching a granite formation was depth to 3,590 m. A series of geological and geophysical researches in granite formation indicated downhole temperature 433 K and naturally occurring fractures filled with water. In granite formation zone a rapid decrease of geothermal gradient was indicated which proves a high

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thermal conductivity factor in rock mass. Geological conditions have a positive impact on project development, which is in progress now. There are plans to create three wells. Well GPK-1 is considered to work as an injection well.

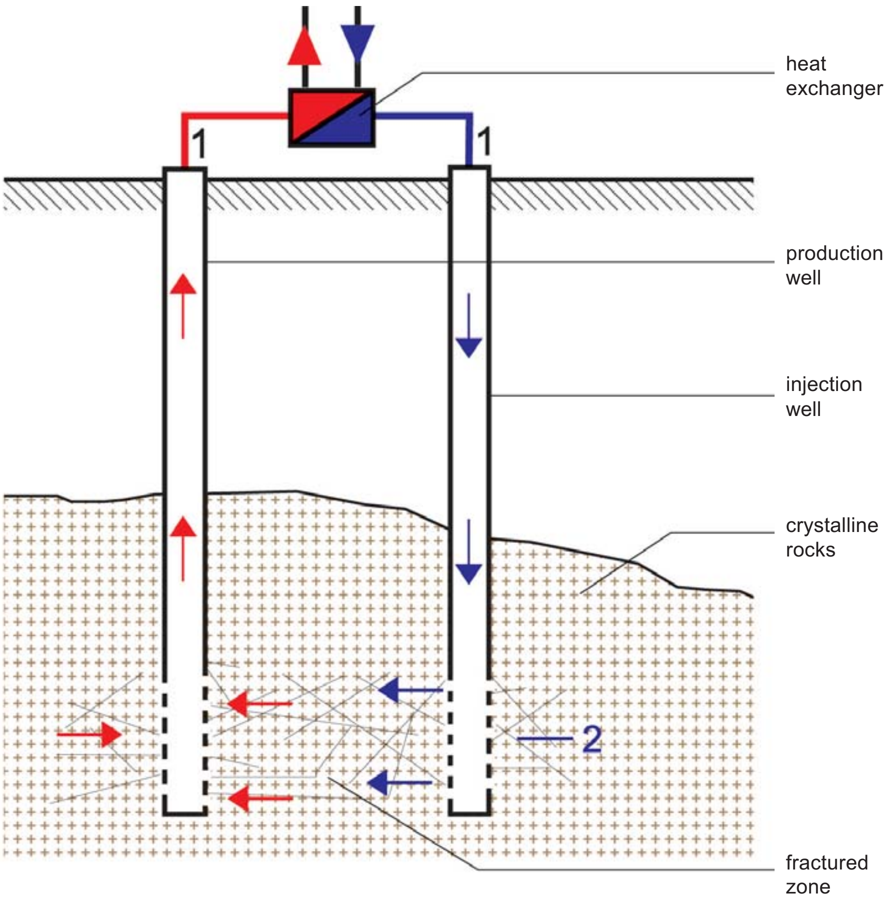

Fig. 1. System of a hot dry rock thermal energy utilization based on a project in Soultz – France

Circulation test between wells are planned before hydraulic fracturing treatments, and also after this treatments. Those test are supposed to give an information about loss of fluid pressure in granite.

In initial well tests on GPK-1 well 45,000 m^3 of water was injected. Maximal volumetric flow rate during the test reached 0.005 m^3/s under 10 MPa of injection pressure which revealed a fluid leakoff in granite formation. Therefore a need of constant water supply appeared and a third additional well on depth 1,000–2,000 m is planned to provide additional source of water. Water from aquifer is considered to supply a loss of water in granite formation. Water from additional well and from GPK-2 well will be injected to GPK-1 well.

Connection between GPK-1 and GPK-2 wells will be possible after a hydraulic fracturing treatment or after fracking with explosives.

2. HYDRAULIC FRACTURING

To create water circulation conditions between an injection and production well in impermeable geological reservoir (geothermal reservoir) it is necessary to create a fracture zone which provides a flow of water between these wells. One of the techniques which is used to create fracture zone is a hydraulic fracturing treatment with proppant.

