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Experimental study of a parabolic trough medium temperature solar thermal system

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Abstract

A parabolic trough concentrator (PTC) with a rim angle of 84˚, a length of 4.2 m, and an aperture area of 6.72 m^2 was designed and manufactured in a way required relatively simple technology and skill. An experimental system with the PTC as the core part was assembled on the top of the Teaching Building No.7 of Ludong University (in Yantai, China). A PLC solar tracking system is employed to realize an orientation of a north-to-south direction. According to the international and national standard, thermal performance of the PTC was measured under various weather and working conditions. The experimental results reveals that the effective radiation, which considers the optical influences including the shading effect, cosine effect, incident angle modifier and end loss, deserves great attention. Peak efficiency of 72% was obtained from the experiment.

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Keywords: Parabolic trough; performance test; medium temperture; heat loss

1. Introduction

The parabolic trough collector (PTC) is currently the most popular one in the solar thermal power plants. By concentrating the beam component of the solar radiation to the receiver positioned at the focus of PTC, working temperature up to around to 400˚C can be reached and thus the thermal energy transferred from solar radiation can be fed to a Rankine cycle to generate electricity.

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PTC is also pursued in China, and several demonstration power plants are under preliminary work and design in the northern and western parts of the country (Inner Mongolia and Qinghai), where the direct normal insolation (DNI) resources are abundant and large areas of arid & semi-arid land are available.

However, in most regions in China, especially the economically developed ones, like the eastern coast, the DNI resource can not support a profitable operation of solar thermal power generation (less than the generally assumed economical level of 1,800kWh/ (m^2a) [1]), and the process and domestic heat production systems become reasonable choices in these areas.

In this study, a PTC experimental system was built on the top of the Teaching Building No.7 in Ludong University (in Yantai, an eastern coastal city in China), to investigate the performance of such system.

Nomenclature	
I_{inc}	radiation reaching the receiver aperture
I_b	beam radiation (DNI)
ξ_i	effective factor regarding shading effect, cosine effect, incident angle modifier and end loss, etc.

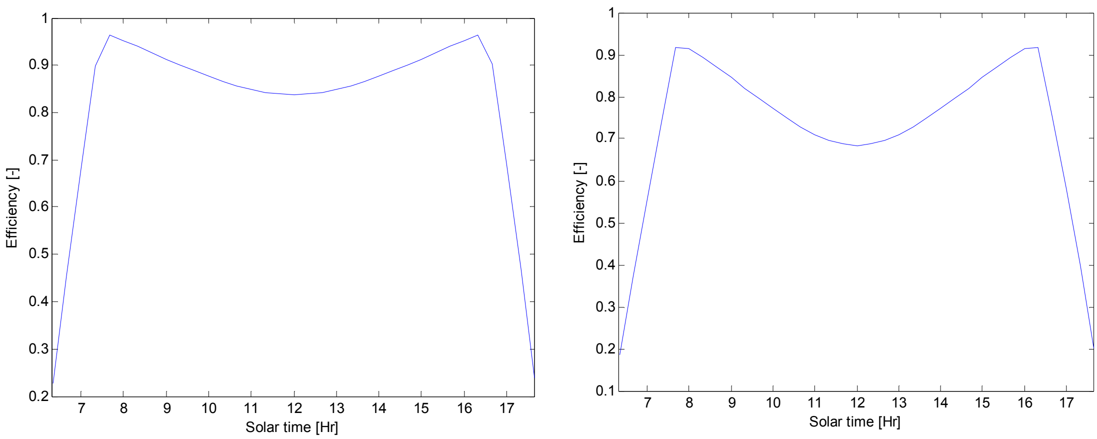
2. Effective radiation and optics efficiencies of the PTC

The receiver can only receive part of DNI due to various optics losses regarding change of latitude, season and time, shading effect, cosine effect, etc.[2][3]. Taking into account all the influences, the radiation reaching the receiver aperture, I_{inc}, can be expressed as,

$$I_{inc} = I_b \Pi \xi_i \tag{1}$$

Where i=1,2,3 and 4, which corresponds to the effective factor regarding shading effect, cosine effect, incident angle modifier and end loss, respectively; I_b is the beam radiation (DNI).

It is important to make clear the available radiation under various condition for a PTC installed in certain place. Figure 1 shows the beam radiation efficiency, which means ratio of effective beam radiation to DNI, for the location of Yantai where the PTC is located, in different seasons. It is obvious that season and time affect the efficiency greatly. The incident angle changes with season and time, thus the radiation efficiency changes between 0 and 1. The maximum efficiency of 1 appears at sunrise and sunset on the summer solstice (June 21); also the figures clearly indicate influence of season to the radiation efficiency, which reaches its maximum on the summer solstice and minimum on the winter solstice. The efficiency is just 0.5333 at the noon on the winter solstice, 46% lower than that increases gradually after the sunrise, reaches the first peak value and then lower gradually, at the noon reaches a trough point and then raises again, get to the second peak value and decline once again.



(a) June 21

(b) September 23 & March 21