1 GENERAL INFORMATIONS

Laboratory	FEMTO_ST
University	Université de Technologie Belfort-Montbéliard (UTBM), Univ. Bourgogne Franche-Comté (UBFC)
Contact	**Thesis advisor: Dr. LAGHROUCHE Salah**

2 TITLE OF THE THESIS AND KEYWORDS

Robust and Adaptive Nonlinear Controls for Floating Wind Turbines

Keywords: Floating wind turbines, Wind energy conversion system, Robust and adaptive control, Hardware-in-the-Loop.

3 THESIS SUBJECT

Terrestrial wind technologies have reached a certain level of maturity, and attention is now increasingly focused on the use of offshore winds for higher speeds with less turbulence. The majority of offshore wind resources are located in waters deeper than 30 m, and a wind turbine installed in these areas must be mounted on a floating base to ensure its stability. However, the floating platform induces additional degrees of freedom and is exposed to dynamics and disturbances created by the combined action of winds and incident waves. This makes it essential to develop robust and adaptive control systems specifically for floating wind turbines. For a floating wind turbine, controlling the blade pitch angle is particularly important for platform stabilization, power capture and fatigue reduction. In addition, since turbine control is dependent on wind speed and incident wave action, the development of controls to mitigate the dynamic load imposed on structures is necessary to preserve the system and ensure optimal production of electrical energy.

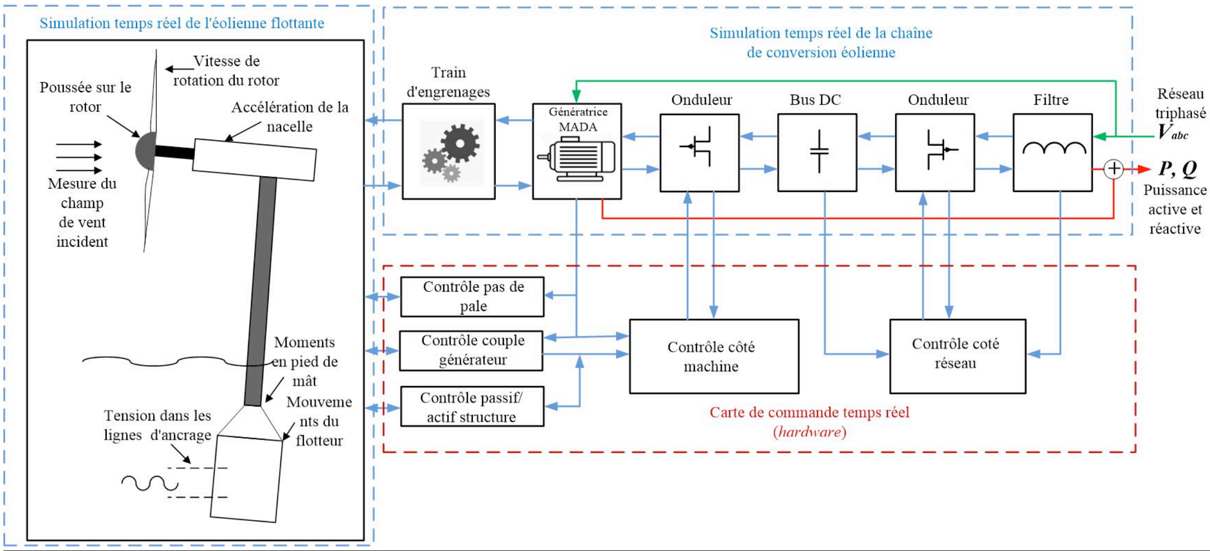

Figure 1: "SIMULEF" simulator structure diagram

The work of this thesis is part of the robust and adaptive nonlinear control of floating wind structures. Indeed, control plays a crucial role in the overall stability of floating wind turbine systems and in their energy production. Controls are already used in terrestrial turbines to dampen unwanted structural resonances and reduce the dynamic response to wind turbulence while ensuring optimal energy production. In floating wind turbines, it is essential that controls be used to reduce the response of the entire turbine / platform system to the combined stochastic action of wind and swell. It should be noted that control solutions for onshore wind turbines give poor results if applied to offshore wind turbines: as a result, much progress remains to be made for offshore. In addition, this hot topic is still a new and challenging in the renewable clean energy research area. It is therefore important to consider the challenges posed by these problems by the development of new control methods to make floating wind turbines efficient. These new methods will be tested and validated on a SIMULEF Hardware-In-The-Loop simulator. "SIMULEF" is a powerful "real time" simulation tool offering complete interaction models between the various components of a 8 MW floating wind turbine, in order to improve its associated performances, particularly in terms of sizing and synthesis of real-time control systems for maximizing electrical energy production. "SIMULEF" is a tool that is being developed by three laboratories of excellence in the field of wind energy conversion systems and control that are: FEMTO-ST in Belfort, LHEEA in Nantes and LS2N in Nantes.

