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SCIENCE DIRECT
Renewable Energy 30 (2005) 855–865
RENEWABLE ENERGY
www.elsevier.com/locate/renene

A new method for the measurement of solar collector time constant

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Received 24 April 2004; accepted 13 August 2004
Available online 30 November 2004

Abstract

A new test method about the time constant of the solar collector has been presented in this paper. It is simple and has been validated through experiments. With the new method it is not necessary to adjust the inlet temperature of the transfer fluid as closely as possible to the ambient air temperature. Also, it is not necessary to know the characteristic parameters of the collector in advance. The model used in the paper is a first order system model, as in most cases. The experimental data obtained from the test of solar collector time constant shows that the solar collector is not a strictly first order system. A criterion is proposed to decide whether the system is a first order system or not and the resemblance of the system to the first order system.

Keywords: Solar collector; Time constant; First order system

1. Introduction

As one kind of solar energy absorbers, solar collectors usually work outdoors, so they are subjected to unsteady weather conditions. For example, when a cloud shades the sun abruptly, the incident solar energy on the collectors abruptly reduces to zero, thus a

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0960-1481/$ - see front matter
doi:10.1016/j.renene.2004.08.005

Nomenclature

A	system amplification coefficient (–)
A_c	collector aperture (m^2)
C_p	specific heat of the heat transfer fluid (J/(kg °C))
F_R	solar collector heat removal factor (–)
G	solar irradiance (W/m^2)
$\dot{m}$	mass flow rate of heat transfer fluid (kg/s)
$(mc)_e$	effective heat capacity of the solar collector (J/(m^2 °C))
T	time constant (s)
T_a	ambient air temperature (°C)
$T_{f,i}$	collector inlet temperature (°C)
$T_{f,o}$	collector outlet temperature (°C)
U_L	solar collector heat loss coefficient (W/(m^2 °C))
$T_{f,o,initial}$	collector outlet temperature at the beginning of time constant test period (°C)
$T_{f,o,\infty}$	collector outlet temperature at time $\tau=\infty$ (°C)
Greek	
$(\tau\alpha)$	effective transmittance absorptance product (–)
τ	time (s)

transient driving force is generated on the solar collectors. The collectors then begin to operate under a transient condition. Thus besides to steady state or quasi-steady state, transient process also needs to be studied. Time constant is one of the most important parameters of solar collectors thermal performance under transient condition. It indicates the response characteristics of solar collector under transient forces. Therefore the solar collector time constant test is one important part of the thermal performance tests.

Although the time constant of the solar collector can be obtained through the two established standards: ISO 9806-1 and ASHRAE 93-86 standard, many limitations are imposed by them. In the two standards, we need to adjust the temperature of the transfer fluid at the inlet $T_{f,i}$ as closely as possible (preferably within ± 1 °C) to the ambient air temperature T_a otherwise ISO 9806-1standard is invalid or another parameter of the solar collector $F_R U_L$ is needed to meet the requirements of ASHRAE 93-86 standard.

2. Test methods about solar collector time constant

Relevant solar collector time constant tests procedures are different in different standards [1,2], which deal with thermal performance test of solar collectors.

In ISO9806-1 standard [1] the test procedure for collector time constant is described by:

1. Testing shall be performed either outdoors or in a solar irradiance simulator.
2. During the test the solar irradiance on the plane of the collector aperture shall be greater than 800 W m^{-2}.