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Study of hybrid photovoltaic/fuel cell system for stand-alone applications

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ABSTRACT

In this paper the modeling of a hybrid photovoltaic/fuel cell system is presented. It consists of a photovoltaic generator (PV), a proton exchange membrane fuel cell (PEMFC), and power conditioning units (PCU) to manage the system operation of the hybrid system. When there is an excess of solar generation available, the electrolyzer is turned on to begin producing Hydrogen which is sent to a storage tank. The produced Hydrogen is used by the fuel cell stack which produces electrical energy to supply the DC bus. The global system is modeled and simulated under Matlab/Simulink and results are presented and discussed.

Introduction

Hybrid systems combine two or more sources of renewable energy. It can be photovoltaic, wind, hydraulic or fuel cells [1–3]. Due to the complementarities of these sources, their combination provides more continuous electrical output [4,5]. The purpose of a hybrid system is to produce as much energy from renewable energy sources to ensure the load demand. In addition, a hybrid system may also include a DC or AC converters, storage and a power conditioning unit. All these components can be connected in different architectures [6].

Energy storage is a dominant factor and different storage technologies are used with wind hybrid systems. It can be electrical, chemical or electrochemical, mechanical, or thermal.

We present in this paper a study of hybrid Photovoltaic/fuel cell system used in stand-alone application. The architecture chosen is with DC bus. In this case, the power supplied by each source is centralized on a DC bus. Thus, the energy conversion system to provide AC power has to be converted then continuously. The generators are connected in series with the inverter to power the loads alternatives. The inverter should supply the alternating loads from the DC bus and the batteries are sized to supply peak loads. The advantage of this

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Nomenclature

E_{Nerst}	voltage Nerst, V
E_s	solar radiation, W/m^2
I_{pv}	output-terminal current, A
I_{ph}	diode-current, A
I_{sh}	shunt-leakage current, A
I_{sc}	short circuit current, A
I_0	saturation current of the diode, A
I_{mpp}	maximum current at PPM, A
K	Boltzmann constant, Joule/K
P_{mpp}	maximum power point, W
P_{load}	load power, W
P_{PV}	photovoltaic power, W
q	electron charge, C
R_s	series resistance, Ω
R_{sh}	shunt resistance, Ω
T_j	temperature cells, K
T_{jref}	reference temperature of the PV cell, K
T_{PEMFC}	absolute operating temperature of the stack, K
U_{act}	activation overvoltage, V
U_{conc}	concentration or diffusion over-voltage, V
U_{ohm}	resistive or ohmic over-voltage, V
V_{mpp}	maximum voltage at PPM, V
V_{oc}	open circuit voltage, V
V_{PEMFC}	fuel cell voltage, V

Greek letters

α_{sc}	temperature coefficient of short-current, A/K
β_{oc}	voltage temperature coefficient, V/K

Abbreviations

FC	fuel cell
PEMFC	proton exchange membrane fuel cells
PV	photovoltaic

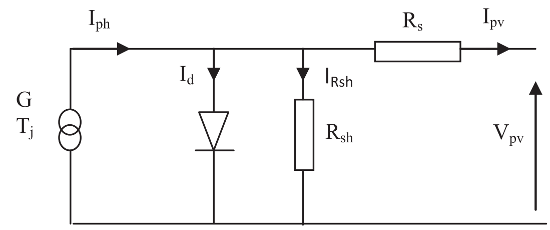

Fig. 2 – Simplified equivalent circuit of solar cell.

topology is the simplicity of operation and the load demand is satisfied without interruption even when the generators charge the short-term storage units [8–15]. The modelisation of each subsystem is given and the simulation of the global hybrid system is made under Matlab/Simulink. Obtained simulation results and some experimental ones are presented and discussed.

Studied system

The studied system comprises photovoltaic panels, a fuel cell stack and a storage system. The coordination between the different energy sources is made by the power management unit (PMU) (Fig. 1).

Modeling of the studied system

Modeling of the PV

The model studied in this work is represented by an equivalent circuit. This one consists of a single diode for the cell polarization function and two resistors (series and shunt) for the losses (Fig. 2.). Thus, it can thus be named “one diode model”. This model runs under the technical characteristics of the solar cells given by the manufacturers (data sheets).

The electrical characteristic of this model is given by the following equation [10]:

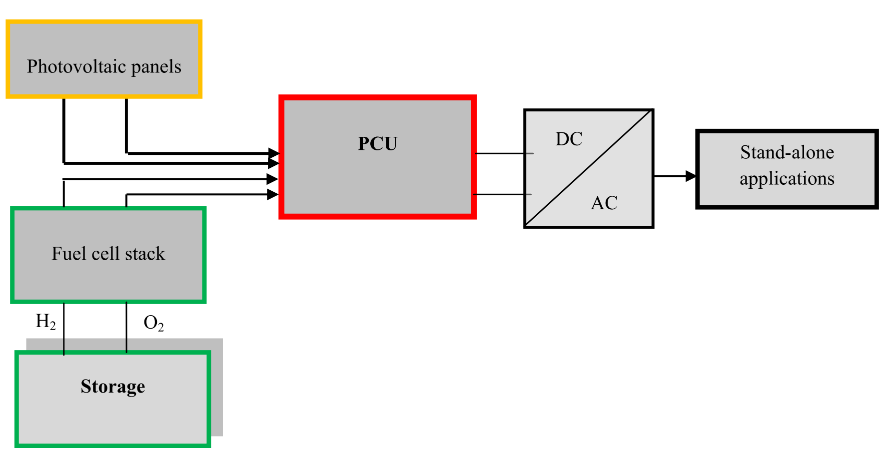

Fig. 1 – Description of the overall system.