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Energy management based fuzzy logic controller of hybrid system wind/photovoltaic/diesel with storage battery

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ABSTRACT

Hybrid renewable energy systems (HRES) are attractive configurations used for different applications and especially in standalone power generation systems as electrification, water pumping, and telecommunications. Considering the multitude of sources, energy management control (EMC) will be necessary. In this paper, supervision of hybrid Wind/Photovoltaic/Diesel system with battery storage is presented. The power balance of the suggested system is made on an intelligent supervisor based on fuzzy logic control (FLC). It is simple, easy and makes it possible to determine the various operating processes of the hybrid system according to the weather conditions. The decisions of criterion required by this method are presented. The study was implemented under Matlab/Simulink and an application is made for Bejaia a site in the coastal region of Algeria. The obtained results are presented and show the feasibility of the proposed control system.

Introduction

Due to the different advantages of PV/Wind energy conversion systems, a great attention has been focused on them. The best advantage of these systems is not only to provide continuous energy whatever the variations of the load and of the weather conditions but to generate different sources in an intelligent manner that allows satisfying the load demand and to maintain the batteries charged. Various architectures of the hybrid energy system have been proposed with different power management controls (PMC). Some of them are based on logical states and others on intelligent algorithms. The lathers are more interesting especially for standalone applications (remote control).

A number of literature have been reported to investigate PMCs. The applications are focused on electrification and smart grids [1–3], water pumping [4], telecommunications [5]. In general, in all the papers, management is always based on power balance. Some author have proposed diverse methods of power management control, in Refs. [6–8] fuzzy logic control, in Ref. [9] flatness Based Control, in Ref. [10] frequency deviation control and in Refs. [4–11] control with microcontroller. Modeling of the different sources is based on well-known mathematical models [12–33]. FLC has been used for Maximum Power Point Tracking (MPPT) of solar PV [34,35] and frequency regulation [36,37], for controlling batteries' output charger current [38], improvement in wind power prediction accuracy [39], and for voltage control of the hybrid energy

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Nomenclature

C_p	Power
G	Solar radiation, W/m^2
I_{pv}	Output-terminal current, A
I_{ph}	Diode-current, A
I_{Rsh}	Shunt-leakage current, A
I_{sc}	Short circuit current, A
P_{mpp}	Maximum power point, W
P_{PV}	Photovoltaic power, W
R_s	Series resistance, Ω
R_{sh}	Shunt resistance, Ω
T_c	Temperature cells, K
T_{cSTC}	Reference temperature of the PV cell, K
V_{mpp}	Maximum voltage at PPM, V
V_{oc}	Open circuit voltage, V
K_1, K_2, K_3, m	Coefficients
T_{wind}	Wind torque, N m
T_{mec}	Mechanics torque, N m
R	Radius of the rotor, m
S	Area swept by the rotor blades, m^2
V_{wind}	Wind speed, m/s
V_{bat}	Battery voltage, V
Q_0	Capacity of the battery, Ah
E_0	Ideal voltage of the charged battery, V
K	Constant that depends on the battery
R_b	Internal resistance of the battery, Ω
I_b	Discharge current, A
I_d, I_q	Stator currents direct and quadratic, A
V_d, V_q	Stator voltage direct and quadratic, V
L_c	Inductance of each stator phase, H
R_C	Resistance of each stator phase, Ω
T_{em}	Electromagnetic torque, N m
P	Power, W
e_d, e_q	Magneto motor force direct and quadratic, V
K_{pv}	Control signal of the switch for the photovoltaic generator
K_{wind}	Control signal of the switch for the wind generator
K_{dies}	Control signal of the switch for the diesel generator
P_{pv}	Photovoltaic power, W
P_{wind}	Wind power, W
P_{die}	Diesel power, W
V_{dc}	DC voltage, V
$V_{dc\text{-}ref}$	DC voltage reference,V

Greek letters

α_{sc}	Temperature coefficient of short-current, A/K
β_{oc}	Voltage temperature coefficient, V/K
ρ_{air}	Air density
ϕf	Amplitude of flux of permanent magnets
ω	Angular speed, rad/s
λ	Tip speed ratio
α_1	Duty cycle
α_2	Duty cycle
α_3	Duty cycle

Abbreviations

AC	Alternate current
DC	Direct current
EMC	Power management control
HPS	Hybrid power system
PMSM	Permanent magnet synchronous motor
PV	Photovoltaic panels
PMSG	Permanent magnet Synchronous generator
PWM	Pulse width modulation
SOC	Battery charge status
SOC_{min}	Minimum battery state of charge
SOC_{max}	Maximum battery state of charge
STC	Standard tests conditions
FLC	Fuzzy logic Control
LOW	Low
MED	Medium
MAX	Maximum
HIGH	High

system (wind/battery) [40,41], In this article Fuzzy Logic Control (FLC) has been opted as it is a flexible tool with rules based on human knowledge and experience that can handle unpredictable variables or uncertainties. FLC can be applied to complex systems such as hybrid energy systems with different types of inaccurate inputs, variables and perturbations, especially if power is supplied by renewable energy sources is consumed by variable and unpredictable loads.

Several publications have also been published on using FLC for energy management of hybrid energy systems and storage batteries [41–47]. In Refs. [42,43], FLC has been used to provide a proper split in power between solar PV, wind and storage batteries according to a pre-defined rule. The SOC of storage batteries in a hybrid micro grid was controlled by a FLC in Ref. [44] to improve the performance of the hybrid generation system with smaller energy capacity of storage batteries [45]. Proposes an efficient controller of Fuzzy Logic Controller (FLC) predetermined power organization for accurate source selection in the right timing for powering telecommunication loads and managing the entire hybrid power system. A fuzzy logic-based controller to be used for the Battery SOC control of the designed hybrid system hybrid solar photovoltaic and wind power system in Battery management for stand-alone applications [46] and in Ref. [47] controller based on fuzzy logic to prevent the battery state of charge and charging/discharging power from exceeding their limits regardless of variations in load and intermittent power of renewable source.

In this paper, an intelligent power management control of a hybrid Wind/Photovoltaic/Diesel system with battery storage is presented. Which is based on fuzzy logic control (FLC). It is simple, easy and enables in the first part, to determine the variant operating processes of the hybrid system according to the weather conditions and thus determine the power supplied for each source facilely and rapidly compared to classical strategies based on logical states. And in the second part, it

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