European Geothermal Congress 2016
Strasbourg, France, 19-24 Sept 2016

Geothermal Development in Europe considering EGS technologies and The Deep Drilling Project

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Keywords: Geothermal energy, EGS systems, deep drilling, Soultz, Icelandic Deep Drilling Project, supercritical fluid.

ABSTRACT

Three components are necessary to form a hydrothermal system: A heat source, water, and permeability. However, in case that a convective hydrothermal resource cannot be found or its exploitation would difficult, an Enhanced Geothermal System (EGS), also known as Engineered Geothermal Systems, is an option to artificially create hydrothermal resources creating permeability through hydraulic stimulation or fracturing and maintaining fluid circulation through these fracture networks. The traditional geothermal plants are limited by the size and specific location of its hydrothermal reservoirs, also are normally considered as stations of sustainable energy due to depends on management and engineering of the reservoir and its exploitation is commonly limited.

Given the cots and limited full-scale system research to date. There are no commercial-scale EGS plants to date and its research is only limited to pilot projects. The technology is promising, one study of MIT projected that EGS could reach an installed capacity of 100,000 MW in United States by 2050 for instance. It would make EGS one of the most important renewable energy technologies in future. Currently in Europe, the Soultz geothermal project in France is one of the most famous EGS systems providing 1.5 MW_e using an Organic Rankine Cycle, this project has provided important information regarding the numerical modelling and the hydrothermo-mechanical conditions of the fluid between others.

The Iceland Deep Drilling Project (IDDP) is a long term study of high-temperature hydrothermal systems in Iceland which aim is to determine if utilizing supercritical geothermal fluids would improve the economics of power production of geothermal fields. In fact, this require drilling wells to a depth of about 5 km in order to reach temperatures of 450 °C to 600 °C. In this conditions every single well can produce approximately 4 times more energy than a conventional geothermal well at 3 times less price.

In order to provide energy in large scale in an economically feasible way, the EGS systems and the Deep Drilling are still in study and most likely they will be the answer to those challenges. Until now, both have contributing with knowledge and new ideas about the hydrothermal systems and how it can be changed and/or modified.

1. INTRODUCTION

Three components are necessary to form a hydrothermal system: A heat source, water, and permeability. These three components have been essential to develop the geothermal energy since the first commercial geothermal power plant in the world (named Larderello 1) was equipped with a turbine generating 250 kW of electricity in Italy in 1913 (Lund, 2005). In 2015, the total worldwide install capacity of geothermal power plants reached 12.6 GWe, generating 73,549 GWh approximately. In Europa, the total install capacity is 2.133 MW standing out countries as: Italy (916 MWe), Iceland (665 MWe) and Turkey (397 MWe) between others (Bertani, 2015).

The typology of the geothermal power plants is diverse, Single Flash is the commonest sort of plant in the world producing 41% of the total geothermal installed capacity. Dry Steam and Double Flash occupied also an important role providing 22% and 21% of the total energy respectively. The Binary Plants are becoming popular in reservoirs classified as medium-low temperature where the generation reached the 12% of the total. Finally, the Back Pressure Technology as well as the Triple Flash systems provide 3% and 1% respectively (Bertani, 2015).

Geothermal is ready to take the next step and produce energy in large scale in economically feasible way and playing an important role between the renewable energy sources, for it, the concepts described above need to be improved or changed without skip all the experience earned since 1913. In the following sections are explained two techniques that could lead the geothermal energy generation in the future: the EGS systems and the drilling into the roots of a geothermal system

2. ENHANCED GEOTHERMAL SYSTEMS (EGS) AND THE DEEP DRILLING PROJECT

2.1 Enhanced Geothermal Systems

The production of electricity from geothermal energy has been mainly associated with the search of hydrothermal systems, once a prospective reservoir is locate and the fluid can be extracted, it is possible to start the conversion to electricity. Nevertheless, the drawbacks are regarding that the reservoir can only be exploited for a limited period of time at least until most of the fluid contained in them has been extracted. This and any other limitations have forced scientists to seek alternative solutions to maintain geothermal energy as a viable, functional power source with a promising future. This alternative is referred to as "Enhanced Geothermal Systems" or EGS (Olasolo, et al. 2015).

The concept of EGS (Enhanced Geothermal Systems) also known as HDR (Hot Dry Rock) describes the formation of an entirely natural tank designed to obtain geothermal energy. This tank is made up of a block of hot rock located at between 4 and 5 km depth (Figure 1) and contains sufficient geothermal energy for it to be possible to extract quantities capable of producing electricity on the surface.

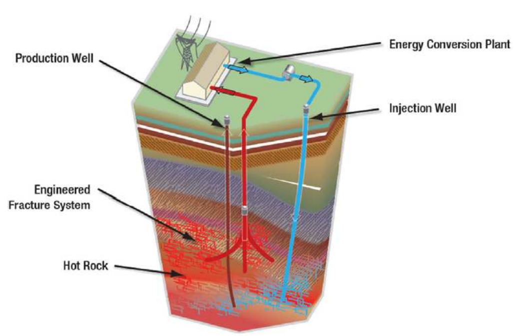

Figure 1: Diagram of a basic EGS (Olasolo, et al. 2015).

