waters with floating foundations, allowing to make use of the strong wind and the plenty of space in oceans.

However, huge progress must be made on this class of wind turbines, especially on their control. This is the main reason of this thesis. This chapter introduces the wind turbines, including the traditional onshore wind turbines, offshore wind turbines, especially the floating ones. The chapter also displays the wind turbines control systems and proposes a review of controllers. Finally, the research motivations and organizations of this thesis are outlined.

Introduction of wind systems

The development of wind energy

Wind turbine is the product of modern science and technology. It is a power generation equipment that uses natural wind energy to firstly convert the kinetic energy of wind into mechanical energy. Then, the turbine driving the generator, power generation is possible. As a kind of clean, renewable and sustainable energy, wind energy plays an important role for the global power supply system and becomes the fastest increasing new clean electric power. In 2019, new installed capacity exceeded the 60 GW milestone for the second time in history, that is +19% compared with 2018 (see Figure 1). Table 1 is listing the top 5 countries of installed wind power capacity by 2019.

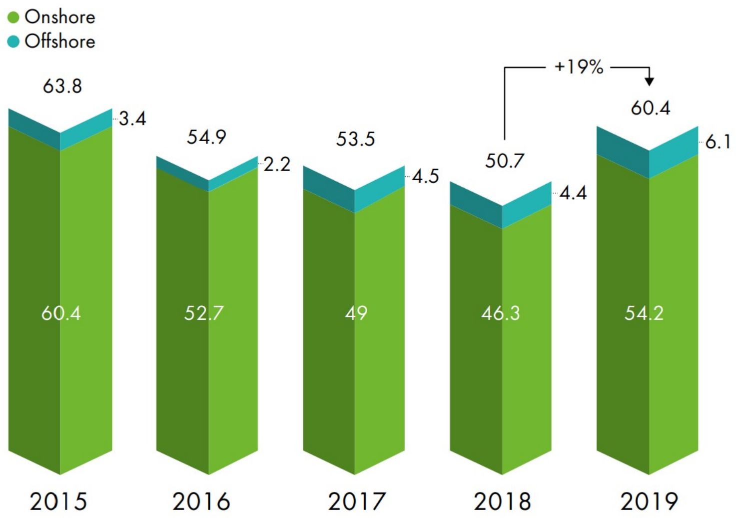

Figure 1 – New installations of wind energy (GWEC 2019).

Country	Installed capacity (MW)
China	237,029
United States	105,433
Germany	61,357
India	37,529
Spain	25,808

Table 1 – Installed capacities for the top 5 countries by the end of 2019 (*Wind Energy International* 2020).

Offshore wind energy

Although the majority of the wind turbines are installed onshore, the offshore wind market is growing rapidly (about 30% per year) since 2010 thanks to the development of technology. For example, in 2019, 6.1 GW (a record) of offshore wind energy has been installed (see Figure 1). The fast development of offshore wind energy is due to the fact that (H. Namik and K. Stol 2013; Olondriz Erdozain 2019):

- the quality of offshore wind resource is better: less turbulence and higher annual mean wind speed. Then, smaller structure load and higher power generation can be achieved;
- the lack of space for onshore wind turbines being a reality in numerous countries, the offshore area provides additional space;
- offshore solutions induce reduced visual and noise impact.

In the next five years, about 150 new offshore wind projects are expected to be completed all over the world, pointing to an increasing role for offshore wind in power supplies. Many european countries stimulate the development of this technology, among them United Kingdom, Germany and Denmark. The United Kingdom and Germany currently have the largest offshore wind capacities in operation, while Denmark produces 15% of its electricity from offshore wind in 2018. China added more capacity than any other country in 2018 (IEA 2019b).

Overview of floating wind turbine

Offshore wind energy has a great potential and is expected in the future to have a greater portion of the global energy mix. However, 80% of offshore wind resources are in the deep water zones (deeper than 60 m). In order to use these resources, floating wind turbines are the solutions.