In 1960s hydraulic fracturing treatment have become a primary method of oil and gas reservoirs stimulation. The use of large volumes of low-cost water based fluid injected under high pressure and with high flow rates had proved to be an effective and economical procedure on many wells and reservoirs in United States. Since its inception hydraulic fracturing has developed from a simple, low volume, low rate fracture stimulation method to a very high engineered, complex procedure that is used for many purposes. Hydraulic fracturing can be use to improve well productivity in conventional reservoirs, to create a fracture zone in unconventional reservoirs (shales), and also to create deeply penetrating, high conductivity fractures in impermeable reservoirs for extracting heat energy from hot dry rocks.

The idea of hydraulic fracturing treatment is to prepare proper fracturing fluid and to inject it under high pressure through the well to rock formation. Injected fluid creates a fractures due to rising tensions and transport proppant deep into fractures. The purpose of the proppant is to keep the walls of the fractures apart so that the conductivity is retained after pumping has stopped and fluid pressure has dropped below value required to hold fracture open.

The propped fracture must have conductivity at least high enough to eliminate most of the radial flow path to the well and to allow linear flow from reservoir into the fracture. To accomplish this, the proppant must enable the propped fracture to have a permeability several orders of magnitude larger than that of the reservoir rock. After the materials are pumped, the fluid chemically breaks back to a lower viscosity and flows back to the well, leaving a highly conductive propped fracture, which allows a flow of reservoir medium.

The most important factor for hydraulic fracturing treatment design in EGS and HDR systems is the in-situ stress field. Stress not only controls or influences most aspects of fracture behavior (parameters of fracture propagation, fracture geometry, pressure required to create fracture of designed length and height), but also influences the values of both reservoir properties and mechanical properties of the rock. The effect of the in-situ stress field on fracture azimuth and orientation in space is well understood. The researches indicated that whenever the stress is anisotropic, there is preferred fracture azimuth perpendicular to the minimum, compressive, principal in-situ stress. Put simply, the fracture prefers to take the path of least resistance and therefore opens up against the smallest stress. Under near-isotropy conditions in the three stresses will the rock fabric possibly be the dominant factor controlling fracture growth. Therefore recognition of geological conditions and mechanical properties of rock is essential to create a proper hydraulic fracturing treatment design of impermeable reservoir for creating a connection between injection and production wells in EGS/HDR systems.

3. EXAMPLES OF RECENT EGS/HDR SYSTEMS AROUND THE WORLD

Hague – Holland

Project will provide geothermal energy to at least 4,000 new homes plus 20,000 m^2 of commercial property in the city of Hague to 2017. In 2010 two boreholes were drilled (injection well and production well). For 2012 three hundred of homes are planned to be heated by an energy from EGS system.

Cooper Basin – Australia (Tab. 1)

The purpose of Innamincka Deeps (EGS) Project on Cooper Basin (South Australia) is to use the heat from hot rocks, generally granite bodies, located between 3–5 km below the surface for power generation. The project is in progress. Six wells were drilled and a several of hydraulic fracturing treatments were performed. Estimated power from the EGS system is planned in a range of 250–500 MW, which make Innamincka Deeps (EGS) Project the biggest performed.

Table1

History of drilling geothermal wells in Cooper Basin

Year of drilling	Name	Depth [m]	Temperature [°C]
2003	Habanero 1	4,421	243
2004	Habanero 2	4,459	244
2008	Habanero 3	4,200	242
2008	Jolokia 1	4,911	278
2009	Savina 1	3,700	well suspended
2012	Habanero 4	4,204	in progress

Eden EGS Plant Project – Cornwall – Great Britain

17^{th} November 2011, EGS Energy Co. granted planning permission for the drilling of two boreholes to create an engineered geothermal system and for the development of the Eden EGS Plant. Project will provide geothermal energy to 5,000 homes and the Eden Botanical Garden. Designed estimated power generated from the system is 4 MW. The Eden EGS plant would be made up of two boreholes, driven around 4 km into the granite beneath surface; the rock at that depth is at about 150–160°C. Water injected down the first borehole will be returned to the surface at around 150°C via the second borehole. The superheated water will be used to generate electricity, and will then be returned to the injection borehole. EGS Energy co. is planning to finish the project in the second half of 2013.

4. CONCLUSIONS

Enhanced geothermal systems (EGS) and hot dry rock systems (HDR) are intensively developed in many countries all around the world. These technologies provide utilization of geothermal energy in reservoirs where conventional methods are not possible due to geological conditions.

Intensive development of hydraulic fracturing technique connected with unconventional reservoirs completion support EGS and HDR systems development.

Current EGS/HDR projects are still in phase of realization. The end of these projects and beginning of it's utilization give an opportunity to system efficiency evaluation both with data essential to develop present technologies.

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