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Vibration Damping of Rotors by Resonant Control

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Extended Abstract

Rotors with blades as e.g. in wind turbines are prone to vibrations due to the fluctuating loading and flexibility of the blades and the support. A theory is developed for active control of a combined set of vibration modes in three-bladed rotors. The control system consists of identical collocated actuator-sensor pairs in the form of an active strut near the root of each blade, see Fig. 1. The three active struts permit addressing a group of vibration modes by suitable combination and calibration of the sensor/actuator signals. In the case of wind turbines the group of primary interest consists of the low-frequency edge-wise collective mode and the corresponding forward and backward whirling modes. The natural frequency of the collective mode is usually lower than the frequencies of the two whirling modes, that are nearly equal.

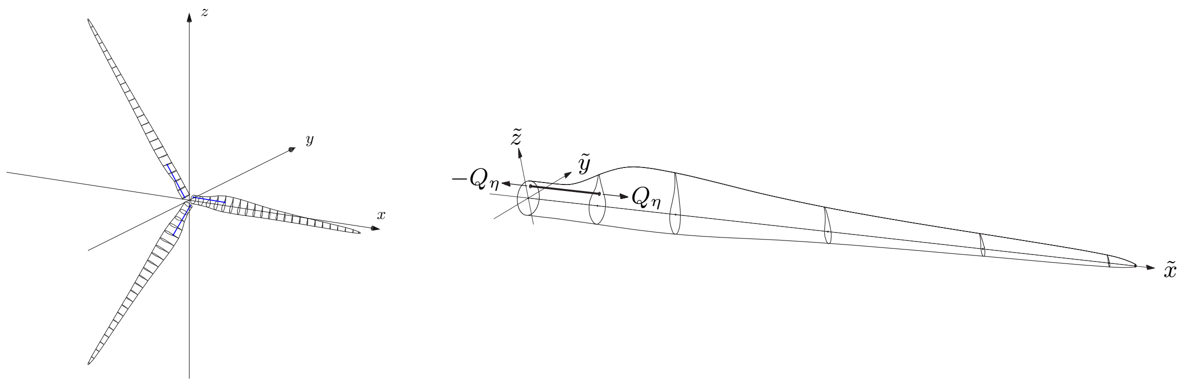

Figure 1. a) Three-bladed wind turbine rotor, b) Single blade with actuator strut.

The control signals from the blades are combined into a mean signal, addressing the collective mode, and three components from which the mean signal has be subtracted, addressing the pair of whirling modes. The mean signal is processed by a resonant filter, and the resulting signal is sent in identical form to each of the blades. The remaining components with zero-mean value are processed identically by a resonant filter, tuned to the natural frequency of the whirling modes. The two filters used for the control are based on acceleration feedback. They are calibrated by a generalized form of the resonance calibration procedure introduced for single-mode control in Krenk and Høgsberg (2009). The principle is based on a generalization of the tuned mass absorber, where a resonant actuator force is tuned such that the two modes arising from adding an additional resonant degree-of-freedom attain identical damping ratio. This principle has been used on a selected vibration mode of a single blade in Svendsen et al. (2011). The acceleration feedback used here is easily replaced by another member of the family of resonant controller formats discussed by Krenk and Høgsberg (2011), thereby permitting a different instrumentation.

The controller struts are placed near the root of the blade, and thus it registers deformation from many of the vibration modes of the rotor. In the calibration of the control parameters it is therefore important to account for the added flexibility of the structure due to influence of other non-resonant modes. The effect of the additional structural flexibility is included in the calibration via an extra quasi-static correction term. The importance of this correction is illustrated in Fig. 2, showing the resulting calibration in heavy full line, while the results without including the additional flexibility are shown as dashed lines. It is clearly seen that the quasi-static correction term plays an important role in the calibration of the present problem.