4 Expected collaboration

This thesis is part of a strong collaboration between three research laboratories around wind turbines:
- The SHARPAC team (Hybrid Electrical Systems, Electrical Actuators, Fuel Cell Systems) of the FEMTO-ST Institute is developing its scientific activity of excellence in the application fields of electric vehicles and renewable energies. The team's research activities are structured around 6 scientific poles: Static converters, Fuel Cell Systems, Power Hardware In the Loop, Energy Control and Management, Electric Actuators, Microgrids.
- LHEEA is a leading research laboratory in the field of floating wind energy. LHEEA addresses its research issues by implementing a complementary approach: the numerical approach (use and development of modelling software, in particular in computational fluid mechanics), experimental modelling on reduced models (test benches, basins, atmospheric wind tunnels, etc.) and experimentation on natural sites (SEM-REV site in the open sea).
- The LS2N "order" team is a major player in the field of control on a national and international scale. Large classes of dynamic systems are considered, including continuous time, discrete time, linear (possibly with varying parameters), nonlinear or switching systems, and delay systems. The fields of applications are multiple, with a focus on transport systems, energy and health.

5 Related Publications

1. - P. Saenger, **M. Hilairet**, *Hardware-In-the-Loop simulation of a DC-machine with INTEL FPGA boards*, IEEE IECON conference, Washington, 2018.
2. Jeffrey R. Homer ; Ryozo Nagamune, "Physics-Based 3-D Control-Oriented Modeling of Floating Wind Turbines", IEEE Transactions on Control Systems Technology, 2018 , Vol: 26 , Issue: 1.
3. I. Guenoune, **F. Plestan**, A. Chermitti, et C. Evangelista, *Modeling and robust control of a twin wind turbines structure*, Control Engineering Practice, vol.69, pp.23-35, 2017.
4. - X. Liu, M. Harmouche, **S. Laghrouche**, M. Wack, *A novel adaptive sliding mode controller for a wind energy conversion system with doubly fed induction machine*, The 4th International conference on renewable energy : generation and applications (ICREGA), Belfort, France, 2016.
5. X. Liu, **S. Laghrouche**, M. Harmouche, R. Fellag and M. Wack, *Super twisting sliding mode MPPT control of an IM based wind energy conversion system*, 2015 4th International Conference on Electrical Engineering (ICEE), Boumerdes, 2015.
6. X. Liu, Jianxing Liu, **S. Laughrouche**, M. Cirrincione, M. Wack. *MPPT Control of Variable Speed Wind Generators with Squirrel Cage Induction Machines*, 3rd International Symposium on Environment- Friendly Energies and Applications, 2014, Paris, France.
7. - J. X. Liu, **S. Laghrouche**, M. Wack. *Adaptive-Gain Second Order Sliding Mode Observer Design for Switching Power Converters*. Control Engineering Practice.Volume. 30, pp. 124-131, 2014.
8. - J. X. Liu, **S. Laghrouche**, M. Wack. *Observer-Based Higher Order Sliding Mode Control of Power Factor in Three-Phase AC/DC Converter for Hybrid Electric Vehicle Applications*. International Journal of Control. Vol. 87, Issue 6, pp. 1117-1130, 2014.
9. Hazim Namik ; Karl Stol, *"Individual Blade Pitch Control of a Spar-Buoy Floating Wind Turbine"*IEEE Transactions on Control Systems Technology, 2014 , Vol.22 , Issue: 1.

6 Candidate profile and Background

The ideal candidate should meet the following criteria: He/she is expected to have a solid background in electrical engineering or control engineering. Adequate knowledge of nonlinear control systems and diagnosis is also required. Hardware-in-the-Loop (HIL) skills will be appreciated.