INTERNATIONAL JOURNAL OF HYDROGEN ENERGY 40 (2015) 13777–13788

Available online at www.sciencedirect.com

ScienceDirect

journal homepage: www.elsevier.com/locate/he

Supervisor control for stand-alone photovoltaic/ hydrogen/ battery bank system to supply energy to an electric vehicle

N. Mebarki, T. Rekioua*, Z. Mokrani, D. Rekioua

Laboratoire de Technologie Industrielle (LTII), Faculté de Technologie, Université de Bejaia, 06000, Algeria

ARTICLE INFO

Article history:
Received 5 January 2015
Received in revised form
27 February 2015
Accepted 7 March 2015
Available online 29 March 2015

Keywords:
Hybrid power system
Photovoltaic
Fuel cells
Battery
Supervisor control
Electric vehicle

ABSTRACT

In this paper, supervisor control for stand-alone hybrid power system to supply energy to an electric vehicle is presented. The hybrid system is used to produce energy without interruption and it consists of a photovoltaic generator (PV), a proton exchange membrane fuel cell (PEMFC) and a battery bank. PV and PEMFC systems work in parallel via DC/DC converter and the battery bank is used to store the excess of energy. The mathematical model topology, the identification of each subsystem and the control supervision of the global system are the contribution of this paper. Obtained results under Matlab/Simulink and some experimental ones are presented and discussed.

Introduction

In hybrid power systems, we can use different sources, conventional ones as coal, natural gazes, fossil fuels, or renewable ones as solar, wind, hydraulic,... [1–13]. However, due to the intermittent character of these sources, a storage system, in general a battery bank must be inserted. These past few years, manufacturers have taken an interest in hydrogen or fuel cell vehicles which can have autonomy of 400–800 km depending on car models, and which reject less carbon dioxide. The fuel cells were invented more than 165 years ago. It was discovered in 1839 that the electrolysis process could be reversed. In a fuel cell, hydrogen and oxygen react to form water and electricity is produced. A fuel cell consists essentially of the electrodes separated by an electrolyte. There are different types of fuel cells depending on the type of electrolyte. In order to obtain appreciable output voltages, several fuel cells have to be combined to obtain a fuel cell stack. Most mobile applications and particularly automobiles are dominated by proton exchange membrane fuel cells (PEMFC). This is due to their low operating temperature, so PEMFCs can produce immediately power after start-up. The delivered power can be of a few kW to several hundred kW. A fuel cell works as a battery but it stores energy using hydrogen. It makes hydrogen react with the oxygen in ambient air to obtain water and energy. However, extracting hydrogen from air or water requires twice as much energy as the use of battery in electric vehicle, thus the cost of hydrogen production is high. It would then be interesting to use another source of energy such as solar.

* Corresponding author.
E-mail address: dja_rekioua@yahoo.fr (T. Rekioua).
http://dx.doi.org/10.1016/j.ijhydene.2015.03.024

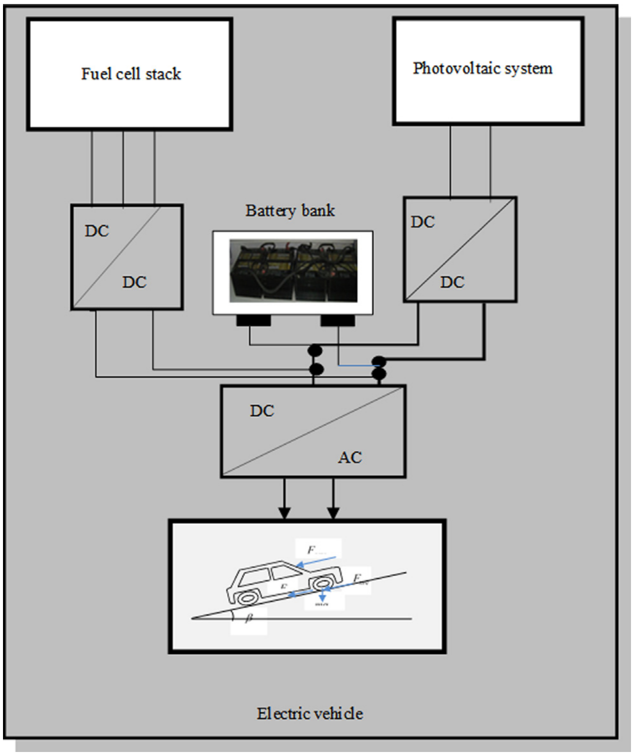

Fig. 1 – Proposed hybrid Photovoltaic/Fuel cells/Battery bank for electric vehicle.

