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Power management of PV/battery hybrid power source via passivity-based control

A. Tofighi*, M. Kalantar

Center of Excellence for Power System Automation and Operation, Department of Electrical Engineering, Iran University of Science and Technology, Tehran, Iran

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ABSTRACT

In this paper, the power electronic interface between a DC hybrid power source with a photovoltaic main source and a Li-ion battery storage as the secondary power source is modelled based on the Euler–Lagrange framework. Subsequently, passivity-based controllers are synthesised using the energy shaping and damping injection techniques. Local asymptotic stability is ensured as well. In addition, the power management system is designed to manage power flow between components.

Evaluation of the proposed system and simulation of the hybrid system are accomplished using MATLAB/Simulink. The results show that the outputs of the hybrid system have good tracking response, low overshoot, short settling time and zero steady-state error. Afterwards, linear PI controllers are provided to compare the results with those of passivity-based controller responses. This comparison demonstrates the robustness of the proposed controllers for reference DC voltage and load resistance changes.

1. Introduction

Renewable energy resources are desirable for electrical power generation because they are environmentally friendly. Among renewable energy resources, solar energy is now widely used because it is free, abundant, and pollution-free [1].

It is estimated that about 80% of all photovoltaic (PV) systems are utilised in stand-alone applications [2]. Furthermore, power generated by a PV system depends on weather conditions. For example, during cloudy periods and at night, a PV system does not generate any power [3]. Thus, hybrid power sources have been introduced to make the best use of solar energy [4]. Batteries are a secondary source that stores solar energy and is utilised when it is needed based on hybrid system constraints [5].

Power electronic converters play a significant role in hybrid systems [6]. They interface between the Distributed Generation (DG) sources and the other parts of a hybrid system [7]. Recently, some researchers have focused on controlling hybrid power sources [8,9]. Controller design methods can be placed into one of two categories: linear and nonlinear. Linear methods rely on locally linearised models. Thus, their performance varies if the equilibrium points change. The PI controller is the main linear controller being used in DG applications [10,11]. The dynamic equations of the power electronic converters have a nonlinear nature because the control inputs cause the number of state variables to multiply [12]. Therefore, nonlinear methods, such as robust [13], feedback linearization [14], sliding mode [15] and passivity-based control [16], are used to control the converters. In particular, a passivity-based control method has been utilised in various industrial applications.

Passivity-cased control (PBC) was introduced by Ortega et al. as a controller design methodology that achieves stabilization by passivation [17]. Two theories for PBC have been developed: Euler–Lagrange (EL)-PBC [18] and interconnection and damping assignment (IDA)-PBC [17]. These methods have been primarily used to control induction motors [19] and to switch power converters [20].

Lee has used EL-PBC to control a three-phase AC/DC voltage source converter [21]. Additionally, a single phase PWM current source inverter control with an IDA-PBC has been implemented by Komurcugil [22]. Ayad et al. have reported a fuel cell/ultracapacitor hybrid system controlled by IDA-PBC [23]. Becherif et al. [24] has used IDA-PBC to manage energy in a solar energy system with a battery.

This study models a PV/battery stand-alone hybrid power source with a Lagrangian model. The PV system is the main power source whenever the generated PV power, which depends on the weather conditions, exceeds the load power, and the battery power is utilised as a secondary power source. The dump load consumes the excess power of the PV system whenever the generated power is greater than the load power, and the battery does not need to be charged. The control signals are achieved by PBC. Power flow between hybrid system components is managed in the power management unit.

* Corresponding author. Tel.: +98 2177240540-50x2665; fax: +98 2177240354.
E-mail addresses: tofighi@iust.ac.ir (A. Tofighi), kalantar@iust.ac.ir (M. Kalantar).

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