The concept of floating wind turbine (FWT) was firstly proposed in (Heronemus 1972): this concept allows to generate electricity in the deep water zones thanks to floating structures that supports the wind turbines. However, since the establishment of commercial wind power industry in the mid 1990's, the topic of FWT has gradually got attention from the research community (Musial, Butterfield, and Boone 2004). Based on the floating technologies derived from oil & gas industry, FWT could imagine using the abundant oceanic wind energy resources.

Current contributions of floating wind systems versus all the wind installations is fairly small, but it will play an increasingly important role toward the end of this decade, accounting for 6 percent of global new wind installations in 2030 (GWEC 2020). Europe has the most developed FWT technologies and has a great potential for the floating wind market (WindEurope 2017). Furthermore, european companies lead three quarters of the floating wind projects, with more than fifty FWT projects all over the world. Numerous of pre-commercial FWT projects (see Table 2) are now announced and will be in operation in the next few years.

Wind farm name	Country	Capacity (MW)	Commissioning date
Windfloat Atlantic	Portugal	25	2019
Flocan 5 Canary	Spain	25	2020
Nautilus	Spain	5	2020
SeaTwirl S2	Sweden	1	2020
Kincardine	United Kingdom	49	2020
Forthwind Project	United Kingdom	12	2020
EFGL	France	24	2021
Groix-Belle-Ile	France	24	2021
PGL Wind Farm	France	24	2021
EolMed	France	25	2021
Katanes Floating Energy Park -Array	United Kingdom	32	2022
Hywind Tampen	Norway	88	2022

Table 2 – Announced pre-commercial FWT projects in Europe (WindEurope 2018).

Notice that, despite Europe's largest seafront, France is lagging far behind in the development of FWTs. This thesis wanted to contribute to the catching up of this delay.

There are four main floating structures currently applied to the FWT systems (*Wind Energy International* 2020): barge, semi-submersible (semi-sub), spar-buoy (spar) and tension leg platform (TLP) as shown in Figure 2. They are classified by the principles of stabilization mechanisms in the water; a brief introduction of the four platforms is given in the sequel (Si 2015; Hazim Namik 2012; Olondriz Erdozain 2019; Scheu et al. 2018)

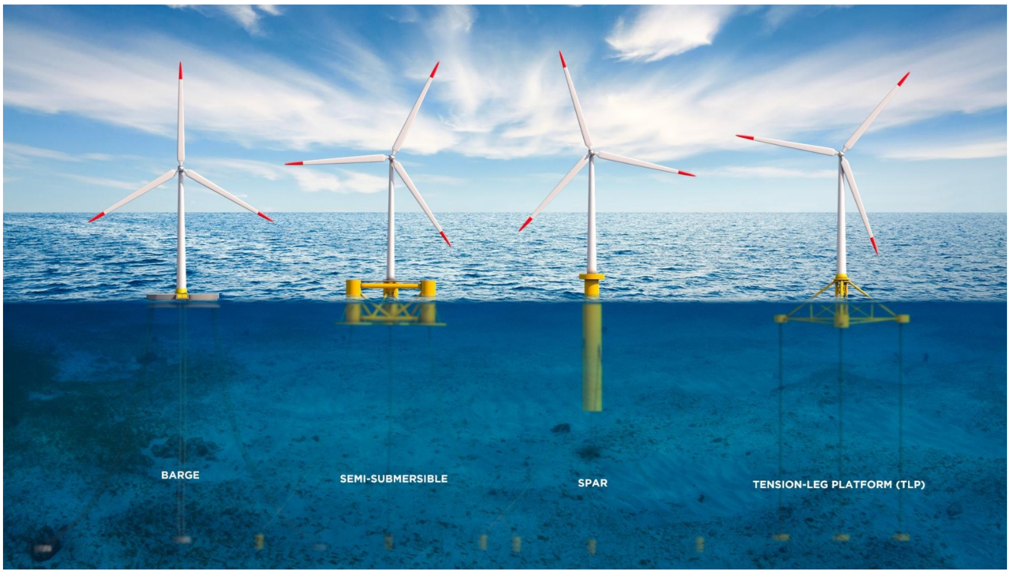

Figure 2 – The four main floating wind turbine concepts (WindEurope 2017).

- **Barge structure:** the barge platform is stabilized mainly by a water-plane area, that is a mechanical structure similar to a ship. Such platform usually has a large area with a shallow draft that gives the minimum water depth requirement. Mooring lines are necessary to maintain the platform at a given spot and prevent the drift displacement. Moreover, moon pool or heave plates can equipped the barge platform in order to increase the damping and reduce the platform motions (Scheu et al. 2018);

- **Semi-submersible (semi-sub) structure:** the semi-sub platform is stabilized by the combination of ballast and water-plane area. The ballast diameters, their distances from each other, the draft and the mass of the structure, affect the stability of the platform. Therefore, the motions of the platform can be adjusted by those parameters. Mooring system is also required to keep the platform at a given position;

- **Spar-buoy (spar) structure:** the spar-buoy platform is stabilized by a ballast, with a lower center of mass lower than the center of buoyancy. Thanks to such structure, a restore moment can be generated so that the stability of the platform is kept from the heeling moment. The platform is moored by catenaries (normally, 3 mooring lines), ensuring that the platform is in a fixed position and without drift displacement. This type of platform can be used in very deep sea water areas;

- **Tension leg platform (TPL) structure:** the TLP structure is stabilized by tension mooring lines that are fixed to the seabed; the tension is generated by the large buoyancy of the floating structure. Such platform has a good stability; however, it needs a high requirement for the mooring system installation and the cost is higher.

Control of wind turbine systems

A wind turbine control system is composed by a set of sensors, actuators, hardware and software. Signals are captured by sensors, and are sent to the hardware and software. Then, output signals such as the blade pitch and generator torque control can be generated for the actuators (Olondriz Erdozain 2019). The main control objectives of a wind turbine control system are the regulation of power output while reducing the fatigue loads. As the size and capacity of wind turbines are getting larger, the control system becomes more and more important.

There are three sequences of control: safety control, supervisory control and closed-loop control (Burton, Sharpe, Jenkins, and E. Bossanyi 2001). Safety control ensures that the wind turbine works under a safety operation state; safety control is responsible for shutting down the system in case of emergency. Supervisory control is responsible for determining the operating state of wind turbines and, for switching from one operating state into another. When a wind turbine starts to produce energy, the first control objective is to maximum the power or limit it at its rated value. The choice of power level production depends on the different operating regions in which the system is evolving as detailed in the next subsection. For large scale wind turbines, the fatigue loads reduction is also an important control objective.

Operating regions

Among the numerous types of wind turbines (Tong 2010), the variable speed horizontal-axis wind turbine is the most popular used in large-scale wind turbines. Such wind turbines admit 4 operating regions which are classified by the wind speed, the control objectives varying with the different regions (E. A. Bossanyi 2000; Bianchi, De Battista, and Mantz 2006; J. Jonkman, Butterfield, et al. 2009; Hazim Namik 2012). Figure 3 displays the 4 operating regions of those wind turbines.

- **Region I:** The wind speed is slower than the cut-in wind speed. In this case, the wind is too slow to start-up the wind turbine; no electric power is generated.

- **Region II:** When the wind speed is between the cut-in and the rated wind speed, the wind turbine works in Region II. In this region, the generator rotation speed is below the rated speed, the main control objective of this region being then to maximize the power output.

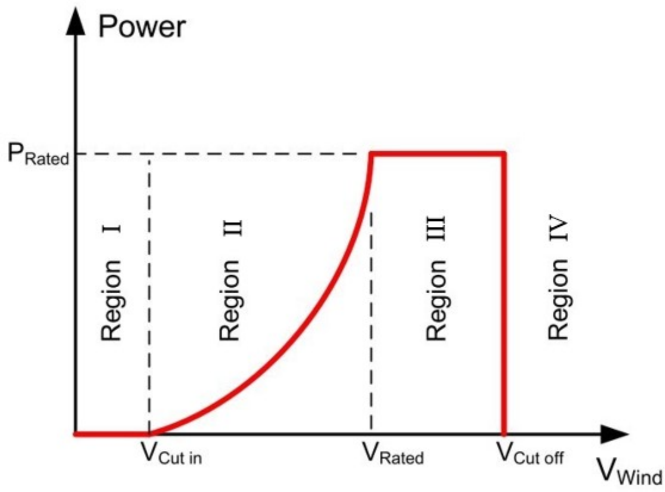

Figure 3 – Four operating regions of wind turbine (Hazim Namik 2012).

This region is also known as the generator torque region since the generator torque is controlled in order to maximize the power. The pitch angle of the blades is so maintained at an optimum value allowing a large value of the power coefficient (Olondriz Erdozain 2019). Therefore, the famous power optimization technique, called maximum point power tracking (MPPT) (Beltran, Ahmed-Ali, and Benbouzid 2008; Bianchi, De Battista, and Mantz 2006) is used.

- **Region III:** When the wind speed is higher than its rated value and lower than the cut-off wind speed, the wind turbine works in Region III (also known as *above-rated* region). In this region, the control goal is no longer to maximize the power output, but to limit it to its rated value in order to protect the components of wind turbine. Then, the blade pitch control is activated to limit the rotor speed, and thereby regulates the power. The generator torque in this region has two control strategies:

  1. keep the generator torque at its rated value (Γ_{g0}). Then, the power P can be regulated by the rotor speed Ω_r according to the following formula (n_g the gear box ratio)

  $$P = n_g \Gamma_{g0} \Omega_r \tag{1}$$

  2. the generator torque is controlled inversely proportional to the rotor speed in order to

limit the of power fluctuation from the rated value P_0, *i.e.*

$$\Gamma_g = \frac{P_0}{n_g \Omega_r} \tag{2}$$

- **Region IV:** Finally, if the wind speed exceeds the cut-off wind speed, for the safety of the wind turbine system, the shut-down mode is activated in this region.

Another operating mode of the wind turbine system is called emergence stop, that is activated for example when a fault is detected. Furthermore, the start-up and shut-down of the turbine are decided by the supervision control. Those control logic are not considered in this work.

Control strategies are designed with respect to the current region. **This thesis is focused on the control problems of FWT in the Region III.**

Blade pitch control

For wind turbine control systems, many actuators such as blade pitch angle, generator torque, turbine yaw drive ..., are available in order to achieve the control objectives in the different operating regions (H. Namik and K. Stol 2013). Among those actuators, the generator torque and, especially, the blade pitch are most commonly used. For the blade pitch control, two different strategies are available: collective blade pitch (CBP) control and individual blade pitch (IBP) control.

Collective blade pitch control

Collective blade pitch control is the most widely used in the installed wind turbines (Njiri and Söffker 2016), This blade pitch control strategy allows to control all the blades (normally 3 blades) collectively, namely, the control signal for all the blade pitch actuators is identical. When the wind turbine operates in Region III, CBP control is able to regulate the power output at its rated value to protect the generator and the mechanical structure of wind turbine. For a conventional wind turbine, generator torque is fixed at its rated value in Region III, the CBP closed-loop control being obtained by a feedback of error between the rotor speed and its rated value. One of the most common control scheme is the proportional-integral-derivative (PID) control (Hand and Balas 2000).

Obviously, given that a similar action is applied to whole the blades, such control scheme is single-input single-output (SISO) one. If additional control objectives must be achieved, the CBP control must be redefined by a particular way (see the sequel of this thesis) to get satisfying performances without compromising power regulation or other objectives (H. Namik and K. Stol 2013).

Individual blade pitch control

Individual blade pitch control is a recently emerging technology that provides individual control signal to each blade. It is typically used to reduce the fatigue load (E. A. Bossanyi 2003; Selvam et al. 2009; Van Engelen 2006). Since the load reduction becomes more and more critical with the increasing size of wind turbines, the research of IBP control is one of the hot points.

Thanks to the IBP approach, the number of inputs is increased; therefore, additional control objectives can be added inducing a multiple-input multiple-output (MIMO) system. Some advanced control schemes (Ossmann, Theis, and Seiler 2017; Petrović, Jelavić, and Baotić 2015; Sarkar, Fitzgerald, and Biswajit Basu 2020; H. Namik and K. Stol 2014; Raach et al. 2014) based on IBP approach are applied to achieve different control objectives, such as blade load reduction, rotor speed regulation and platform pitch motion reduction (for the FWT). However, because of the intensive use of blade pitch angle actuators, the requirements for the actuators are relatively high that can explain why IBP control approach is not currently widely used in commercial wind turbines (Menezes Novaes, Araújo, and Bouchonneau Da Silva 2018).

