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ACO based speed control of SRM fed by photovoltaic system

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ABSTRACT

This paper proposes a speed control of Switched Reluctance Motor (SRM) supplied by Photovoltaic (PV) system. The proposed design of the speed controller is formulated as an optimization problem. Ant Colony Optimization (ACO) algorithm is employed to search for the optimal Proportional Integral (PI) parameters of the proposed controller by minimizing the time domain objective function. The behavior of the proposed ACO has been estimated with the behavior of Genetic Algorithm (GA) in order to prove the superior efficiency of the proposed ACO in tuning PI controller over GA. Also, the behavior of the proposed controller has been estimated with respect to the change of load torque, variable reference speed, ambient temperature, and radiation. Simulation results confirm the better behavior of the optimized PI controller based on ACO compared with optimized PI controller based on GA over a wide range of operating conditions.

Introduction

Over the past decades, the Switched Reluctance Motors (SRMs) have been the focus of several researches [1,2]. The SRM has a simple, rugged, and low-cost structure. It has no Permanent Magnet (PM) or winding on the rotor. This structure not only reduces the cost of the SRM but also offers high speed operation capability for this motor. Unlike the induction and PM machines, the SRM is capable of high speed operation without the concern of mechanical failures that result from the high level centrifugal force. In addition, the inverter of the SRM drive has a reliable topology. The stator windings are connected in series with the upper and lower switches of the inverter. This topology can prevent the shoot through fault that exists in the induction and permanent motor drive inverter [3,4].

Many techniques have been illustrated to deal with the speed control of SRM. Fuzzy Logic Control (FLC) [5–10], Artificial Neural Network (ANN) [11,12], robust controller [13], and adaptive controller [14] have been employed to solve the problem of speed control of SRM. Moreover, optimization techniques like Genetic Algorithm (GA) [15], Particle Swarm Optimization (PSO) [16–18], Bacteria Foraging [19–23] and BAT algorithm [24] have attracted the attention in designing controller and speed control of various motors.

A new evolutionary algorithm known as Ant Colony Optimization (ACO) algorithm is proposed in this paper to design a robust speed control of SRM. ACO is multi-agent system in which the behavior of each single agent, called artificial ant is inspired by the behavior of real ants [25]. ACO has been successfully employed to optimization problems in power system such as power quality enhancement [26], optimal reactive power dispatch [27]. The feature of this technique is different from other method since it can be implemented easily and flexible for many problems. Finally its capability in avoiding the occurrences of local optima for a given problem is achieved [28].

ACO is developed in this paper for controlling the speed of SRM supplied by Photovoltaic (PV) system. ACO is used for tuning the PI controller parameters to control the duty cycle of DC/DC converter and therefore speed control of SRM. The design problem of the proposed controller is formulated as an optimization problem and ACO is employed to search for the optimal controller parameters. By minimizing the time domain objective function representing the error between reference speed and actual one, the system performance is improved. Simulation results assure the effectiveness of the proposed controller in providing good speed tracking system over a wide range of load torque, ambient temperature and radiation with minimum overshoot/undershoot and minimal settling time. Also, the results assure the superiority of the proposed ACO method in tuning controller compared with GA.

System under study

The system under study consists of PV system acts as a voltage source for a connected SRM. The speed control loop is designed using ACO. The speed error signal is obtained by comparing the

