INTERNATIONAL JOURNAL OF HYDROGEN ENERGY XXX (2014) 1–11

Available online at www.sciencedirect.com

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Modeling of hybrid photovoltaic/wind/fuel cells power system

N. Mezzai [a,*], D. Rekioua [a], T. Rekioua [a], A. Mohammedi [a], K. Idjdarane [a], S. Bacha [b]

[a] Laboratoire LTII, Universite de Bejaia, 06000 Bejaia, Algeria
[b] G2lab INPG Grenoble, France

Keywords:
Fuel cells
Photovoltaic
Wind system
Battery storage
Modeling

ABSTRACT

In this paper, identification and modeling of a hybrid photovoltaic/wind/fuel cells power system is presented. This system comprises also a battery storage supplying a load via an inverter. The identification of each subsystem has been made and then the proposed system is modeled and simulated under Matlab/Simulink Package. The power control of the hybrid system is introduced by using LabVIEW Software. The mathematical model topology and its power management of the global system with battery bank system are significant contributions of our work. The proposed control strategy has been experimentally implanted and practical results are compared to those obtained by simulation under the same metrological conditions, showing the effectiveness of the proposed hybrid system.

Introduction

In recent years, hybrid power systems using renewable energy sources have received considerable attention worldwide [1–5], [6–18] and [21–37]. These systems may include different components as DC or AC distribution system, storage system, converters, filters and control system for load management, which can be connected in different architectures [1, 2 and 16]. Most researches based on renewable hybrid system include optimization using maximum power point tracking methods, technico-economic feasibility of the HPS using mathematical models in Matlab/Simulink, and on energy management in real time. For instance, in Ref. [26], authors present a real-time energy management of a stand-alone hybrid wind-micro turbine energy system using optimization. Moreover, power Management of a Stand-Alone Wind/Photovoltaic/Fuel Cell Energy System is presented in Ref. [27], but the simulation model for the hybrid energy system has been developed using MATLAB/Simulink. However, intelligent optimal energy management system for hybrid power sources including fuel cell and battery is presented by authors in Ref. [28]. They compare conventional management system without the fan temperature control and with a fixed hydrogen pressure and a CC/CV charging framework. In addition, Refs. [29,35] present an optimization and techno-economic feasibility analysis of hybrid (photovoltaic/wind/fuel cell) energy systems considering the effects of electrical load and energy storage technology. Authors in Ref. [30] examines dynamic operation and control strategies for a microgrid hybrid wind–photovoltaic-fuel cell based power supply system using intelligent controllers for maximum

* *Corresponding author*. Tel.: +213 34215090; fax: +213 34205061.
E-mail address: mezzai.nabil@yahoo.fr (N. Mezzai).
http://dx.doi.org/10.1016/j.ijhydene.2014.06.015

Nomenclature

C_{batt}	capacity battery, Ah
C_p	power coefficient
E_{Nernst}	voltage Nernst, 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
n_b	number of cells
P_{mpp}	maximum power point, W
P_{PV}	photovoltaic power, W
q	electron charge, C
R_{batt}	internal resistance, Ω
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
X_{batt}	reactance battery, Ah
Z_{batt}	impedance battery, Ah

Greek letters

α_{SC}	temperature coefficient of short-current, A/K
α_i	constants
β	road slope angle, °
β_{oc}	voltage temperature coefficient, V/K
ΔT	heating of the accumulator, K
ρ_{air}	air density
φ	shift-phase between current and voltage, °

Abbreviations

AC	alternate current
DC	direct current
FC	fuel cell
HPS	hybrid power system
PMSM	permanent magnet synchronous motor
PEMFC	proton exchange membrane fuel cells
PV	photovoltaic
NI	national instruments
DAQ	data acquisition

power point tracking control. Other works are focused on hybrid Systems with storage system [31–34]. For example in Ref. [30], authors examine the possibility of hybrid plants with a variable consumption in necessary conditions, by using adaptive controller, including fuzzy controller. And in Ref. [31], authors present a hybrid power source fed by renewable energy sources (wind and photovoltaic) and fuel cell sources, with an energy storage device (battery/ultra-capacitors). All other cited works in this paper [8, 9, 35, 36 and 37] use Matlab/simulink to study the mathematical model of HPS.

Data-acquisition systems are widely used in renewable energy source applications in order to collect data regarding the installed system performance, for evaluation purposes. The collected data is first conditioned using exact electronic circuits and then interfaced to a PC using a data-acquisition card [1,2]. LabVIEW is an environmental development program, developed by NI. Similar to C and BASIC's environment development. There is an obvious difference between LabVIEW and other computer languages. Other computer languages are used to generate a based code on the language of the text, whereas LabVIEW uses a graphical editing language G. The resulting program is the form of a block diagram [19,20].

In this paper, modeling hybrid photovoltaic/wind/fuel cells power system is presented. The control of the global system is made using LABVIEW software. This program is used for further process, display and storage of the collected data in a hard disk PC. The sizing of the proposed system is detailed. It depends mainly on the site location that dictates the average wind speed, the turbine orientation and the average energy consumption of the application. The originality of our work focuses first on the identification of the different parameters of each subsystem separately before its installation in the site. Second, the design and the installation of various voltage and current sensors, data acquisition in LabVIEW environment which allowed us to have real-time data that permits the management and data processing. And finally, the overall system can be designed and installed for higher power and can be considered as a prototype for the development of multi-sources renewable energy systems. The global obtained system is fully practical and the mathematical model, based on real parameters, is more elaborated. The obtained results are presented to demonstrate the effectiveness of the proposed system.

Proposed hybrid system with DC bus

In the hybrid system with DC bus, the power supplied by each source is centralized on a DC bus. Thus, the energy conversion system to provide AC power has then to be converted 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 topology is the simplicity of the operation and the load demand is satisfied without interruption even when the generators charge the short-term storage units. The different sources can be photovoltaic and wind energy; fuel cells and diesel generators (see Fig. 1).

Photovoltaic power system

The photovoltaic model studied in this work consists of a single diode for the cell polarization function and two resistors for the losses. The $I_{pv}(V_{pv})$ characteristic of this model is given by Ref. [16]: