Geophysical Research Abstracts
Vol. 16, EGU2014-3966, 2014
EGU General Assembly 2014

Using estimated risk to develop stimulation strategies for induced seismicity in enhanced geothermal systems

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Enhanced Geothermal Systems (EGS) are an attractive source of low-carbon electricity and heating. Consequently, a number of tests of this technology have been made during the past couple of decades and various projects are being planned or under development. EGS work by the injection of fluid into deep boreholes to increase permeability and hence allow the circulation and heating of fluid through a geothermal reservoir. Permeability is irreversibly increased by the shearing of pre-existing factures or fault segments, and hence by the generation of microseismicity. One aspect of this technology that can cause public concern and consequently could limit the widespread adoption of EGS within populated areas is the risk of generating earthquakes that are sufficiently large to be felt (or even to cause building damage). Therefore, there is a need to balance stimulation and exploitation of the geothermal reservoir by injecting fluids against the pressing requirement to keep the earthquake risk below an acceptable level.

Current strategies to balance these potentially conflicting requirements rely on a traffic light system based on the observed magnitudes of the triggered earthquakes and the measured peak ground velocities from these events. Douglas and Aochi (Pageoph, 2014) propose an alternative system that uses the actual risk of generating felt (or damaging) earthquake ground motions at a site of interest (e.g. a nearby town) to control the injection rate. This risk is computed by combining characteristics of the observed seismicity rate of the previous six hours, with a (potentially site-specific) ground-motion prediction equation to obtain a real-time seismic hazard curve, and then the convolution of this with the derivative of a (potentially site-specific) fragility curve. Based on the relation between computed risk and pre-defined acceptable risk thresholds the injection is: increased (if the risk is below the amber level), decreased (if the risk is between amber and red levels) or stopped completely (if the risk is above the red level). Based on simulations using a recently developed model of induced seismicity in geothermal systems (Aochi et al., GJI, 2014), which is validated here using observations from the Basel EGS in 2006, it is shown that the proposed procedure could lead to both acceptable levels of risk and increased permeability.