Control of floating wind turbines

Versus the onshore wind turbine that has a fixed bottom, floating wind turbine has additional degree of freedoms (DOFs) due to the floating platform, including platform roll/pitch/yaw rotations; platform horizontal surge/horizontal sway/vertical heave translations (see Figure 4).

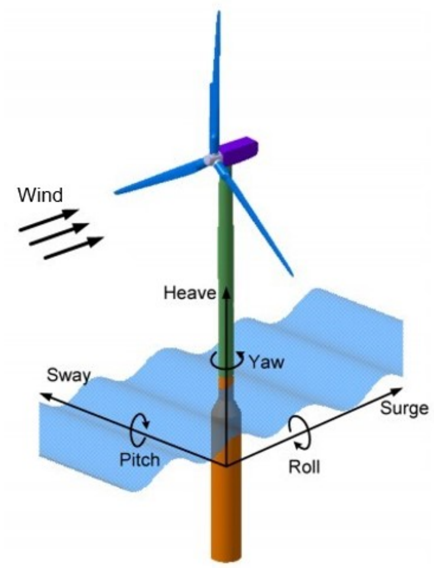

Figure 4 – 6 DOFs platform motions of floating wind turbine (T. Tran, D. Kim, and Song 2014).

Among these motions, the platform pitch motion/rotation has the most significant influence on the FWT system when the wind speed exceeds its rated value (Region III). Such motion can lead to the reduction of power generation quality and the increase of load, and can reduce the lifetime of the FWT (Y. Shi et al. 2017). Hence, the reduction of the platform motions being critical for FWT, there are some solutions available to solve this problem, such as design of different kinds of floating platforms to damp these motions, use of tuned mass dampers providing stiffness and damping or development of control strategies reducing the motions and regulating the power (Hazim Namik 2012). The thesis is focused on the latter improvement way.

Some previous studies (Skaare et al. 2007; Larsen and Hanson 2007; J. Jonkman 2008a) have shown that the traditional control approach for onshore (fixed bottom) wind turbines cannot be directly used for the floating ones due to the fact that these approaches do not take the platform pitch into consideration. In case of use, they result in large resonant platform motions, also known as negative damping (Skaare et al. 2007) (see Figure 5). Such unstable dynamics can be explained as follows: assume that the floating platform is pitching against the wind in Region III; the relative wind speed captured by the rotor increases. So, the traditional blade pitch controller reduces the aerodynamic torque in order to ensure a constant rotor speed/power regulation. However, at the same time, the aerodynamic thrust on the rotor is reduced as well. Such phenomenon leads to the platform pitching forward more, this motion will increase the relative wind speed on the rotor, accelerating the rotor rotation speed (Fischer and Loepelmann 2016). In summary, because of the negative damping, there exists a trade-off between the power regulation and the platform pitch motion reduction (Figure 5). Thus, specific controllers for FWT must be developed.

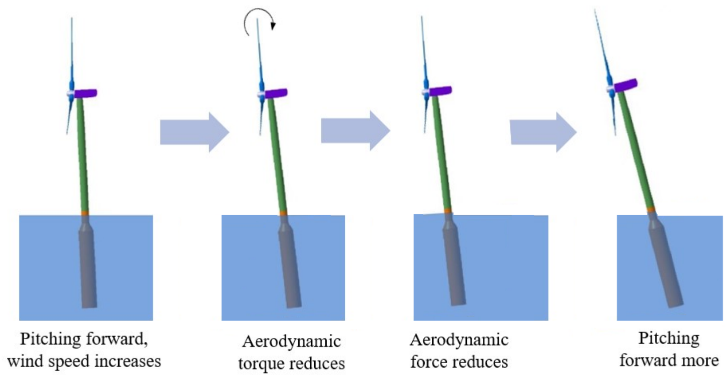

Figure 5 – Negative damping phenomenon of floating wind turbines, adapt from (T.-T. Tran and D.-H. Kim 2015).

