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Zero Emission Geothermal Flash Power Plant

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Abstract

The successful exploitation of geothermal energy for power production relies on the availability of nearly zero emission and efficient technologies. Two zero emission flash plant layouts, with full reinjection of the geothermal fluid (non-condensable gas included), are considered. This paper focusses on the CO_2 issue, and therefore only the carbon dioxide is considered as non-condensable gas present in the geothermal fluid; the CO2 flow is separated, compressed, and reinjected with the geothermal fluid. Both the reservoir and the power plant are simulated. A first scheme of plant presents a conventional layout in which the CO_2 is separated and compressed after the condenser. The second scheme presents a plant layout that allows the separation of the CO_2 at higher pressure with respect to the conventional layout, thus reducing the requested power consumption.
The conventional plant scheme performs always better at higher temperature and at lower concentration of CO_2. The new layout results better for low temperature and higher gas content.

Keywords: Geothermal plant; geothermal energy; ;CO_2 separation; CO_2 reinjection; zero emission; non-condensable gas; reservoir simulation.

1. Introduction

The successful exploitation of geothermal energy for power production relies on the availability of nearly zero emission and efficient technologies, able to provide flexible operation. The binary cycle and flash steam technology are both eligible technologies for geothermal power generation. Non-condensable gases, possibly present in the

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geothermal fluid, represent an important issue as far as environmental aspects are concerned. Due to the climate change concern, major attention is presently paid to the CO_2 content.

In the traditional flash plant layout non-condensable gases are extracted from the condenser, and, though the most harmful gases are usually treated and disposed, the CO_2 still represents an issue, because it is commonly released in the ambient. Flash technology is a well established technology, generally adopted when the geothermal fluid consists of a mixture of liquid and vapors at wellhead, with temperature higher than about 160-180 °C. The main feature of this technology is the adoption of a direct cycle, whereby the geothermal fluid coming from wellhead is flashed, and separated steam enters a steam turbine, followed by a condenser. The whole plant scheme is then tailored on the geothermal fluid characteristics: salts and non-condensable gases are often present in the geothermal fluid. The geothermal fluid is treated before entering the turbine [1] and, if non-condensable gases (NCG) are present, an extraction system is required, in order to allow condenser proper operation; afterwards, depending on the chemical composition, separated NCG are treated in a removal plant or directly released in the ambient. The chemical composition of the geothermal fluid is strongly site dependent: as far as the gaseous phase is concerned, CO_2 is often present, and H_2S may be present as well; sometimes hydrocarbons are also present. As reported in [2], steam from Italian steam dominated geothermal fields may be available with a temperature of about 200°C, with a non-condensable gas content ranging from 4 to 10% by weight. In [3] the non-condensable gas are mixed with inlet air in the gas turbine and burnt in the combustion chamber. Up to a few years ago, the adoption of a direct contact condenser, coupled to a wet cooling tower, was an easy and common technical solution; the flowing of the condensed geofluid through the cooling tower, however, prevents a thorough separation of the geothermal fluid loop from the ambient. In recent years, surface condenser are becoming popular, as they allow more effective removal and treatment of the NCG [4]. The concern for "climate change" encourages the investigation of possible power plant schemes which do not release CO_2 in the atmosphere.

The binary cycle technology is accomplished by means of two completely separated cycles, a geothermal loop, and a power cycle (ORC or Kalina cycle) [5]. It is commonly adopted for all liquid sources or medium-low-temperature sources (generally between 100-170 °C). It entails an important advantage, i.e. the thorough confinement of the geothermal fluid in a closed loop, which is beneficial to the environment (possible pollutants are not released into the ambient but reinjected underground). A common configuration of binary cycle technology is equipped with submersible pump that can guarantee a stable well production, but that is subjected to scaling, cavitation that determine a short lifespan.

This paper focusses on flash technology, and, in order to realize a zero-emission plant, with full geothermal fluid reinjection, the separated CO_2 is compressed, liquefied and mixed with the geothermal condensate prior to reinjection. Two different layouts of flash plant without gas emissions are considered for the temperature range of 150°C-200°C:

- a standard flash configuration: the separated CO_2 , removed from the condenser, is compressed, liquefied and mixed with the geothermal condensate prior to reinjection. The compression ratio required is high and the consumption of the compressor significantly affects the net power production.
- an alternative flash plant layout: CO_2 separation occurs at wellhead, so that the compression ratio required is lower than in previous case.

The thermodynamic model adopted to study the performances of the plants is validated with experimental results available in literature. This paper focusses on the CO_2 issue, and therefore only the carbon dioxide is considered as non-condensable gas present in the geothermal fluid. The work proposes the comparison of these layouts on an innovative and coherent basis, starting the comparison from the geothermal reservoir conditions, according to the approach presented in [6] and aiming at an integrated- reservoir-plant approach [7].

The trade-off point between the two flash plant layouts, and, afterwards, between the best of them and the binary plant, depends on both technical and economic aspects. In this paper, however, the focus will be on technical aspects typical of the flash configuration, considering plant performance; environmental aspects and other possible peculiar technical problems (e.g. scaling) and economic aspects are left for future work.