Available online at www.sciencedirect.com

ScienceDirect

Energy Procedia 139 (2017) 49–54

Energy Procedia

www.elsevier.com/locate/procedia

International Conference On Materials And Energy 2015, ICOME 15, 19-22 May 2015, Tetouan, Morocco, and the International Conference On Materials And Energy 2016, ICOME 16, 17-20 May 2016, La Rochelle, France

A General fractional-order heat transfer model for Photovoltaic/Thermal hybrid systems and its observer design

Lahoucine Ouhsaine[a,b]*, Yassine Boukal[c,d], Mohammed El Ganaoui[a], Mohammed Darouach[c], Michel Zasadzinski[c], Abdelziz Mimet[b] and Nour Eddine Radhy[d]

[a]*LERMAN and* [c]*CRAN, Université de Lorraine, IUT Henri Poincaré de Longwy, 186rue de lorraine, 54400 Cosnes et Romain, Longwy, France*
[b]*Energetic Laboratory, Faculty of Sciences, Abdelmelek Essaâdi University P.O. Box 2121M'hannech II, 93030, Tetouan, Morocco*
[d]*LMPMAT, Faculty of Sciences, Hassan II University, P.O. Box, 20100, Casablanca, Morocco*

Abstract

This paper presents the results of heat transfer process modelling for Photovoltaic/Thermal PV/T hybrid system in state-space. The heat transfer process in solid materials can be described by an integer-order partial differential equation. However, in Photovoltaic (PV/T) hybrid systems, which is characterized by heterogeneous media due to the multilayers that make up the system, it can be described by a fractional-order partial differential equation. The major objectives of this study were to establish a new mathematical model of the Photovoltaic/Thermal (PV/T) hybrid systems and their fractional-order observers in time domain. This model has been constructed in the context of a new consideration of heat conduction with a time fractional-order derivative. On the other hand, after obtained the general model of the system in state-space, the existence conditions of the fractional-order observer of such systems are given. Then, a necessary and sufficient condition for the asymptotic stability of the estimation error is given in a Linear Matrix Inequality (LMI) formulation.

Peer-review under responsibility of the scientific committee of ICOME 2015 and ICOME 2016.

Keywords: PV/T systems, fractional-order diffusion equation, fractional-order system, fractional-order observer, linear matrix inequality (LMI)

* Corresponding author : Lahoucine Ouhsaine,
E-*mail address:* ouhsaine.la@gmail.com ; lahoucine.ouhsaine@univ-lorraine.fr

1876-6102
Peer-review under responsibility of the scientific committee of ICOME 2015 and ICOME 2016
10.1016/j.egypro.2017.11.171

1. Introduction

Photovoltaic/Thermal hybrid solar system (PV/T) is a combination between photovoltaic (PV) and solar thermal components systems that would produce both electricity and heat from one integrated system. Recently, several methods are devoted to simplify the mathematical model of such systems. Also several theoretical and academic works are considered that the non-linearity in the thermal behaviour of solar panels [1,2]. Therefore, some numerical solutions are proved such as finite element method [3] and finite difference method [4] in order to perform simulation and improve system sizing. However, an adequate thermal modelling using fractional-order approach applied to buildings is proposed in [5]. In [6], the Authors had discussed more generally heat transfer in heterogeneous media using fractional calculus.

For past centuries, fractional calculus has been very interesting topic, but only for mathematicians, to make the subject well understandable for engineers or scientists point of view [7-9]. Only in the last decades, fractional calculus have been caught much attention, because it has been shown that non-integer models can be both theoretically challenging and pertinent for many fields of science and technology such as chemistry [10], biology [11,12], economics [13-15], psychology [16,17], mass diffusion, heat conduction, physical and engineering applications [18-20] etc. In certain systems, the measurements of all system states may not possible because the system output measurements do not provide complete information on the internal state of the system, not only purely technological, but also for financial reasons, the number of sensors is limited. For these reasons, observer design for estimating the state of a system has received considerable attention in the past [21-23]. This need for internal information may be motivated by several objectives such as identification, feedback control and system diagnosis [24-29].

In this work, the results of dynamics thermal modeling by fractional order differentiator are discussed aiming to provide the possibility to present the thermal dynamics of "hybrid PVT" system by fractional-order state space model. Therefore, by using the fractional-order observers, the temperature in all chosen nodes are estimated.

The asymptotic stability of the estimations error following the fractional-order value α= 0.5 is investigated, and formulated in Linear Matrix Inequality (LMI). Then, the observer gains are computed by solving the obtained LMI.

2. Model description

2.1. Preliminaries

In this section, some useful definitions of the fractional-order derivatives are presented

The fractional-order derivative definition introduced by Caputo for a function f(t) can be given as [30], [31]

$$ {}_{a}^{C}D_{t}^{\alpha} f(t) = \frac{1}{\Gamma(n-\alpha)} \int_{a}^{t} \frac{f^{n}(\tau)}{(t-\tau)^{\alpha-n+1}} \mathrm{d}\tau \,, \quad (n-1) < \alpha < n \qquad (1) $$

where $n \in \mathbb{N}^{*}$ and $\alpha \in \mathbb{R}^{+}$, while $\Gamma(.)$ is the Gamma function. t and a refer to upper and lower limits, respectively, of the Caputo derivative.

The physical interpolation of the fractional derivatives and the solution of fractional differential equations are given in [30, 31]. Usually the Caputo definition is used since its Laplace transform allows the use of initial values of classical integer-order derivatives with clear physical interpretations.

2.2. Fractional heat diffusion equation

The fractional heat diffusion equation can be described by the following partial fractional differential equation [6]:

$$ H(t,\lambda) = \kappa \frac{\partial^{\alpha} T(t,\lambda)}{\partial t^{\alpha}} \qquad (2) $$

with the following boundary conditions $T(0,\lambda) = 0,\ T(t,0) = \varphi(t)$