PhD Public Defence

Title: Advanced Control and Operation of Wind Power Plants

Location: Pontoppidanstræde 111, room 1.177

Time: Wednesday 23 August 2017 at 13.00

PhD defendant: Baohua Zhang

Supervisor: Professor Zhe Chen

Moderator: Associate Professor Jayakrishnan Radhakrishna Pillai

Opponents: Associate Professor Sanjay K. Chaudhary, Dept. of Energy Technology, Aalborg University (Chairman)
Professor Geert Deconinck, University of Leuven, Belgium
Professor Dr.-Ing. Kai Strunz, TU Berlin, Germany

All are welcome. The defence will be in English.

After the defence there will be an informal reception in Pontoppidanstræde 111 (coffee room).
Abstract:

Reducing the Cost of Energy (CoE) of wind power can increase the profit of the wind power plants’ owners and increase the competitiveness of wind power with regard to other types of energies. From the perspective of control and operation at plant level, the reduction of CoE can be achieved by maximizing the annual energy production and reducing the operational expenses. These objectives need the coordination of Wind Turbines (WTs) inside the plant, because the WTs are interacted with each other through their wakes and the collection system.

The WT wake effects include the reduction of wind velocity and the increase of turbulence intensity inside the wakes. The wind velocity reduction induces the loss of captured power at the downwind WTs and the increased turbulence intensity brings more fatigue loads on the downwind WTs, thus reduces the lifetime of the WTs. Apart from the aerodynamic interaction through wakes, the WTs are also interacted through collection systems. The power flow inside the collection systems causes electrical loss. Meanwhile, the power flow is controlled by the active power and the reactive power settings at the WT nodes and limited by the power settings at the node of the point of common coupling. Therefore, advanced control strategy is needed to coordinate the settings of each WT to reach a global objective for the wind power plant.

This PhD project studies the advanced control and operation strategies that allow wind power plants to operate in an optimal manner with respect to maximizing the output power (Capturing more power and reducing electrical loss) and minimizing the operational costs over the lifetime of WTs (reducing fatigue load to extend their lifetime). The contributions of this project include three parts:

1) The coordination of different objectives. The control objective of the plant can be divided into three sub-objectives: a) Capturing more power by reducing the wake loss; b) Reducing fatigue load by mitigating the added turbulence intensity of wakes; c) Decreasing electrical loss inside wind power plants. These objectives may contradict each other, therefore they are researched individually first and then some of them are combined.

2) The coordination of the active power dispatch and reactive power dispatch. The active power and reactive power of each WT are interacted by the current and voltage limits of the converters and generators. In addition, the control objectives of the active power dispatch and reactive power dispatch may contradict each other. Therefore, they are coordinated in this project to reach a global objective.

3) The coordination of the plant level dispatch and WT level control. Different WT control strategies cause different fatigue load and electrical loss for the WT under the same power setting. Therefore, the plant level dispatch should consider the influence of the WT control strategy and choose the best WT control strategy that matches the control objective of the plant controller. In this project, different WT level control strategies are studied and their combinations with the plant level dispatch strategies are compared.

The methodology used in this project is model-based method, therefore the detailed models of the wind power plants are built first, including the wake model, the WT model (the power capturing model, the thrust force model and the fatigue load model) and the electrical loss models of WTs, transformers and collection cables. In addition, parts of the wind power plant model are modelled as lookup tables in order to increase the speed of the optimization problems at the plant level. Since the problems are quite nonlinear and nonconvex, interior point method and heuristic method are chosen to solve them. The proposed strategies are compared with traditional strategies and the simulation results show the effectiveness of the proposed strategies.