Available online at www.sciencedirect.com
ScienceDirect
Energy Procedia 69 (2015) 879 – 890
Energy Procedia

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

Object-oriented modeling of molten-salt-based thermocline thermal energy storage for the transient performance simulation of solar thermal power plants

I. Hernández Arriaga[a], F. Zaversky[b]*, D. Astrain[a]

[a]*Public University of Navarre (UPNA), Department of Mechanical, Thermal and Materials Engineering, Address: Campus Arrosadía s/n CP 31006, Pamplona, Spain*
[b]*National Renewable Energy Center (CENER), Solar Thermal Energy Department Address: c/ Ciudad de la Innovación 7, Sarriguren (Navarre), Spain*

Abstract

This paper presents a one-dimensional numerical model of a molten-salt-based thermocline thermal energy storage tank. The model is explained and referenced in detail, allowing for a complete reproduction. It has been successfully validated against experimental and theoretical data from the literature. Unlike previous works, the full boundary conditions of the performed validation simulations are given, enabling future model comparison studies and thus a further check for consistency against other codes. Finally, the model has been optimized regarding simulation speed for CSP performance simulations on system level.

© 2015 The Authors. Published by Elsevier Ltd. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).
Peer review by the scientific conference committee of SolarPACES 2014 under responsibility of PSE AG

Keywords: Concentrated solar power; thermal energy storage; thermocline; Modelica

1. Introduction

Solar thermal power, also known as concentrated solar power (CSP) or solar thermal electricity (STE) can be considered as a very promising technology when it comes to dispatchable and thus grid-friendly supply of renewable

* Corresponding author. Tel.: +34 625 234 628
E-mail address: fzaversky@cener.com, fritz.zaversky@alumni.tugraz.at

1876-6102 © 2015 The Authors. Published by Elsevier Ltd. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).
Peer review by the scientific conference committee of SolarPACES 2014 under responsibility of PSE AG
doi:10.1016/j.egypro.2015.03.116

electricity. This is due to the possibility of thermal energy storage (TES) that enables the decoupling between solar energy collection and electricity production. Additionally considering the fact that solar thermal power plants directly (the indirect usage of solar energy would be, e.g., the application of wind turbines) harness the abundant amount of solar energy incident on planet earth [1], they form a highly promising alternative to conventional fossil-fuel or nuclear technology, setting new standards in terms of environmental impact, sustainability and safety, and thus quality of life.

Nomenclature

CSP	concentrated solar power
DAE	differential-algebraic equation
MSL	Modelica Standard Library
TES	thermal energy storage
A_c	cross sectional area of the storage tank (m^2)
A_{fs}	surface area of solid fluid interface (m^2)
A_w	wall surface area (m^2)
c_f	specific heat capacity of fluid ($J\ kg^{-1}\ K^{-1}$)
c_s	specific heat capacity of solid ($J\ kg^{-1}\ K^{-1}$)
C_s	heat capacity of solid medium node (J/K)
d_p	particle diameter in packed bed (m)
$h_{fs\ nc}$	not corrected heat transfer coefficient between fluid and solid ($W\ m^{-2}\ K^{-1}$)
h_{fs}	heat transfer coefficient between fluid and solid ($W\ m^{-2}\ K^{-1}$)
k_f	thermal conductivity fluid ($W\ m^{-1}\ K^{-1}$)
k_s	thermal conductivity solid ($W\ m^{-1}\ K^{-1}$)
k_{fe}	effective thermal conductivity fluid ($W\ m^{-1}\ K^{-1}$)
k_{se}	effective thermal conductivity solid ($W\ m^{-1}\ K^{-1}$)
L	length of packed bed (m)
$\dot{m}_f$	fluid mass flow rate (kg/s)
M_f	mass of fluid (molten salt) per unit height of storage tank (kg/m)
M_s	mass of solid (packed-bed filling) per unit height of storage tank (kg/m)
n	number of nodes (integer)
P_{fs}	perimeter of fluid solid interface (m)
P_w	perimeter of wall fluid interface (m)
t	time (s)
T_a	ambient temperature (K)
T_f	fluid temperature (K)
T_s	solid temperature (K)
U	overall heat loss coefficient to ambient ($W\ m^{-2}\ K^{-1}$)
v	flow velocity (m/s)
v_e	fluid velocity based on empty cross section (m/s)
x	coordinate along storage tank height (m)
Δp	pressure drop across packed bed (Pa)
ϵ	ratio of liquid phase volume to total volume - porosity (-)
μ_f	dynamic viscosity of fluid (Pa s)
ρ_f	density of fluid ($kg\ m^{-3}$)
ρ_s	density of solid ($kg\ m^{-3}$)

At today's commercial solar thermal power plants, the two-tank molten-salt-based sensible heat thermal energy storage system [2] is at the moment the state-of-the-art solution and is applied in indirect [3] (thermal-oil-based parabolic trough technology) or direct mode [4] (molten-salt-based central receiver technology). However, in order

Download English Version:

https://daneshyari.com/en/article/1510260

Download Persian Version:

https://daneshyari.com/article/1510260

Daneshyari.com