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A variable-capacity power system driven by geothermal energy: research methodology and preliminary experimental study

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Abstract

To match for the different temperature of the geothermal resource and strengthen the flexibility of organic Rankine cycle (ORC), this paper proposes a variable capacity power generation superstructure based on Flash and ORC for geothermal energy. A combined Flash-ORC experimental prototype is newly established to investigate its performance on both steady and dynamic conditions in this paper. Pressured hot water is adopted as the extensive worldwide existed hydrothermal geothermal resource, eliminating the influence of the used heat transfer oil on evaporating process. Important variables are investigated including the working fluid mass flow rate, loads quantity and outdoor environment of ORC subsystem in the preliminary experimental study. Firstly, steady experiment indicates that the maximum net power generation of ORC subsystem is 0.74 kW, revealing the existing optimal working fluid mass flow rate of the specific system. Secondly, dynamic on-off investigation of working fluid pump illustrates that ORC system has a certain extent self-adaption capacity and reliability. In addition, power generation increases with the decrease of the loads, and the condensing temperature makes a big influence on system performance when ORC using the cooling tower.

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Keywords: Geothermal resource; Combined Flash-ORC system; Variable capacity; Superstructure; Dynamic response

1. Introduction and research methodology

The feasibility of geothermal power generation system is determined by ecological cleanliness, economic efficiency, and higher indicators of installed capacity utilization [1]. According to World Geothermal Congress 2015, Flash cycle (Flash) is commonly adopted for utilizing relatively higher temperature geothermal resources worldwide. Although ORC is verified as a better choice for lower temperature geothermal resources, it is not used as common as Flash due to its immaturity [2]. Therefore, ORC have been investigated on its working fluid screening, expander

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optimization, dynamic simulation and prototypes in the past decades [3-7].

It is noted that the progress of ORC and Flash provides a promoting way of combined Flash-ORC system, which combines the benefits associate with both Flash and ORC, is acknowledged as one of the most efficient way of geothermal power system. Although thermodynamic, economic, exergoeconomic analysis and optimization have been carried out on combined Flash-ORC system [8-11], investigations all above were designed only on the specific temperature of geothermal resource, and the optimal operating parameters were explored in specific structure. In fact, as shown in Fig. 1, to match for the different temperature and scale of the geothermal resources, multiple configurations of combined Flash-ORC system need to be assembled with a variable capacity output of power generation. In other words, performance of the combined Flash-ORC system not only depends on the optimal operating parameters in Flash or ORC cycles respectively, but also decided by the scheme and number of the Flash or ORC cycles to a large extent, namely superstructure of geothermal power generation system based on Flash and ORC. In addition, although lots of ORC experiments have been studied, experiment on power generation superstructure for geothermal energy was not carried out. While, less dynamic performance of the key components were observed in ORC experiment.

The aim of the present work is to experimentally analyze a combined Flash-ORC geothermal power superstructure from the view of variable capacity. To fill the gap of experiment of variable-capacity power system, and eliminate the influence of the heat transfer oil on evaporating process, overall performances on both steady and dynamic conditions are investigated in this paper. Pressured hot water of 120 °C is adopted to simulate the hydrothermal geothermal resource. Scroll expander reversed from an air-conditioning compressor and R245fa are employed, and the system is tested in winter and summer for the different condensing temperatures.

2. Experimental system, facilities and performance indexes

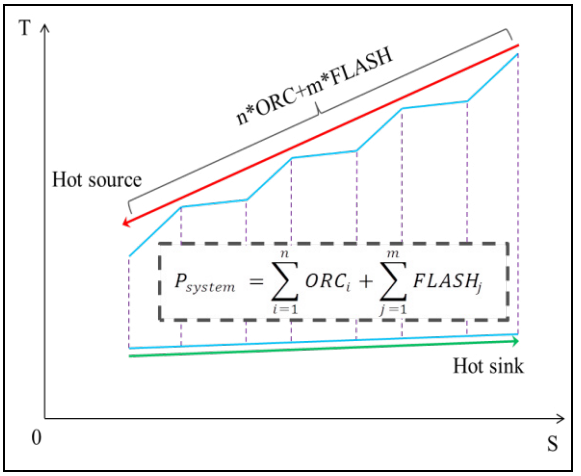

Fig. 1 The variable capacity power generation superstructure for geothermal energy

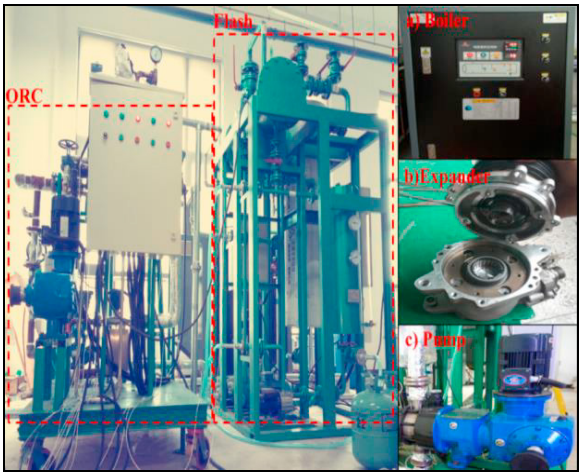

Fig. 2. Photographs of the system components.
(a) Hot water boiler, (b) Expander, (c) Fluid pump.

The combined Flash-ORC system, by introducing ORC subsystem to recover heat from exhausted from the separator in Flash, was constructed in the laboratory at Tianjin University, as shown in Fig. 2 and Fig. 3. It includes a Flash and an ORC driven by an electric pressurized water boiler, the corresponding TS map can be found in Fig. 4. ORC subsystem is able to separate from the combined system. This study is only intended on ORC. ORC subsystem is made up of six major components: a diaphragm pump, a preheater, an evaporator, a scroll-type expander, a condenser and a cooling tower. An electric pressurized water boiler (AEWT/H-30-80) is simulated as the geothermal water, with four electrical heating rods having capacity of 80 kW. The working fluid mass flow rate is controlled by the diaphragm pump (SJ3-M-630/1.5) with different values of startups. The preheater, evaporator and condenser are plate heat exchangers, and insulating foam is equipped around them to avoid the heat loss. The scroll-type expander is modified from a small auto air-conditioning compressor (ATC-066-J10) with a volume ratio