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A study on selecting optimum flash and evaporation temperatures for four geothermal power generation systems under different geofluid's conditions

Yangyang Zhao[a,b], Xinli Lu[a,b,*], Jialing Zhu[a,b], Wei Zhang[a,b], Kaiyong Hu[a,b], Guanglei Xin[a,b], Feng Jiang[a,b], Zhen Qin[a,b]

[a] *Tianjin Geothermal Research and Training Center, Tianjin University, Tianjin 300350, PR China*
[b] *Key Laboratory of Efficient Utilization of Low and Medium Grade energy, MOE, Tianjin University, Tianjin 300350, PR China*

Abstract

In this study, the optimum flash and evaporation temperatures have been selected for the following four geothermal power generation systems: single-flash system (SF), double-flash system (DF), flash-organic Rankine cycle system (FORC), and double-flash-organic Rankine cycle system (DFORC). Optimization is based on the maximum net power output of each system, with the pump and fan consumptions being taken into account. Under the given geofluid's condition (temperature= 170ºC; dryness= 0.2), the optimum flash temperature of SF, the optimum 2nd-stage flash temperature of DF, the optimum evaporation temperatures of FORC and DFORC are found to be 150ºC, 100ºC, 100ºC, and 70ºC, respectively. More scenarios have been analyzed for geofluid's temperatures ranging from 80ºC-260ºC and geofluid's dryness values of 0, 0.2, and 0.4 respectively. The result shows that the optimum 2nd-stage flash temperature of DF is close to the optimum evaporation temperature of FORC under the same geofluid's condition, especially when the geofluid's temperature is below 170ºC and the dryness is below 0.2.

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Keywords: Geothermal power generation systems; Different geofluid's conditions; Optimum flash temperatures; Optimum evaporation temperatures; Trial method

* Xinli Lu. Tel.: +8618522972804.
E-mail address: xinli.lu@tju.edu.cn

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1. Introduction

Geothermal power generation systems usually include single or double flash systems, organic Rankine cycle (ORC) system, or a combination of them. Single-flash system accounted for 43% of the total installed geothermal power capacity in the world [1]. Double-flash system is an upgraded version of the single flash system in order to generate more power [2,3]. ORC system has a better power generation performance for medium-and-low temperature geothermal resources [4-7], and is good at corrosion inhibition [8].

Many studies have been carried out on geothermal power generation systems. As to the single flash system, Di Pippo R [1], Edrisi BH, et al. [9], Michaelides EES [10], Kestin J [11] and Zeyghami M [12] suggested that flash temperature should be the average of geofluid's temperature and condensing temperature. However, Chao L, et al. [2], Wu ZJ, et al. [13] and Pang LM, et al. [14] advised that optimum flash temperature be geometric mean of geofluid's temperature and condensing temperature. In terms of the double flash system, Wand XY, et al. [15] advised that the 1st-stage flasher should just be a separator (no pressure drop) and the 2nd-stage flash temperature should be optimized to get maximum power output. Clarke J, et al. [16] advised to get optimum flash temperature by trial method. In the work of Pambudi NA, et al. [3], the 1st-stage flash temperature was equal to the geofluid's, and the optimum 2nd-stage flash temperature was obtained by trial method. In the studies of Di Pippo R [1] and Harvey W, et al. [17], each stage optimum flash temperature of a multi-stage flash system can be obtained following the philosophy of "equal temperature split". As to the flash-ORC systems, Luo C, et al. [18] studied the effect of flash temperature on flash-ORC systems' thermal efficiency and power output for the geofluid's temperature ranging from 80ºC-150ºC, but the evaporation temperature of combined systems was not studied. Chao L, et al. [2] studied energy conversion of single-flash and double-flash systems and advised that plants should choose flash-ORC systems when the geofluid has high temperature and large flux. Luo C, et al. [19] and Luo C, et al. [20] studied net power output and advised that double-flash systems should be used when geofluid's temperature has a range from 80ºC to 130ºC and flash-ORC systems should be used for the geofluid's temperature ranging from 130ºC-150ºC. Wu [13] advised to get optimum flash temperature by trial method for flash-ORC systems. Harvey W [17] pointed out that the higher the flash temperature, the more power can be generated by steam turbine, but less power by the ORC.

It can be seen that the selecting optimum flash and evaporation temperatures for power generation systems is essential and useful in engineering application. Trial method can be a practical way.

It will be more useful if a wider range of geofluid's condition can be considered in the optimization. In this paper, we will carry out the temperature optimization through following procedures:

- Set up thermodynamic models for four kinds of power generation systems using Engineering Equation Solver (EES: Academic Professional V10.150-3D [2016-10-26]) – a software that provides many built-in mathematical and thermophysical property functions and can solve a set of algebraic or engineering equations. Under the given geofluid's condition (T=170ºC; x=0.2), determine the optimum temperatures for each power generation system.
- Carry out more studies for wider ranges of geofluid's temperature and dryness, and find the corresponding optimum temperatures for different systems.

2. System description

The schematic diagrams of four geothermal power generation systems in this study are shown in Fig.1. They are single-flash system (SF), double-flash system (DF), flash-ORC system (FORC), and double-flash-ORC system (DFORC). The temperature-entropy diagrams of SF, DF, and ORC are shown in Fig.2.

The schematic diagram of SF is shown in Fig.1 (a), and its temperature-entropy diagram is shown in Fig.2 (a). Geofluid flows into the separator (flasher) and is separated into liquid and vapor. The vapor flows through the steam turbine to generate power that drives generator. The liquid which remains in the separator is reinjected into the reservoir. The turbine exhaust is directed into the condenser and then reinjected into the reservoir.

The DF has one more flasher (2nd-stage flasher) than the SF, shown in Fig.1 (b). Its temperature-entropy diagram is shown in Fig.2 (b). FORC can be considered as a modified DF system where the 2nd-stage flasher is replaced by an ORC system, shown in Fig.1 (c). Its temperature-entropy diagram is a combination of Fig.2 (a) and Fig.2 (c). DFORC is a combination of the DF system and an ORC system, with the ORC being analogs to a bottoming cycle, shown in Fig.1 (d). Its temperature-entropy diagram is a combination of Fig.2 (b) and Fig.2 (c).