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# Intelligent control of a DFIG wind turbine using a PSO evolutionary algorithm

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**Abstract**

This paper presents an intelligent proportional integral sliding mode controller (*i*PI-SMC) for power capture optimization of a doubly fed induction generator (DFIG) based wind turbine system. The designed method is based on a combination of proportional integral (PI) control, swarm optimization and sliding mode control (SMC). For this approach, the PI action is included in the sliding surface in order to improve the performances of standard SMC. Thus, the proposed controlling method is associated to particle swarm optimization (PSO) based evolutionary algorithm to improve the controller performances by optimizing PI and SMC gains. The stability of the system using the proposed controller is investigated by Lyapunov theory. The simulation results of the investigated PSO based PI-SMC method are compared with integral sliding mode control (ISMC) as well as conventional SMC. The results reveal that the proposed controller presents low tracking error and less chattering. In addition, the proposed method shows more robustness to uncertainties and faster transient response compared to the others methods control (i.e. ISMC and SMC).



*Keywords:* Doubly fed induction generator; Proportional integral; Sliding mode control; Particle swarm optimization

## 1. Introduction

Nowadays, the exploitation of wind energy for electric power production remains of great interest for research [1]. Thus, wind turbines are mainly used as wind energy conversion systems (WECS), which variable-speed wind turbine (VSWT) has been considered, due mainly to its great ability to extract wind energy and to preserve power quality [2]. Moreover, doubly fed induction generator (DFIG) remains one of the most important generators for WECS that is largely used for variable speed generation. However, DFIG-based wind turbine system is more


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complex and requires an efficient control strategy. Generally, the wind turbines control strategy is adopted based on a specific wind speed called rated wind speed. In practice, two operating areas of the VSWT can be distinguished; below and above the rated wind speed. Below the nominal wind speed, the main objective of the controller is wind energy capture optimization; the torque control is used to maximize the wind turbine power coefficient [3]. However, for a wind speed that exceeds its nominal value, the control is manifested by the power regulation to its rated value. Thus, two control inputs can be applied; the generator torque and the pitch angle [4].

Sliding mode control (SMC) [5]-[9], is considered as a particular designed technique for VSWT. This method is one of the most interesting robust control approaches that remain less sensitive to uncertainties variation. However, for large uncertainties, it is necessary to have a high discontinuous control gain leading to chattering phenomenon. The integral sliding mode control (ISMC) [10]-[12], is also a robust control allowing to improve the performance of standard SMC; ISMC consists to design a sliding surface such that it is zero for initial time. Indeed, the sliding mode exists from the initial time, which eliminates the reached surface phase. Thus, the ISMC theoretically guarantees greater robustness by eliminating the static error due to the integral action introduced into the surface. Therefore, in the presence of large uncertainties, ISMC control technique produces oscillatory phenomenon due to the higher needed gain. In order to reduce these oscillations, proportional integral sliding mode control (PI-SMC) may be investigated.

This paper presents an intelligent power control allowing DFIG-based wind turbine to extract maximum wind energy. In this study, the stator of DFIG is directly connected to the grid and the rotor is linked to the grid by a bi-directional converter. In order to maximize the captured energy from the wind, the active and reactive power between DFIG and the grid are controlled by the rotor converter. The proposed method consists of a combination of PI control and SMC. Moreover, efficient particle swarm optimization (PSO) technique is adopted to improve the controller performances by optimizing PI and SMC parameters [13]-[15]. The stability of the proposed PSO based PI-SMC controller is shown by the Lyapunov theory, and the effectiveness of the designed method is illustrated by the comparison with ISMC and conventional SMC controllers. The simulation results are reported to demonstrate the performances of the PSO based PI-SMC controller.

This study is organized as follows: The next section presents the DFIG system modeling. Section 3 shows the design of the proposed PI-SMC control for power capture optimization. In section 4, simulation results are provided to demonstrate the control performance of the proposed approach. Finally, in section 5 a concluding remark is given.

**Nomenclature**

| | |
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| $T_{em}$ | DFIG torque, N m |
| $\omega_g$ | generator speed, rad s$^{-1}$ |
| $\omega_s$ | synchronous generator speed, rad s$^{-1}$ |
| $P_s$ , $Q_s$ | active and reactive stator power, W |
| $V_{sd,q}$ | stator d-q frame voltage, V |
| $V_{rd,q}$ | rotor d-q frame voltage, V |
| $I_{sd,q}$ | stator d-q frame current, A |
| $I_{rd,q}$ | rotor d-q frame current, A |
| $L_s$, $L_r$ | stator inductance and rotor inductance, H |
| $\sigma_r$ , $L_m$ | leakage coefficient, mutual inductance, H |
| $R_s$, $R_r$ | stator and rotor resistances, $\Omega$ |
| $p$ | number of poles |