The Soultz geothermal project in France is one of the most famous EGS systems in Europe, it consists in three deviated wells of 5 km depth from the same platform and cased from surface to 4.5 km depth. The drilling of these wells have provided insights into geology, nature of fracturing, fluid geochemistry, temperature and hydraulic properties of deep crystalline rock masses. One of the aims of the project was generate a technical and economically feasible way to generate electricity in a large scale. Therefore, using isobutene as working fluid, a binary power plant based on an ORC system (Organic Rankine Cycle) of 1.5 MWe of net capacity was installed between 2005 and 2009. The project also has generated important information regarding to the numerical modelling, the hydrothermo-mechanical and geochemical behaviour of the fluid at these conditions.

The EGS system is in general a promising technique, in a matter of fact, an study conducted by the Massachusetts Institute of Technology (MIT) projected that this technology could reach an installed capacity of 100,000 MWe just in the United States by 2050 (C2ES, 2012). Unfortunately, the technology is fairly expensive currently, the capital costs of an EGS plant would be roughly twice that a traditional geothermal plan, approximately. Despite the limitations, this technique of energy extraction is still in study, for instance, Pruess mentioned in 2006 the advantages to replace the water for CO_2 as heat transmission fluid, between others important remarks, it was estimated that a 1000 MWe of this sort of plant could store all the CO_2 generated by 3000 MWe of coal-fired power plants.

In the following section is explained an option based on the knowledge gained by the EGS, and which likely is going to play an important role in the development of the geothermal energy in the future: the drilling into the roots of a geothermal system, which is explained through the experience gained at the Iceland Deep Drilling Project (IDDP)

2.2. Iceland Deep Drilling Project

In 2000 three Icelandic energy companies: HS Orka hf, Landsvirkjun (LV) and Orkuveita Reykjavikur (OR) founded a consortium in order to develop the Iceland Deep Drilling Project (IDDP). The aim of the project was drill 5 km into an active mid-ocean ridge hydrothermal system and consequently improve the economics of geothermal energy by producing supercritical hydrous fluids (Fridleifsson, et al. 2005).

Initially, the Reykjanes Geothermal field (Southwestern part of Iceland) was proposed for this aim. The well RN-17, completed in 2005 at 3.1 km depth, was elected to be drilled deepen into the supercritical zone. Because the reservoir fluids on the Reykjanes Peninsula have seawater salinities, the Reykjanes geothermal field seems more typical characteristics of a Mid-Ocean Ridge than other geothermal system in Iceland. Unfortunately, the well collapsed and became blocked after a well testing in November 2005. Thus, this well was abandoned in February 2006 (Fridleifsson, et al. 2010).

After discussion the decision was made to move operations to Krafla, in northern Iceland. The plan was to drill a 3.5 km deep until reach a subcritical part of the formation, and then deep into the supercritical zone at 4.5 km approximately and ovoid mixing between the fluids of these formations. Thus in March 2009 started the drilling of well IDDP-1 and was completed at 1958 m with a 9 5/8” slotted liner to the bottom and a total depth about 2104 m. Due to colourless rhyolitic glass cuttings were returned at surface followed by abundant, darker, obsidian drill cutting, was suspected that the magma was reached (Fridleifsson, et al. 2010).

A total loss feed zone was in the open bottom section of the well, which was injected for 2-3 months by cold water. The well was expected to produce superheated dry steam at 500ºC approximately and subcritical pressure barely reaching 100 bar. The well IDDP-1 has provided important information regarding: rock permeability at 400 °C, high concentrations of HCl at the supercritical region but easily manageable at surface with wet scrubbing, silica can appear in steam phase, an improvement on valves, cementing and casing is needed in this sort of projects and finally the condensing in the wellbore or rapid cooling can be neglected (Fridleifsson, et al. 2010).

In the Figure 2 is presented a general diagram of the goals of the IDDP. The new challenges considering a reservoir at supercritical conditions are mainly related with the properties of the fluid which can change drastically with small changes of temperature and pressure, it is not possible to predict the chemical composition of the fluid prior to drilling, the nature of the heat transfer from the hot bodies to the groundwater is not known in detail, it is not known at what depth this interaction takes place, neither the depth range of the water circulation. Finally the financial assess of these project shown a relation about 3 to 4 in price and energy (the well is 3 times more expensive than a conventional well but releases 4 times more energy).

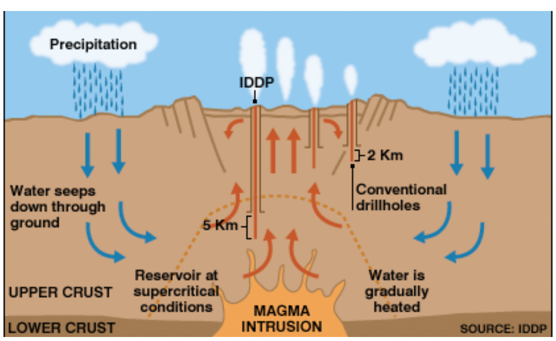

Figure 2: Drill targets and diagram of the IDDP (IDDP, 2016)

3. CONCLUSIONS

The EGGS systems as well as the Deep Drilling into the magma are techniques which probably will lead the new age of the geothermal energy. Both supposed the drilling at high deeps and obtain large amounts of energy using water as heat transport. It is also possible to combine both and create a Magma-EGS system or use CO_2 instead water which simplify the dissolution issues of components which normally create troubles at surface as is the case of silica.

These two technologies need to be improved and set in motion, valuable information about these kind of systems will be released whit a full-time power plant production. Unfortunately, nowadays is high expensive to drill at these depths (<4 km in general) and development and research are limited. However, considering the necessity to replace the conventional sort of energies as coal, gas or oil, it is possible to obtain sponsors in the near future.

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