Available online at www.sciencedirect.com

ScienceDirect

Energy Procedia 69 (2015) 434 – 443

Energy Procedia

International Conference on Concentrating Solar Power and Chemical Energy Systems, SolarPACES 2014

The required concentration ratio for two stage water/steam cavity receiver

X. Li[a,]*, Z.F.Wang[a]

[a]Key Laboratory of Solar Thermal Energy and Photovoltaic System, Institute of Electrical Engineering, Chinese Academy of Sciences, Beijing 100190, China.

Abstract

The pioneering water/steam cavity receiver CESA-1 is not very successful for that the evaporator and superheater are in the same cavity cause it is very difficult to control the heat flux distribution on the absorber surface and hence the flow stability inside the receiver. The two-stage water/steam receiver is a promising way for separating the evaporator and superheater in two different cavities or parts. Because the two different parts have different thermal performance, the required concentration ratio(CR) of per heliostat projected two different parts will be different. Based on the transient efficiency equation and existed DAHAN solar tower power plant, the paper research the influence principle of many factors such as receiver thermal performance, superheater operation capacity, heliostat size and numbers of heliostats projected to the absorber. The results show that the required CR of per heliostat for superheat part is decreasing with the superheater thermal performance improving. When the receiver operates in lower capacity, the required CR of per heliostat is lower. With more heliostats project to the superheater, the required CR of per heliostat becomes lower. The smaller heliostat size, the lower required CR of per heliostat. The results also give us some inspirations that: 1) using the method in the paper, one can evaluate whether the existing heliostat field is fit for the two-stage receiver. 2) two stage receiver capacity and heliostat size should be in harmony for different CR requirement for evaporator and superheater. 3) the results about how the heliostat size influences the required CR of per heliostat for superheater give the reference to industrial choose of heliostat size. 4) from the required CR point, the smaller heliostat is better than bigger one. Of course, in the real commercialization process, the cost of the heliostat should also be considered.

Peer review by the scientific conference committee of SolarPACES 2014 under responsibility of PSE AG

Keywords: Two stage water/steam receiver; concentration ratio;

* Corresponding author. Tel.: +86-10-62558289; fax: +86-10-62587946.
E-mail address: drlixin@mail.iee.ac.cn

Peer review by the scientific conference committee of SolarPACES 2014 under responsibility of PSE AG
doi:10.1016/j.egypro.2015.03.050

1. Introduction

For the water/steam cavity receiver such as CESA-I, one of the problem is that the evaporator and superheater are in the same cavity cause it is very difficult to control the heat flux distribution on the absorber surface and hence the flow stability inside the receiver, therefore, it is very easier to be overheated or overcooled inside the receiver and other related problems[1~4].

To solve such kind of problem, two-stage receiver is a very promising way. The new Ivanpah solar tower power plant uses the two-stage external water/steam receiver and now in commissioning[5]. The advantages of two-stage water/steam receiver are the following:

- Using different heliostats to separately project onto the evaporator and superheater part of the receiver. Therefore, it is easier to control evaporation and superheating process separately and increase the safety and operation flexibility.
- It is easier to start the receiver and shorten the startup time because it avoids the evaporation and condense process happening at the same time in the same cavity receiver which makes the projecting more or less heliostats onto the receiver surface is a dilemma.

For the two-stage receiver, because the evaporator and superheater operation temperature are different, therefore, the heat loss are different and the required concentration ratios for the heliostats are different. Up to now, there are not papers to show how to calculate the required concentration ratio of per heliostat for two separate part of two-stage receiver. And in the commercialized solar tower power plant, the same size heliostats are used. It maybe cause some waste that the higher CR heliostats is used in the condition that only the lower required CR of per heliostat is needed.

This paper provides an easy-to-use method to evaluate the required concentration ratio for the heliostats projected to the separate receiver stage based on the receiver's transient efficiency equation. On the basis of the Beijing DAHAN solar tower power plant heliostat field which has 100 heliostats. Every heliostat is $100m^2$. The required concentration of per heliostat for superheater was simulated. And many influence factors such as receiver heat removal factor, numbers of heliostats, superheater heat operation capacity and heliostae area are studied in the paper. The results can give reference to the joint design of two-stage steam receiver and required heliostat concentration ratio.

2. Methodology

2.1. Mathematical model and calculation flowchart

In the two stage water/steam receiver the energy equation for the evaporator is:

$$Q_{sat} = \dot{m}\Delta h_1 \tag{1}$$

Where Q_{sat} is the output power of evaporator where the heat transfer fluid change the state from subcooling water to saturation steam. The $\dot{m}$ is the fluid mass flowrate. Δh_1 is the enthalpy change.

The energy equation for the superheater is:

$$Q_{\sup} = \dot{m}\Delta h_2 \tag{2}$$

Where $Q_{\sup}$ is the output power of superheater where the heat transfer fluid change the state from the saturation steam to the superheating steam. Δh_2 is the enthalpy change.

The total energy balance equation is:

$$Q_{in} \cdot \eta_{rec} = Q_{sat} + Q_{\sup} \tag{3}$$