Applied Thermal Engineering 43 (2012) 29–41

Contents lists available at SciVerse ScienceDirect

Applied Thermal Engineering

journal homepage: www.elsevier.com/locate/apthermeng

Defining optimal configurations of geothermal systems using process design and process integration techniques

Léda Gerber*, François Maréchal

Industrial Energy Systems Laboratory, Ecole Polytechnique Fédérale de Lausanne, CH-1015, Switzerland

ARTICLE INFO

Article history:
Received 15 August 2011
Accepted 17 November 2011
Available online 26 November 2011

Keywords:
Geothermal energy
Energy conversion systems
Combined heat and power
Process design
Multi-objective optimization
Multi-period strategy

ABSTRACT

This paper presents a systematic methodology for the optimal design of geothermal systems. First, the different components of the system superstructure are separately modeled using flowsheeting software. The superstructure includes the different conversion technologies, the potential resources and the demand profiles in energy services. It covers a wide panel of conventional resources and technologies like deep and shallow aquifers, heat pumps, organic Rankine cycles for combined heat and power production, as well as emerging resources and technologies, like enhanced geothermal systems. Then, resources, technologies and demand profiles models are integrated together using process integration techniques. The configuration of the geothermal system is hence extracted from the superstructure. Finally, the performance of the integrated system is calculated and includes energy and exergy efficiency, investment costs, operating costs and district heating or electricity levelized costs. To account for the seasonal variations of the demand, a multi-period approach is used for the simulation of the superstructure, its integration and the performance calculation. The overall sequence is implemented in a multi-objective optimization framework. The methodology is illustrated by an application case study. The implications of the results are discussed in terms of important effects to be accounted for in the design of geothermal systems.

1. Introduction

In the perspective of increasing the share of renewable energy to mitigate global warming issues and to respond to fossil resources depletion, the use of geothermal energy has gained interest. Major usages of geothermal energy include electricity production (67,246 GWh/y in 2010) and direct use for heating (117,740 GWh/y in 2010) [1]. As stated by the International Energy Agency (IEA) in its roadmap for geothermal energy [2], by 2050 the geothermal power production should be increased to 1400 TWh/y, and the direct use to 1600 TWh/y. These objectives are expected to be reached by developing both conventional resources like hydrothermal aquifers and emerging ones like enhanced geothermal systems (EGS). Hence, geothermal heat and power production are expected to know an important development in the future.

However, its economic competitiveness is still a critical point [2]. While the drilling of wells dominate the repartition of the investment costs, already proposed strategies for increasing cost-effectiveness pay all major attention to the design of the conversion system. In this optic, Desideri and Bidini [3] state the bases of a methodology to select and design cycles for power generation from low-temperature geothermal resources, for flash systems, organic Rankine cycles (ORC) and Kalina cycles. Later, several studies extended this method specifically for ORCs, including many potential working fluids [4,5,6,7,8]. Similar approaches were developed for the design of advanced conversion cycles, such as supercritical cycles [9] or fluid mixtures [10]. Recently, Lazzaretto et al. [11] demonstrated the validity of the thermo-economic optimization approach to design geothermal power plants.

While the above studies focus on electricity production, other ones show the attractiveness of geothermal combined heat and power (CHP) production. Kanoglu et al. [12] demonstrated the advantages of incorporating district heating and cooling systems in existing geothermal power plants. Later, Heberle and Brüggemann [13] and Guo et al. [14,15] extended the approach for the selection of working fluids in ORCs including CHP possibilities. Guo et al. [14,15] discuss the influence of district heating parameters, but do not conduct a systematic optimization including all the decision variables, neither account for the seasonal variations of the district heating demand.

* Corresponding author. Tel.: +41 21 693 35 21.
E-mail address: leda.gerber@epfl.ch (L. Gerber).

1359-4311/$ – see front matter © 2011 Elsevier Ltd. All rights reserved.
doi:10.1016/j.applthermaleng.2011.11.033