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Nomenclature

N_r and N_s	number of rotor and stator poles respectively
q	number of phases
C_r	the commutation ratio
β_s and β_r	the stator and rotor pole arc respectively
I and V	module output current and voltage
I_c and V_c	cell output current and voltage
I_{ph} and V_{ph}	the light generation current and voltage
I_s	cell reverse saturation current
I_{sc}	the short circuit current
I_o	the reverse saturation current
R_s	the module series resistance
T	cell temperature
K	Boltzmann's constant
q_o	electronic charge
KT	(0.0017 A/°C) short circuit current temperature coefficient
G	solar illumination in W/m^2
E_g	band gap energy for silicon
A	ideality factor
T_r	reference temperature
I_{or}	cell rating saturation current at T_r
n_s	series connected solar cells
k_i	cell temperature coefficient
k	the duty cycle of the Pulse Width Modulation (PWM)
V_B and I_B	the output converter voltage and current respectively
J_t	the objective function
K_P and K_i	the parameters of PI controller
n	number of nodes
m	number of ants
t_{max}	maximum iteration
d_{max}	maximum distance for each ant's tour
β	the relative importance of pheromone versus distance ($\beta > 0$)
ρ	heuristically defined coefficient ($0 < \rho < 1$)
α	pheromone decay parameter ($0 < \alpha < 1$)
q_a	parameter of the algorithm ($0 < q_a < 1$)
τ_o	initial pheromone level
d_i	distance between two nodes
u	unvisited node
r	current node
τ_{ij}	the pheromone trial deposited between node i and j by ant k
η_{ij}	the visibility and it equals to the inverse of the distance ($\eta_{ij} = 1/d_{ij}$)
T^k	the path effectuated by the ant k at a given time

reference speed and the actual one. The output of the ACO controller is denoted as duty cycle. The schematic block diagram is shown in Fig. 1.

Construction of SRM

The construction of a 8/6 (8 stator poles, 6 rotor poles) poles SRM has doubly salient construction [14]. The windings of the SRM are simpler than those of other types of motors, and winding exists only on stator poles, and is simply wound on it with no winding on the rotor poles. The winding of opposite poles is connected in series or in parallel forming a number of phases, and exactly half the number of stator poles, and the excitation of a single phase excites two stator poles. The rotor has a simple laminated salient pole structure without winding. SRMs have the advantage of reducing copper losses while its rotor is winding. Its stampings are made preferably of silicon steel, especially in higher efficiency applications [29,30]. The construction of an 8/6 SRM is shown in Fig. 2.

Torque is developed in SRMs due to the tendency of the magnetic circuit to adopt the configuration of minimum reluctance. The magnetic behavior of the SRM is highly nonlinear. The static torque produced by one phase at any rotor position is calculated using the following equations [30,31].

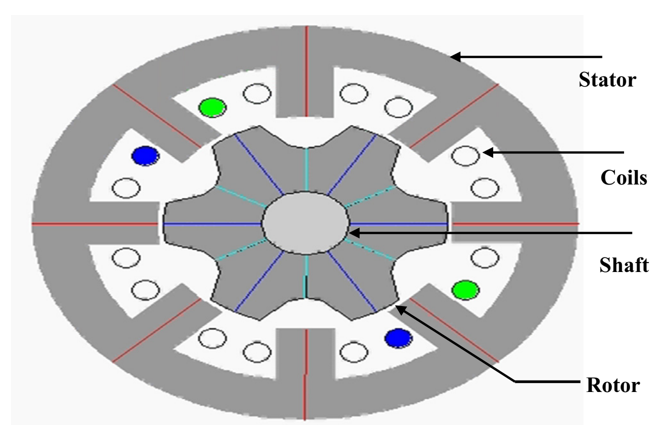

Fig. 2. The SRM 8/6 poles construction.

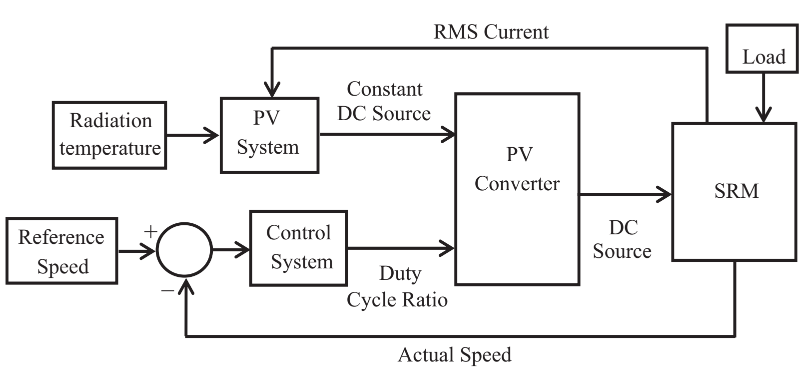

Fig. 1. The overall system for SRM control.