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Parabolic troughs to increase the geothermal wells flow enthalpy

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Abstract

This work investigates the feasibility of using parabolic trough solar field to increase the enthalpy from geothermal wells' flow in order to increase the steam tons; in addition, it is possible to prevent silica deposition in the geothermal process. The high levels of irradiance in Northwestern Mexico make it possible to integrate a solar-geothermal hybrid system that uses two energy resources to provide steam for the geothermal cycle, like the Cerro Prieto geothermal field. The plant consists of a geothermal well, a parabolic trough solar field in series, flash separator, steam turbine and condenser. Well "408" of Cerro Prieto IV has enthalpy of 1566 kJ/kg and its quality must be increased by 10 points, which requires a Δh of 194.4 kJ/kg. Under these considerations the parabolic troughs area required will be 9250 m^2, with a flow of 92.4 tons per hour (25.67 kg/s). The solar field orientation is a N–S parabolic trough concentrator. The silica content in the Cerro Prieto geothermal brine causes problems for scaling at the power facility, so scale controls must be considered.

1. Introduction

Cerro Prieto is the most important geothermal field in Mexico, and this area has the highest levels of irradiance in the country. These levels of irradiance made it feasible to set up a solar field in a geothermal process to get a hybrid system to increase electricity production during the day. Parabolic troughs can also be effectively integrated with a conventional geothermal cycle plant in order to increase the enthalpy and, subsequently, increase the steam tons. The plant consists of a geothermal well, a parabolic trough solar field in series, flash separator steam turbine and condenser.

This configuration will increase the capacity factor of the steam generating system during the noon and afternoon demand peaks. It is possible to obtain an increase of enthalpy that represents an increase in steam flow; this increase in flow is limited in part by the content of dissolved salts, in order to avoid a liquid flow with a high salt concentration. In addition, it is possible to prevent scale deposits.

Geothermal wells have been classified as low, medium and high enthalpy resources according to their specific temperature indices. A low enthalpy resource must be considered in a better classification with solar field integration. In this case of study, the well characteristics are taken from the Cerro Prieto geothermal field.

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Nomenclature

s	collector area	x	quality
G	irradiance	CP	Cerro Prieto
η	efficiency	DSG	direct steam generation
h	mixture enthalpy	SGHS	solar geothermal hybrid system
h_f	liquid enthalpy	$\dot{m}$	mass flow
h_{fg}	vaporization enthalpy	Δh	enthalpy increment [kJ/kg]

Well 408 of Cerro Prieto has enthalpy of 1,566 kJ/kg. Its quality must be increased by 10 points from 37.9% to 47.9% which will require a Δh of 194.4 kJ/kg to bring the final enthalpy to 1760.5 kJ/kg. Under these considerations, with 900 W/m^2 of beam irradiance and 0.6 of solar field thermal efficiency, the collector area required will be 9250 m^2, with a flow of 92.4 tons per hour (25.67 kg/s). The 900 W/m^2 corresponds to the maximum value of beam irradiance multiplied by the angle of incidence for the N–S alignment of the concentrators.

Comision Federal de Electricidad (CFE), a Mexican Power Company, asked for a study referring to these subjects. The National University of Mexico (Universidad, Nacional Autónoma de México, the UNAM) is the only group in Mexico that makes Direct Steam Generation (DSG) (Lentz et al., 2002; Almanza et al., 2002; Flores and Almanza, 2004), so a technical feasibility study was carried out and the results are presented in this paper.

Several options have been proposed to increase the steam enthalpy in the geothermal cycle; the options vary depending on the location of the solar field in the cycle. Three preliminary options were presented at the SolarPaces 2002 meeting (Lentz et al., 2002).

2. Geothermal resources

Geothermal resources take advantage of underground heat and water (Barbier, 2002), known as a geothermic bed. Geothermic energy is the heat from the nucleus of the earth. Most of the world's productive geothermal systems are associated with young volcanism around the 'Pacific ring of fire.'

2.1. Classification of geothermal resources

Geothermal resources have been classified as low, medium and high enthalpy resources according to their reservoir fluid, Table 1. Armstead, 1983 classified geothermal fields into semi-thermal fields, which produce hot water up to 100 °C at the surface; hyperthermal wet fields, which produce hot water and steam at the surface; or hyperthermal dry fields, which produce dry saturated or superheated steam. The temperature ranges used for these classifications are arbitrary and they are not generally agreed upon. Temperature used is the average reservoir temperature measured in exploration wells or estimated by geothermometers.

Table 1
Classification of geothermal resources by temperature

	Muffer and Cataldi	Hochstein	Benderitter and Cormy	Haenel
Low enthalpy	<90 °C	<125 °C	<100 °C	<150 °C
Intermediate	90–150	125–225	100–200	–
High enthalpy	>150	>225	>200	>150

Geothermal resources should be classified to reflect their ability to do thermodynamic work. It is recommended that geothermal resources be classified as low, medium and high quality resources as referenced to their specific energy (Lee, 2001).

2.2. The geothermal cycle in Cerro Prieto

Cerro Prieto (CP) is the largest known water-dominated geothermal field. It is probably the most thoroughly investigated geothermal field. The fluids at CP are contained in sedimentary rock; its original cement has been replaced by hydrothermal minerals such as quartz, calcite, chlorite, epidote, prehnite, etc.

CP wells provide a mixture of liquid and steam; in this case, a mixture is sent to a centrifugal separator that feeds steam to the turbine and the remaining liquid is sent either to a second separation system or to an evaporation pond. CP would be classified as a hyperthermal wet field.