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Short Communication

# Particle swarm optimization based sliding mode control of variable speed wind energy conversion system

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ABSTRACT

This paper proposes a particle swarm optimization based sliding mode control of squirrel cage induction generator of a variable speed wind energy conversion system. The key feature of sliding mode control is a wisely chosen sliding surface which allows the turbine to operate more or less close to the optimal regimes characteristic. Optimal control parameters which are the convergence speed to the sliding-mode, the slope of the surface and the switching component amplitude of SMC are determined using particle swarm optimization approach. The simulation results prove the viability of the proposed control structure.



## Introduction

Wind energy conversion systems, being an environmentally friendly and economically competitive means of producing electricity; have experienced a tremendous growth in the past decade [1]. Generally, a constant speed wind turbine coupled with a squirrel cage induction generator designed to extract maximum power at a specified speed is used for the wind power generation. However, as the wind speed varies, it becomes necessary to vary the turbine speed accordingly in such a way that the optimum tip speed ratio is maintained at its optimum value despite wind variations [2]. This requirement can be facilitated by means of power electronic circuits along with appropriate control strategies. The common approach is the utilization of aerodynamic control systems involving the pitch angle control of the turbine blades. However, this method makes the system expensive and complex, particularly for systems with large wind turbines. This paper proposes a sliding mode controller for variable speed wind turbine systems using cage induction generator (SCIG).

The sliding-mode control (SMC) approach is one of effective tools to design robust controllers for nonlinear systems

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with uncertain operating conditions. It is a variable structure system which switches with high-frequency between several controls laws. The first step of SMC design is to select a sliding surface that models the desired closed-loop performance in state variable space. Then, design the control such that the system state trajectories are forced towards the sliding surface and stay on it [3]. There is certain difficulty about the VSC design, concerning the definition of a sliding surface with guaranteed properties of attractiveness and stability [4]. In this paper, particle swarm optimization (PSO) is utilized to optimize the parameters of sliding mode surface function so as to maximize a low power fixed-pitch SCIG-based wind energy conversion system. PSO is an evolutionary computation technique developed by Eberhart and Kennedy in 1995 which is inspired by social behaviour of bird flocking. The PSO algorithm is an optimization tool which is initialized with a population of random solution, and proceeds to the optimum solution by updating generations [5,6].

The remaining part of this paper is organized as follows: The details of system modelling are given in Section 2, followed by the details of SMC in Section 3. Section 4 discusses about the PSO algorithm. The test system details and simulation results are given in Section 4, and conclusion in Section 5.

## Wind energy conversion system model

Fig. 1 shows the complete block diagram of the studied system. The major components of a variable speed wind turbine system are: a turbine, a gear box, a SCIG connected to the grid. The models used to represent these components are discussed in this section.

### *Wind turbine model*

The turbine converts the kinetic energy of wind into mechanical energy and the total kinetic power available from the wind turbine is given by

$$E_k = \frac{1}{2} m v^2 \tag{1}$$

where $m$ is the air mass that passes the disc in a unit length of time, and v is the wind velocity.

The mass m could be derived from:

$$m = \rho A d \tag{2}$$

where $\rho$ is the air density, A is the area swept by the rotor blades and d is the distance travelled by the wind.

According to Betz theory, the mechanical power that is extracted by a wind turbine $P_a$ is expressed as:

$$P_a = \frac{1}{2} \rho \pi R^2 v^3 C_p(\lambda, \beta) \tag{3}$$

where R is the blade radius of the wind turbine, $v$ is the wind speed, $\lambda$ is the tip speed ratio, $\beta$ is the pitch angle and $C_p$ is the wind turbine energy coefficient.

The tip speed ratio is defined as:

$$\lambda = \frac{w_r R}{v} \tag{4}$$

$w_r$: is the wind turbine rotor speed.

The $C_p - \lambda$ characteristics, for different values of the pitch angle $\beta$ , are illustrated in Fig. 2. This figure indicates that there is one specific $\lambda$ at which the turbine is most efficient. Normally, a variable-speed wind turbine follows the $C_{Pmax}$ to capture the maximum power up to the rated speed by varying the rotor speed to keep the system at $\lambda_{opt}$.

The rotor power (aerodynamic power) is also defined by:

$$P = w_r T_a \tag{5}$$

Moreover

$$C_q(\lambda) = \frac{C_p(\lambda)}{\lambda} \tag{6}$$

It, thus, follows that the aerodynamic torque is given by

$$T_a = \frac{1}{2} \pi \rho R^3 C_q(\lambda) v^2 \tag{7}$$

### *Squirrel cage induction generator model*

The squirrel-cage asynchronous generator (SCIG) is represented by its voltage equations in the d–q frame of reference, given by Ref. [7,8].

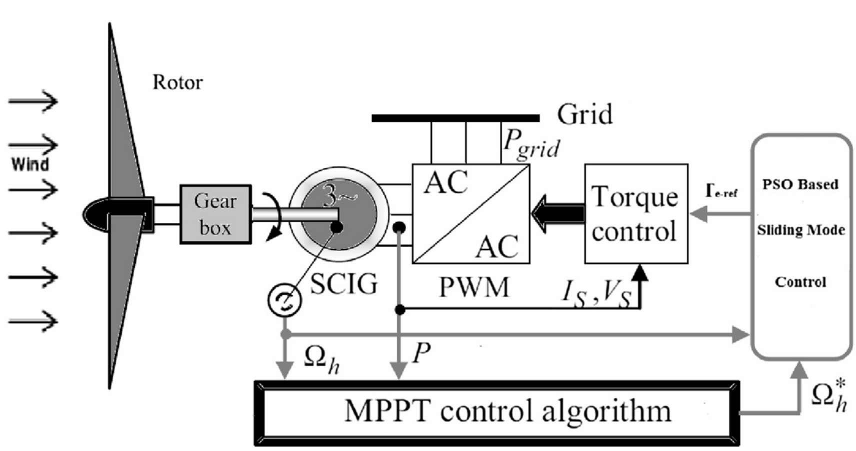


**Fig. 1 – Wind energy conversion system based SCIG.**

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