Performance Enhancement and Load Reduction on Wind Turbines Using Inflow Measurements

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Wind energy is being applied at a larger and larger scale worldwide, and is one of the technologies eligible for accommodating the increasing demand for renewable energy. However, wind energy is still not competitive compared to technologies that are based on fossil energy sources. Therefore, much wind energy research is focused on decreasing the cost of the energy that can be produced from the wind. The cost of energy can for example be decreased by ensuring that wind turbines are operated in a way that ensures that the maximum amount of energy is extracted, and that the turbines are not loaded excessively. The operation of a wind turbine is governed by a number of controllers that are based on a series of sensors and actuators. Classical wind turbine control utilizes sensors for measuring turbine parameters such as rotor speed, power and shaft torque, as well as actuators for applying generator torque and collective pitch angle changes. Thus, classical wind turbine control schemes are based on measurements of the effects of the inflow on the turbine. Therefore, the reactions of the control system to the inflow changes are inherently delayed compared to the actual inflow changes. Because of the inherent delay of the control system, the ability of the system to react promptly to inflow changes is limited. Control schemes that are based on inflow measurements have been developed to overcome the limitations of the classical wind turbine control system. By measuring the inflow directly, actuation can be initiated instantly as the inflow changes. If the inflow is measured upstream of the turbine, actuation can be initiated prior to the occurrence of a wind speed change at the turbine. Hereby, even the actuator delay can be compensated for. Upstream inflow measurements could for example be acquired using "Light Detection and Ranging". In this thesis, the potentials for improving the power production and decreasing the load variations of horizontal axis upwind turbines by applying inflow measurement based control are assessed. The potential for increasing the power output through improved yaw alignment is studied by analyzing operational data from different turbines, and through experiments with a modified yaw controller. The results demonstrate that there is no significant potential for increased power output through improved yaw alignment for well calibrated turbines. The potential for increasing the power output through pitch control is studied through optimization of collective and individual pitch actuation. The results show that there is a potential for increasing the power output through individual pitch control. However, the increased power output is penalized by increased load variations. The load variations on a wind turbine can be alleviated using either yaw or pitch actuation. A method is presented for alleviating load variations using yaw control, and it is shown how the method can be efficiently applied for decreasing the load variations that are caused by a vertical wind shear. The potential of reducing the load variations using both inflow measurement based collective and individual pitch control is studied through simulations. The results demonstrate that tower and blade load variations can be efficiently alleviated in situations with large scale inflow variations using collective pitch control. For individual pitch control, it is demonstrated that control based on upstream inflow measurements can lead to great load reductions in certain situations. However, it is also shown that the potential load variation reductions are sensitive to uncertainties relating to the estimated inflow.

This thesis is comprised of a collection of scientific papers that covers the various results presented in this summary.

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