The present work is dedicated to a supervisor control for stand-alone hybrid power system which supplies energy to an electric vehicle (EV). The advantages of each source used, allow us to obtain a cheaper and less polluting electric vehicle. We use in our case an induction motor (IM) of 3 kW for propulsion of the EV. To keep the DC bus voltage at a constant value when the speed of the rotor varies, different control techniques can be used as stator oriented control (SFOC), rotor flux oriented control (RFOC), Direct Torque Control (DTC), Fuzzy logic controller (FLC),⋯.In our work, the IM is controlled using DTC Strategy, which is a powerful control method for motor drives. The global system is presented, modeled and simulated under Matlab/Simulink. Each subsystem is identified and then simulated separately, and hence the control supervision of the proposed system is given. Obtained simulation results and some experimental ones are presented and discussed.

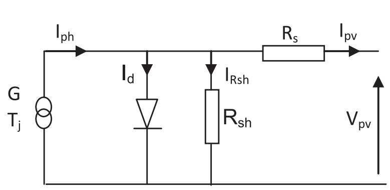

Fig. 2 – Equivalent circuit of photovoltaic cell.

Proposed studied system

The studied hybrid system supplies an electric vehicle of 3 kW and it consists of a photovoltaic generator, a proton exchange membrane fuel cell and a battery bank Fig. 1.

Studied system modeling

Modeling of photovoltaic panels

The model employed in this work consists of a single diode for the cell polarization function and two resistors for the losses (Fig. 2).

Where: I_{pv} is the output-terminal current, I_{ph} is the light-generated current, I_d is the diode-current, I_{sh} is the shunt-leakage current, R_s is the series resistance and represents the internal resistance to the current flows, and depends on the p-n junction depth, the impurities and the contact resistance, R_{sh} is the shunt resistance and it is inversely related to leakage current to the ground, G is the solar irradiance (W/m^2).

The $I_{pv}(V_{pv})$ characteristic of this model is given by Refs. [1,4,9,13]:

$$I_{pv} = I_{ph} - I_d - I_{Rsh} \tag{1}$$

$$I_{pv} = I_{ph} - I_0 \times \left[\exp\left(\frac{q \times (V_{pv} + R_s \times I_{pv})}{A \times N_s \times K \times T_j}\right) - 1\right] - \frac{V_{pv} + R_s \times I_{pv}}{R_{sh}} \tag{2}$$

To identify the four parameters required for Eq. (2), we use a method [1] which treats the product A. Vth in Eq. (2) as a single parameter and denoted a.

$$a = A \cdot V_{th} \tag{3}$$

$$I_{pv} = I_{ph} - I_0\left[\exp\left(\frac{(V_{pv} + I_{pv} \cdot R_s)}{a}\right) - 1\right] - \frac{V_{pv} + R_s \cdot I_{pv}}{R_{sh}} \tag{4}$$

The following Eqs. (5)–(8) are used to find values of the four parameters under reference conditions (G_{ref} = 1000 W/m^2, T_{jref} = 25 °C)

$$I_{ph-ref} = I_{sc-ref} \tag{5}$$

Table 1 – Parameter of the PV panel SIEMENS SM110-24 [1].

P_{PV}	Photovoltaic power (W)	110 W
I_{mpp}	Maximum current at PPM (A)	3.15 A
V_{mpp}	Maximum voltage at PPM (V)	35 V
I_{sc}	Short circuit current (A)	3.45 A
V_{oc}	Open circuit voltage(V)	43.5 V
α_{sc}	Temperature coefficient of short-current (A/°K)	1.4 mA/°C
β_{oc}	Voltage temperature coefficient (V/°K)	−152 mV/°C
P_{mpp}	Maximum power point (W)	110 W