

# Adaptive nonlinear robust control of PMSG based floating wind turbine

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**RESUME** – In this work, adaptive high order sliding mode (HOSM) control schemes are applied to a permanent magnet synchronous generator (PMSG) based floating wind turbine (FWT) in above rated region. The adaptive control method is especially efficient for systems with uncertainties and external perturbations and is well adapted to floating wind turbine systems. Such controllers can be implemented with few knowledge of system model (only the relative degree is necessary) and greatly reduced the controller gains tuning effort. Simulations are made on FAST software and compared with a standard gain-scheduled PI controller.

*Adaptive, High Order Sliding Mode, Floating Wind Turbine.*

## 1. INTRODUCTION

In order to use wind energy in the ocean area, floating wind turbines (FWT) have been developed. It is a promising solution for renewable energy. Such wind systems are installed in deep water (deeper than 60 m), the turbine is supported by a floating platform. The control is a key point for the improvement of such large wind turbines efficiency, not only to ensure a high level of power production but also to limit mechanical fatigue of the structure. However, the control algorithms for the offshore wind turbines can not be applied to the floating one directly, the floating structure introduces additional degree of freedoms to the system especially the platform pitching that excites platform resonant motion (also known as negative damping) and degrades power output [1]. The floating wind turbine system is not only withstand the system uncertainties caused by flexible structures, but also the influence of wind and waves. Hence, such system is highly perturbed, uncertain and nonlinear. The linear controller proposed in the literature, such as GSPI [2], is designed based on the linearized model around an operating point, it works well when system working around the range of this point, however, large scale of gains need to be tuned in order to keep the control efficiency at different operating points (in this case, at different wind speed). Concerning the electrical part, the temperature, humidity and other external environments introduce the perturbations as well. It is necessary to design a nonlinear robust controller with a *single* set of parameter tuning meanwhile keeping the control efficiency among the large operating range despite of the uncertainties and perturbations of turbine and electric machine.

## 2. APPROACH

In this study, the robust nonlinear strategy, sliding mode control SMC [3] is applied to a PMSG floating wind turbine. SMC a well-known nonlinear control strategy with properties of robustness, accuracy and finite time convergence. In fact, the standard first order SMC can be easily implemented; however, the control law of standard SMC is discontinuous. Due to the discontinuous term of the control input, chattering phenomenon is introduced and can damage the physical components such as blade pitch actuator. In order to reduce chattering and keep robustness, high order sliding mode (HOSM) [4] control is employed. Furthermore, since the unknown terms of the rotor and platform pitch dynamic, the uncertainties of turbine and elec-

trical part, and the perturbations of wind, waves, etc. The gains of the controllers should be sufficiently large to accommodate those effects; it means that the gains are tuned in order to ensure high performances, *i.e.* in the *worst* case. However, when the perturbation is relatively small, the gains are so large that lead to unnecessary variations of control and reduces the control performance. A method to avoid the problem above and increase the accuracy is to use adaptive algorithm, in this work, two kinds of HOSM control with different adaptive laws are considered

- super twisting control [5] with gain adaptation [6]. The gain is dynamically adapted to the “just sufficient” value with respect to uncertainties and perturbations. This fact allows to reduce the amplitude of the chattering since the gains are not overestimated.;
- homogeneous controller [7] with exponent adaptation [8]. A parameter  $\bar{\alpha}$  on the exponent terms of the controller is adapted based on the closed loop accuracy. When the trajectory of the system is far from the origin, the controller is equivalent to HOSM (by fixing  $\bar{\alpha}$  to 0) increasing the robustness of the system. When the trajectory of the system is close to the origin, a smoother control is applied (by varying  $\bar{\alpha}$  between 0 and 1) decreasing the chattering.

Those two control algorithms have been very recently and successfully applied to a FWT in our previous work [9], but the electrical part of the wind turbines are not taken into consideration. In the current work, a permanent magnet synchronous generator is now included to the system. The adaptive nonlinear controllers based on HOSM algorithm are applied for the complete model of FWT including aerodynamic, hydrodynamic and electrical parts. Hence, the control scheme combines the collective blade pitch angle control and the generator torque control.

## 3. CONCLUSIONS

Adaptive high order sliding mode algorithms are applied on the PMSG floating wind turbine in above rated region. The control strategy is aim to regulate the rotor speed as a function of platform pitch velocity to reduce the platform pitch motion; control the generator torque through the d-axis current to keep generator torque inverse proportion to the generator speed in order to keep rated power output; furthermore, ensure d-axis current of PMSG at zero to avoid the oscillations of the electromagnetic torque. The controller has been evaluated on the full DOFs FAST nonlinear model in 18m/s stochastic wind and irregular waves, simulation results show better performances versus standard GSPI on platform pitch motion, structure fatigue load reduction and power regulation. The main features of the two proposed controllers are : very few information of system model is required, controller gains are adapt in accordance with uncertainties and perturbations that reduced the gains tuning workload and decreased the tracking error.

Future work will focus on the further reduction of the structure fatigue loads by using individual blade pitch control and application on a experimental model.

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