To summarize, as detailed before, the control objectives of a FWT in Region III are:

- firstly, regulation of the power at its rated value to protect the generator and the mechanical structure;
- then, reduction of the platform pitch motion, ensuring the stability of the platform;
- in addition, in order to extend the service life of FWT, another control objective lies in the reduction of structure load.

Linear approaches

Lot of works have been done in the development of control algorithms to counteract the negative damping of FWT. The most well-known approach is the gain-scheduled proportional-integral (GSPI) control (Larsen and Hanson 2007; J. Jonkman 2008a) using CBP control technology; such method is based on the baseline rotor speed control of onshore wind turbines (J. Jonkman, Butterfield, et al. 2009). By detuning the controllers gains such that the natural frequency of close-loop system is lower than the platform pitch natural frequency, then the platform pitch motion can be greatly reduced. However, due to the low bandwidth of the control, the rotor speed variation is increased, that means that the power regulation in Region III is degraded. In (Wakui, Yoshimura, and Yokoyama 2017), novel parameters setting is proposed for the GSPI controller, the parameters being determined to obtain a natural frequency of the closed-loop system higher than the natural frequency of the platform pitch motion. Furthermore, the objective is to get a damping coefficient greater than 1.0. These parameters tuning results in a similar platform pitch motion reduction as the tuning given in (J. Jonkman 2008a), but with a significantly reduction of the power fluctuations around the rated.

In (Lackner 2009; Lackner 2013), gain-scheduled collective blade pitch control is used to track the set point of rotation speed that is defined as a function of the platform pitch velocity, so-called variable power pitch control (VPPC). With this approach, the platform pitch motion is greatly attenuated; however, the power fluctuation is increased.

Linear quadratic regulator (LQR) control based on linear model has been firstly applied to a FWT system in (Hazim Namik, Karl Stol, and J. a. Jonkman 2008), in which the rotor speed variation and platform pitch motion are reduced compared to (J. Jonkman 2008a). Notice that CBP strategy is used in this work, the two control objectives being achieved by using a penalty function that optimizes the trade-off between the speed regulation and the platform pitching. More recently, many works have been proposed based on LQR approach (Christiansen, Knudsen, and T. Bak 2011) combining with a wind estimator and a state observer to improve the control performances. In (Christiansen, Knudsen, and T. Bak 2014), an additional LQR control loop has been added to an onshore wind turbine controller and reduces power fluctuations and platform oscillations; such approach simplifies the control design of FWT without modifying the onshore controller.

Another popular optimal algorithm, H-infinity (H_∞) control is also used for FWT (Bakka and Karimi 2012; Bakka and Karimi 2012; X. Li and Gao 2015). This class of controllers is designed based on a family of linear state-space model, namely the linear parameter varying (LPV) models. By this way, the controllers ensure better performances than the controllers based on a single linear model. In (Hara et al. 2017), H_∞ control law is implemented to a scaled FWT system. The experimental results show the effectiveness of rotor speed regulation and platform pitch motion reduction. Nevertheless, the authors point out that, for further improvement of the control performances, the use of LPV model is necessary.

In (Hazim Namik and Karl Stol 2010; Namik and Karl Stol 2011; H. Namik and K. Stol 2014), individual blade pitch control is considered with disturbance accommodating control (DAC) for barge, TPL and spar-buoy floating systems. Multiple objectives are achieved by the multiple inputs (IBP angles) controller: the platform motions and tower fatigue are significantly reduced versus the GSPI, as well as the power and rotor speed regulation are improved. However, such improvements have a cost: extensive use of blade pitch actuator (4-12 times larger than GSPI CBP control).