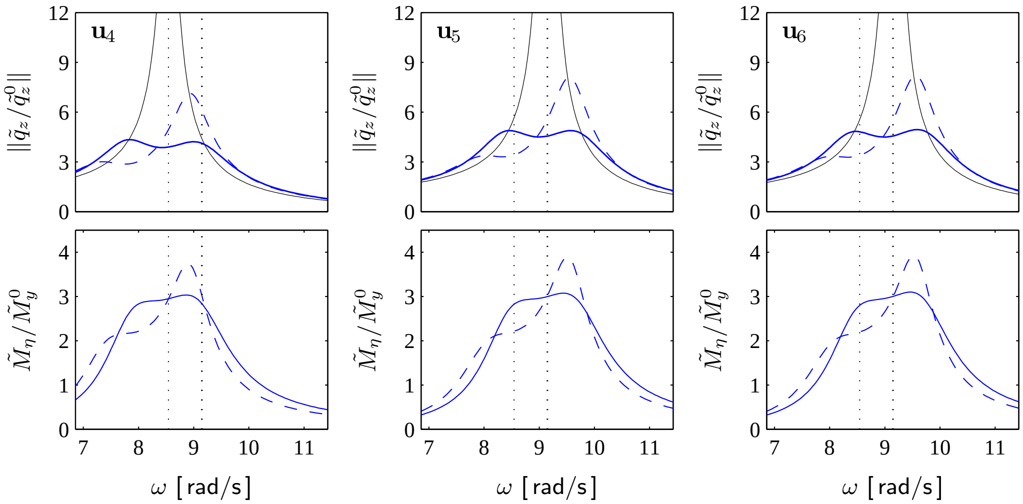

FIGURE 2. Dynamic amplification of collective and whirling modes. Top: blade tip response; Bottom: normalized control moment.

The efficiency of the present control procedure is illustrated by application to a particular wind turbine rotor with 42 meter blades. The load is provided by a simple but fully three-dimensional correlated wind velocity field. The control system provides a significant reduction in the response amplitude of the targeted modes as illustrated in Fig. 3a. The figure also illustrates that the control moment is in the order of 5-10% of the structural moment at the blade root. Figure 3b illustrates the power dissipation. It is seen that although the system requires active power, the power consumption is considerably smaller that the dissipated power, and also of significantly smaller peak level.

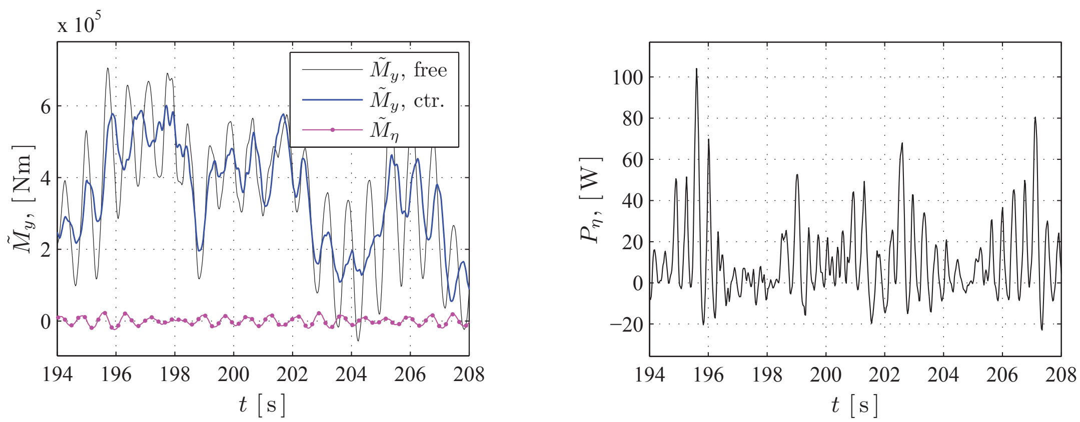

FIGURE 3. a) Blade and control moment, b) Power dissipation.

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