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A real-time control of photovoltaic water-pumping network ☆

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ABSTRACT

In this paper a dynamic modeling, simulation, control and energy management of photovoltaic water-pumping network system is presented. A fuzzy-logic controller has been proposed for a real-time control of the system. The controller generates the reference speeds needed for the pulse-width-modulation generator to control each DC/DC boost converter taking into account the water levels in three tanks and the instantaneous value of the solar radiation. The main objectives of the fuzzy-logic controller are the design of an adequate maximum power-point tracker to extract the maximum power, regulate the water in the three tanks and finally ensure the correct operation for all the conversion strings in order to optimize the quantity of pumped water. The system performance under different scenarios has been checked carrying out Matlab/Simulink simulations using a practical load-demand profile and real weather data and comparing them to another control algorithm.

1. Introduction

Renewable energy sources have gained significant attention in the last decades due to the harmful effects of the fossil fuels on the environment and to the very high price of fuel energy.

One of the most popular applications of renewable energy is water-pumping systems driven by electrical motors. The PhotoVoltaic (PV) energy presents the most important one for water pumping because of the strong relation between water needs and energy availability, especially in hot weather. Thus, the optimization of both using PV energy and controlling PV pumping systems has presented the object of a lot of researches.

Many renewable energy sources, including PV, wind, solar-thermal, biomass sources and gas producer, can be used in water pumping systems [1–3]. Hence, a lot of scientific works have been interested in PV water-pumping systems. Some of them focused essentially on water-pump modeling [4,5]. Earlier reviews, reported in this area, highlighted the historical development of PV water-pumping control [5,6]. Some works have shed light on renewable energy sources with an auxiliary source, diesel engines [7] and a battery [8].

Many works have been also developed in sizing PV water-pumping systems [9,10]. In [9] the authors presented a mathematical method of sizing PV water-pumping systems with more accuracy. The method took into consideration the calculation of hydraulic losses and the effect of temperature and solar radiation. Firstly the variation of power versus a hydraulic

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Nomenclature

PVP	photovoltaic panel
A	ideal factor
NOCT	normal operating cell temperature
V_{MPP}	rated voltage
I_{SC}	short-circuit current
C_T	temperature coefficient of I_{SC}
h	constant of proportionality between G and I_{ph}
I_{ph}	photocurrent
V	PVP output voltage
V_{opt}	optimal values V
q	electronic charge
K	Boltzmann's constant
T	cell temperature
R_{sh}	PVP shunt resistance
I_{opt}	optimal values of I
G_{ref}	reference of solar radiation
C_T	temperature coefficient
V_s	stator voltage
i_s	stator current
L_s	stator inductance
R_s	rotor resistance
M_{sr}	mutual inductance
Ω	mechanical speed of the machine
C_{em}	electromagnetic torque
Ω_{refi}	reference speed of motor i
L_i	level of tank I
Q_{si}	output flow of tank I
C_{dc}	DC link capacity
E_G	band-gap energy
P_{max}	maximum power
I_{MPP}	rated current
N_s	serial cells
V_{OC}	open circuit voltage
N_p	parallel cells
G	solar radiation
I	PVP output current
n	ideality factors
I_{rs}	cell-reverse-saturation current
I_s	reverse-saturation current
R	PV array-series resistance
T_r	cell-reference temperature
V_{dc}	DC link voltage
C_{dc}	DC link capacity
I_{rr}	saturation current for T_r
V_r	rotor voltage
i_r	rotor current
L_r	rotor inductance
R_r	stator resistance
f	coefficient of friction
J	total inertia of the machine
C_r	load torque
α_i	duty cycle of DC inverter i
Q_{ei}	input flow of pump i
V_{dc}	DC link voltage