Model predictive control (MPC) is another popular algorithm that is widely adapted to the control of FWT. In (Lemmer, Raach, et al. 2015), a MPC controller using IBP scheme is applied to a 10 MW FWT; good performances have been shown for rotor speed tracking and tower fatigue reduction versus a PI controller. In (Cunha et al. 2014), MPC is adopted combining with the VPPC algorithm: the platform pitch motion is reduced with less power variation than (Lackner 2009). Moreover, the blade as well as the tower fatigue loads are also reduced. In (Raach et al. 2014; Schlipf, Sandner, et al. 2013), nonlinear MPC using wind speed prediction have been introduced, where the incoming wind information is obtained by the light detection and ranging (LIDAR) remote sensing technology. Results show a better performance than the baseline GSPI control.

Limits and nonlinear approaches

The study carried out in this work is motivated by the requirement of developing efficient controllers for floating wind turbines in Region III. The main idea is to propose efficient control strategies that require very reduced effort of modeling and tuning. As previously recalled, the control algorithms used for the bottom-fixed wind turbines cannot be directly applied to the floating ones. The dynamics of floating platforms, especially the platform pitch motion, must be taken into consideration in the control design process in order to deal with negative damping (Skaare et al. 2007).

> The control objectives of a FWT in Region III are: the regulation of the power output at its rated value (as the bottom-fixed wind turbine) and the reduction of the pitch motion of the floating platform. Moreover, the fatigue loads of the structure must be limited.

As detailed in the previous section, numerous works have been made on the control of FWT in Region III. The traditional GSPI controller is adopted to FWT by detuning the controller gains in order to damp the platform pitch motion; modern control theories have also been used based on linear state-space models, such as the LQR, H_∞, DAC ..., in which some studies use optimal algorithms to deal with the trade-off between the power regulation and platform pitch motion by CBP control. Some studies also used MIMO control that uses IBP angles as control inputs to achieve several control objectives (power regulation, platform motion reduction and fatigue load reduction). However, the main part of these studies uses linear representations of the FWTs, these linear models being obtained for a given operating point depending on wind conditions and rotor speed. The linear models are used for the control design: the drawback is that, once the turbine is working away from the operating point, the controller loses its efficiency and its desired performances. As a consequence, the controller must be tuned for each operating point to ensure its efficiency; another way is the use of LPV model to schedule the controller gains. Such tuning and gain scheduling process is fastidious and is not friendly to wind turbine manufacturers.

An alternative solution would be to base the control law design on more general nonlinear systems. However, the applications of nonlinear control strategies to FWTs are very limited in the literature (Sandner et al. 2012; Homer and Nagamune 2018), the nonlinear models developed in these works appearing to be limited in the frame of control.

> Therefore, it is necessary to develop control solutions for FWTs that
>
> - reduce the tuning effort and guarantee high level performances;
>
> - require very few information on system model.

In this thesis, sliding mode control (V. Utkin 1977) is adopted for its robustness and its simplicity; the adaptive versions of such control approach (in its high order version) can deal with the robust control problem with very limited information of the model and high level performances in spite of uncertainties and perturbations. Notice that, in order to attenuate the negative chattering phenomena of SMC, high order sliding mode control (Yuri Shtessel, Edwards, et al. 2014) combined with gain adaptation (Plestan et al. 2010; Yuri Shtessel, Taleb, and Plestan 2012) have been chosen. Indeed, such algorithms are particularly well-adapted to the FWT control problems because:

- the used adaptive algorithms offer continuous control and thus reduce the chattering that allows to protect the actuators (*i.e.* the blade pitch actuators) from high frequency oscillations;
- they are simple for application that is friendly for manufacturers;
- moreover, the adaptation algorithms dynamically adapt the gains versus uncertainties and perturbations: it avoids the over-estimation of controller gains, and strongly reduces the tuning effort;
- the adaptive versions of SMC algorithms require very reduced information on modeling;
- finally, these approaches allow to propose controllers with a single set of tuning parameters for the whole operating domain that strongly simplifies the control design.

Organization and contributions

This thesis consists of five parts:

Chapter 1 describes the modeling of a FWT, simulation set-up and performance analysis tools. The modeling includes the physical model that concerns the coordinates system, the power capture system, the drive train system and a brief explanation of hydrodynamics of the floating structure. Then, linearized models of FWT are introduced. Simulation context (FAST (Jason M Jonkman, M. L. Buhl Jr, et al. 2005)) and the research object (a 5MW spar-buoy FWT) are also introduced.

