Available online at www.sciencedirect.com

ScienceDirect

Energy Procedia 105 (2017) 149 – 154

Energy Procedia

The 8th International Conference on Applied Energy – ICAE2016

The impact of solar radiation on the annual net solar to power efficiency of a Solar Aided Power Generation plant with twelve possible "configuration-operation" combinations

Jiyun Qin, Eric Hu*

School of Mechanical Engineering, the University of Adelaide, Adelaide 5000, Australia

Abstract

Solar Aided Power Generation (SAPG) has been approved to be an efficient method of using solar thermal energy. In an SAPG plant, the solar thermal energy carried by the heat transfer fluid is integrated into a regenerative Rankine cycle power plant to preheat the feedwater to the boiler. A heat exchanger which is termed as solar preheater facilitate this heat transfer process. The extraction steam which is bled from the turbine to preheat the feedwater is displaced and expended further in steam turbine to generate power. Depending on the arrangement of the solar preheater, an SAPG plant has different configurations, which is termed as solar preheater configurations. When the solar input changes, the flow rates of extraction steam is needed to be adjusted, which is termed as solar preheater operation strategies. The combinations of solar preheater configuration and operation strategies are called "configuration-operation combinations". Previous studies proposed twelve possible "configuration-operation" combinations [1]. It was found that twelve combinations fall into six different groups in terms of annual net solar thermal to power efficiencies [1]. In present paper, the influence of solar collector area and solar radiation on the annual net solar to power efficiencies of twelve combinations has been evaluated. The SAPG plant is modified from a 300 MW power plant, and only the extraction steam to high pressure/temperature feedwater heaters is assumed to be displaced by the solar thermal energy. In addition, the annual solar radiation in three locations have been used for evaluation. The results indicate that the annual net solar to power efficiencies of twelve combinations are more sensitive to the variation of solar collector area in the location with higher annual solar radiation.

Peer-review under responsibility of the scientific committee of the 8th International Conference on Applied Energy.

Keywords: Solar Aided Power Generation; "configuration-operation" combinations; power boosting; solar collector area; solar radiation; solar thermal to power efficiency

* Corresponding author. Tel.: +61-8-83130545; fax: +61-8-83034367.
E-mail address: eric.hu@adelaide.edu.au.

Peer-review under responsibility of the scientific committee of the 8th International Conference on Applied Energy.
doi:10.1016/j.egypro.2017.03.294

1. Introduction

A Solar Aided Power Generation (SAPG) plant is a hybrid power system that solar thermal energy is integrated into a regenerative Rankine cycle power plant. In such a hybrid power system, the feedwater of the Rankine cycle power plant is preheated by the solar thermal energy carried by the heat transfer fluid (HTF). While, the extraction steam of the power plant which is used to preheat by the feedwater is displaced by the HTF. These displaced extraction steam is then expended further to generate the power. In an SAPG plant, the heat exchange process between the feedwater and HTF occurs in a heat exchanger which is termed as solar preheater (SP). Depending on the arrangement of the SP according to the feedwater heater (FWH) of power plant, SP can be arranged in parallel or series with FWHs [1]. The arrangement of the SP is termed as SP configuration. Qin et al. proposed four possible configurations of the SP [1]. In an SAPG plant, when the HTF flow rate input into the SP changes, the extraction steam should be adjusted to response to the variations of HTF flow rate, which is termed as the SP operation strategies. There are three typical SP operation strategies [1]. In an SAPG plant, each SP configuration can be operated in one of the three SP operation strategies. The combinations of SP configuration and SP operation strategy are termed as "configuration-operation" combinations.

Most previous studies about the SAPG plant are based on a single "configuration-operation" combinations. The early studies about the SAPG plant is based on the SP configuration that SP is arranged in parallel with the FWH of the power plant [2-6]. Some other studies are based on the SP configuration that SP is in series with the FWH of the power plant [7, 8]. The SP operation strategy of these studies is based on the assumption that adjusting the extraction steam to keep the feedwater outlet temperature of FWHs constant.

Recently, Qin et al. proposed that an SAPG plant have twelve possible "configuration-operation" combinations [1]. The instantaneous and annual technical performance of twelve proposed combinations have been compared. It was found that with the same solar thermal input or solar collector area, an SAPG plant with different combinations would have different instantaneous solar to power efficiency and annual net solar to power efficiency. However, the impact of the different annual solar radiation on the annual net solar to power efficiency has not been analyzed. It was pointed that the annual net solar to power efficiency is influenced by the annual solar radiation [7]. Therefore, there is a need for evaluation the influence of the solar radiation on twelve combinations.

The aim of present paper is to understand the influence of the annual solar radiation on the annual net solar to power efficiency of twelve "configuration-operation" combinations. The annual solar radiation data in three locations are used for evaluation.

2. Twelve Possible "Configuration-Operation" Combinations

Figure 1 presents the four possible SP configurations of an SAPG plant. In an SAPG plant, the extraction steam to deaerator (DEA) is not displaced by the solar thermal energy. In Fig. 1, the HTF 1 is used to displace the extraction steam to FWH 1 to FWH 3, while HTF 2 is used to displace the extraction steam to FWH5 to FWH 8. As shown in Fig. 1 (a) and Fig. 1 (b), the SP is in parallel with the FWH. In Fig. 1 (c) and Fig. (d), the SP is in series with the FWH.

When the HTF flow rate changes, there are three possible SP operation strategies [1]:

- Constant temperature (CT) strategy: Adjusting the displaced extraction steam flow rate to keep the feedwater outlet temperature of each displaced FWHs unchanged.
- High to low varying temperature (VT-HL) strategy: Adjusting the displaced extraction steam from high to low temperature extraction points. Namely, the higher temperature extraction steam is