Economic feasibility of low-temperature geothermal CHP plants

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ABSTRACT

Introduction

Low-temperature geothermal energy is readily available all over the world. Since binary geothermal power plants are mostly not economically feasible without some kind of feed-in tariff, we investigate the economic feasibility of binary geothermal combined heat-and-power (CHP) plants which are connected to a district heating system in this paper. Two types of district heating (DH) systems are considered: a 90/60 DH system for the connection of houses with a conventional heating system and a 65/40 DH system for houses with newer heating systems (floor heating/heat pumps).

Methodology

Figure 1 shows the three CHP configurations which are discussed in this work: the conventional series and parallel CHPs and the preheat-parallel configuration which was presented by the authors in [1].

We have developed a thermoeconomic optimization code which allows the design optimization of the CHP plants. A standard and a recuperated ORC with shell-and-tube heat exchangers and an air-cooled condenser are considered. The design of the heat exchangers (length, shell diameter, tube diameter, tube pitch, baffle cut, length between baffles) and the design of the air-cooled condenser (length, fin height, fin spacing, number of tubes) are optimized together with the operating conditions (flow rates and temperatures). The Net Present Value (NPV) is the optimization objective.

The CHP design optimization procedure is based on the optimization framework for stand-alone electrical power plants which we have described in previous work [2]. The optimization framework has been extended to include heat delivery to a DH system with a certain heat demand and given operating temperatures.

Brine and wells	Economics	CHP and ORC cycle
Brine temperature: 130°C	Electricity price: 60EUR/MWh	ORC pump efficiency: 80%
Brine pressure: 40 bar	Heat price: 25EUR/MWh	Generator efficiency: 98%
Brine flow rate: 150kg/s	Electricity price increase: 1.25%/year	Motor efficiency: 98%
Wells investment: 15MEUR	Discount rate: 5%	Fan efficiency: 60%
Well pumps power: 500kW	Lifetime: 30 years	Min. temperature difference: 1°C
	Availability: 90%	Min. superheating degree: 1°C

Table 1: Reference parameter values.

Isobutane is considered as the ORC working fluid due to its good thermodynamic performance and its low environmental impact. The other model parameters are summarized in Table 1, and are all assumed constant. The brine is modeled as pure water and all brine parameter values are based on the preliminary tests of the Balmatt geological site in Belgium [3]. 2016 is considered as the reference year and the average environment conditions are 10.85°C and 1.02bar for Balmatt (Mol, Belgium) in 2016.

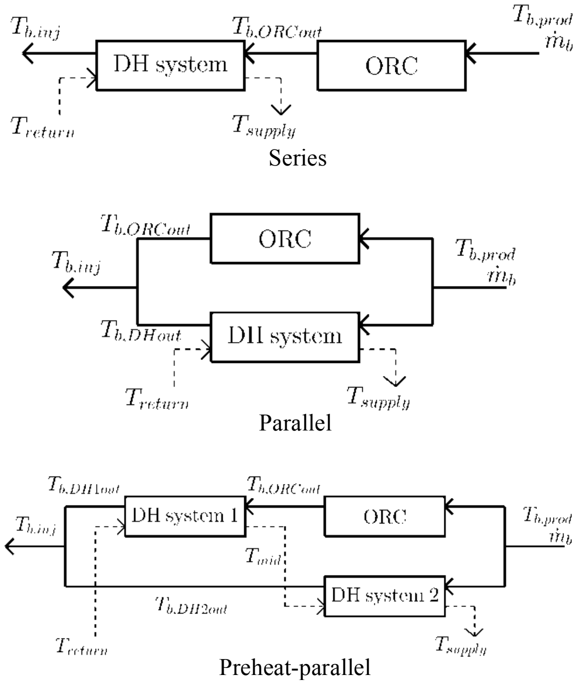

Figure 1: CHP configurations.

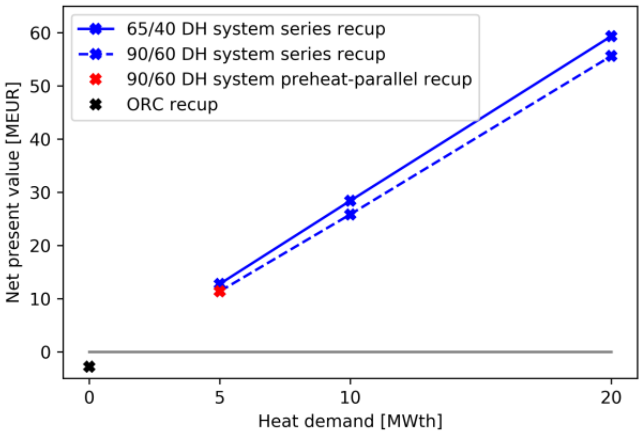

Figure 2: Net present value of the optimal CHP plant as a function of the heat demand.

Results and conclusions

Figure 2 shows the NPV for the optimal CHP configuration as a function of the heat demand. The series CHP with recuperated ORC is the best configuration for all considered heat demands in case of a 65/40 DH system. For the connection to a 90/60 DH system, the preheat-parallel configuration shows better performance for a low heat demand (5 MWth). If we would not consider the preheat-parallel configuration, the parallel CHP would be the best configuration in this case, with a 3.81% lower NPV.

Furthermore, from Figure 2 follows that the optimal CHP configurations have way better economic feasibility than the pure electrical power plant (indicated in black). We can see that the pure electrical power plant is not economically feasible (NPV=-2.81MEUR<0) for the considered conditions of Table 1, which are typical for the Belgian economic situation and climate. But by delivering heat and electricity, the geothermal project becomes feasible (NPV>0). However the electricity production – and the corresponding revenue from selling this electricity – is smaller than for a pure electrical power plant, the revenue from selling heat as a second product more than compensates for this lower electricity production. And finally, from Figure 2 also follows that lower temperatures of the DH system enable better integration of the low-temperature geothermal energy source and a higher NPV of the CHP plant.

Remark that this design optimization framework considers a constant heat demand. Off-design operation due to changing heat demand, district heating system temperatures and environment conditions, and the impact on the real NPV are studied in further work.

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