In **Chapter 2**, adaptive high order sliding mode control is applied to the FWT based on collective blade pitch approach. Firstly, the problem statement and the control objectives of the FWT are discussed: regulation of the rotor speed at its rated value (assuming that the generator torque is fixed) and reduction of the platform pitch motion. Then, high order sliding mode control with different adaptation strategies are recalled, including the adaptive super-twisting (ASTW) proposed by (Yuri Shtessel, Taleb, and Plestan 2012) and a recently developed homogeneity based controller with varying exponent parameter (HCVP) (Tahoumi, Plestan, et al. 2019). Meanwhile, a new simplified adaptive super-twisting (SAST) algorithm with very few tuning parameters (only 2 parameters are required) is proposed. All of those algorithms are applied to FWT in the FAST/SIMULINK environment and the performances are compared with the GSPI (J. Jonkman 2008a) control for different scenarios. Simulation results shows that the controllers designed in this chapter have better performances than the GSPI controller with reduce tuning effort and knowledge of system model.

In **Chapter 3**, a permanent magnet synchronous generator (PMSG) is supposed to equip the FWT. The control is not only acting on the aero/hydrodynamic part, but also considers the control of electrical part. The control objectives are stated as the regulation of the power at its rated value, the reduction of the platform pitch motion, and the reduction of the ripple effect of the generator. Unlike the previous chapter (in which the generator torque was fixed at its rated value), the power regulation is achieved by the combination of torque control and rotor speed control. Both ASTW and SAST controllers are used in this chapter; the simulation results are compared with GSPI.

In **Chapter 4**, the individual blade pitch (IBP) approach is studied. Therefore, besides regulating the power and reducing the platform pitch motion, the controller proposed in this chapter takes the structural load reduction into consideration. The overall control scheme consists in two parts: the CBP control loop for the rotor speed regulation and platform pitch reduction, and the IBP control loop for the blade load reduction. The ASTW approach is applied in this chapter, simulation results and their analysis being given at last.

In **Chapter 5**, the proposed simplified adaptive super-twisting (SAST) controller is applied to an experimental floating wind turbine set-up in the ECN wave tank. The experimental set-up is composed by a reduced scale system in the wave tank and a numerical one modeled by FAST software. The introduction of the reduced scale system and the numerical model are firstly described. Then, three kinds of controllers are briefly introduced and implemented: the university of Denmark (DTU) GSPI controller (Hansen and Henriksen 2013) with Olav Olsen (Yu et al. 2018) parameters setting, the LQR control developed by D-ICE company and the SAST control proposed in Chapter 2. Experiments are made by using the three controllers under same wave and wind conditions in Region III; experimental results are analysed and compared.

Some of the results presented in this thesis have been published or submitted for publication in the following journals and conferences.

International journals

[1] Zhang. C and Plestan. F, "Adaptive sliding mode control of floating offshore wind turbine equipped by PMSG", *Wind Energy*, DOI 10.1002/we.2601, 2020.

[2] Gutierrez. SV, Zhang. C, Plestan. F and de León-Morales. J, "A simplified version of adaptive super twisting for control of floating wind turbine", *Control engineering Practice*, first revision, 2020.

[3] Zhang. C and Plestan. F, "Individual/collective blade pitch control of floating wind turbine based on adaptive second order sliding mode", Ocean Engineering, submitted, 2020.

International conferences

[1] Zhang. C, Gutierrez. SV, Plestan. F and de León-Morales. J, "Adaptive super-twisting control of floating wind turbines with collective blade pitch control", *IFAC Workshop on Control of Smart Grid and Renewable Energy Systems*, Jeju, Republic of Korea, 2019.

[2] Zhang. C, Tahoumi. E, Gutierrez. SV and Plestan. F and de León-Morales. J, "Adaptive robust control of floating offshore wind turbine based on sliding mode", *IEEE Conference on Decision and Control*, Nice, France, 2019.

[3] Zhang. C and Plestan. F, "Power and motion control of a floating wind turbine: an original approach based on adaptive second order sliding mode control", *IFAC World Congress*, Berlin, Germany, 2020.