Damping of wind turbine tower vibrations

Damping of wind turbine vibrations by supplemental dampers is a key ingredient for the continuous use of monopiles as support for offshore wind turbines. The present thesis consists of an extended summary with four parts and appended papers [P1-P4] concerning novel strategies for damping of tower dominated vibrations. The first part of the thesis presents the theoretical framework for implementation of supplemental dampers in wind turbines. It is demonstrated that the feasibility of installing dampers at the bottom of the tower is significantly increased when placing passive or semiactive dampers in a stroke amplifying brace, which amplifies the displacement across the damper and thus reduces the desired level of damper force. For optimal damping of the two lowest tower modes, a novel toggle-brace concept for amplifying the bending deformation of the tower is presented. Numerical examples illustrate that a minimum of three braces in a symmetric circumferential configuration are needed to introduce homogeneous damping in the two lowest vibration modes, independent of the rotor direction. A novel hybrid viscous damper concept is described in the second part. The hybrid damper consists of a viscous dash-pot in series with an actuator and a load cell. The controllable actuator displacement is regulated by an Integral Force Feedback (IFF) with the measured force from the load cell as sensor input. By controlling the actuator displacement exactly 180° out of phase with the damper force, the displacement across the passive viscous dash-pot is increased, thus improving the feasibility of placing dampers at the root of the wind turbine tower. Furthermore, attainable damping can be increased when introducing a filtered version of the proposed IFF control, and explicit design concepts are presented in the thesis. An Active Tuned Mass Damper (ATMD) concept is described in the third part of the thesis. By controlling the supplemental actuator force with absolute tower displacement and relative damper velocity as sensor input a stable control scheme is constructed for effective damping by the ATMD of the two critical tower modes. The frequency response performance of the ATMD is equivalent to that of the passive Tuned Mass Damper, but with a reduced damper mass. Furthermore, it is demonstrated that the active control force can be significantly reduced. Finally, in the last part the performance of the hybrid viscous damper with IFFs validated by a series of real time hybrid simulations (RTHS). The experimental results illustrate the ability of the hybrid damper concept to increase damper stroke or attainable damping. The results also show that the actuator signal is quite sensitive to drift due an offset in the measured damper force. Thus, for the stroke amplifying IFF control a filtered integration is introduced, which almost retains the desired amplification and reduces drift. For the filtered IFF control, aimed at enhancing attainable damping, an augmented filtering similarly reduces drift, but also deteriorates the damping performance.