Energy Management and Control of a Hybrid Water Pumping System with Storage

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Abstract—This paper aims to define a control and management strategy for water pumping system which would be powered by a hybrid PV/diesel generator system with battery storage. The particularity of the proposed power management method is to ensure the water volume in need and to maximize the use of PV generator while limiting the use of the diesel generator. In order to capture the maximum power from PV generator, a fuzzy logic maximum power point tracking controller is applied. On the other hand, a PI regulator is used with a boost converter in order to adapt the voltage of the battery bank to the DC bus. The water flow of the pump is also controlled. The developed power management and control strategy has been implemented using SIMPOWER toolbox in Matlab/Simulink. The obtained satisfying simulation results prove the efficiency of the proposed solution that assures continuous supply of water and electricity.

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1. INTRODUCTION

Due to the exhaustion of fossil fuels, the technology is now leading towards the inexhaustible energy sources of which solar energy is the prime one [1]. In the history, the cult of the sun has a great importance and has left many traces in monuments, since then, many scientists have invented new ways to use this energy [2]. Solar energy is an alternative energy source widely used for industrial and domestic applications, such as, lighting, electrification of remote site, charging vehicle, solar drying, solar pumping [3, 4], the statistics expresses that the world’s total output of the solar photoelements increased by 50% in 2007 [5].

The most important domain of application of solar photovoltaic (PV) installation is the PV water pumping system, the solar (PV) energy can play a significant role in increasing access to clean water [6]. Researches published in photovoltaic water pumping system were interested essentially in optimization [7], control [7–10], or in overall system modeling and simulation. Other researchers developed strategies in order to offer optimum energy management of PV pumping systems [11–13]. There are several approaches for the development of management of the energy in renewable energy system, most of them emphasized on hybrid PV/battery system [14, 15]. Often the control and energy management of the PV pumping system is still a challenging field of research which is essential for improving their effectiveness.

To improve the efficiency of the PV system, the implementation of a tracker of the maximum power point is necessary. This is obtained by inserting a power converter controlled by an MPPT algorithm between the PV generator and the load. A lot of MPPT algorithms have been developed by researches. They are perturbation and observation method P&O [9, 11] fuzzy control method [9, 16, 17]. In this paper we apply fuzzy logic controller.

A number of experimental AC and DC motor driven PV pumps are already in use in several parts of the world [7–9]. A DC motor coupled with a pump is studied in this work. To regulate the flow of the pump a PI controller is used.

In this work, a new operating mode in pumping system is proposed, beside the PV generator and the battery, the diesel generator is used like another source to supply the load when the battery is empty during the night. An energy management algorithm of the overall hybrid system is proposed and is implemented using MATLAB/simpower as a programming tool. The dynamic simulation results are presented with some conclusions given about the global design.
2. MODELING OF THE PROPOSED SYSTEM

The PV/battery/diesel water pumping system considered in this work is shown in Fig. 1. It consists of PV generator, battery, diesel generator and a motor pump.

2.1. Solar Cell Model

Photovoltaic cell is the most basic generation part in PV system. In the literature several models of the PV cell are found (one diode, two or three diodes). They differ from each other by the number of parameters involved in the calculation of the voltage and current of the PV final.

The model for a single diode is the most cited in the literature consists of a photo current source, a diode, an equivalent parallel resistor and an equivalent series resistor which can be shown in Fig. 2 [3, 18].

So we can mathematically express the current produced by the solar cell as:

\[ I = I_p - I_d - I_{sh}. \]  

(1)

The mathematic relationship for the current and voltage in the single diode equivalent circuit can be described as:

\[ I = I_p - I_s(e^{\frac{q(V + R_s I)}{AKT}} - 1) - \frac{V + IR_s}{R_{sh}}, \]

(2)

where

- \( V \): the voltage at the terminal of the cell (in volt)
- \( I_p \): light-generated current or photocurrent
- \( I_{sh} \): cell saturation of dark current.