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HAWC2 simulations of a floating wind turbine for deep water

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Introduction

The aeroelastic multi-body code for wind turbine response HAWC2 has been coupled with the state-of-the-art code for floating structures SIMO/Riflex. The HYWIND concept is investigated.

Stability problems discovered

Early calculations showed an unstable motion of the tower directly coupled to the pitch control at wind speeds higher than rated. Amplitudes rises to an unacceptable high level. See Figure 1.

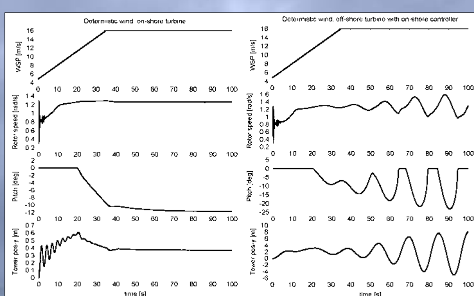

Figure 1. Difference in behaviour between normal on-shore foundation and the floating foundation. The floating concept is unstable regarding tower motion oscillations.

The reason

Aerodynamic damping of the tower motion is mainly affected by the thrust characteristic. A positive gradient between change in thrust and change in wind speed causes positive damping and vice versa. For on-shore turbines the pitch motion is normally slow related to the tower motion causing a positive instantaneous gradient. For floating turbines the tower eigenfrequency is very low (<0.04Hz) and the gradient changes to the negative slope of the quasisteady relation, hence negative damping. See Figure 2.

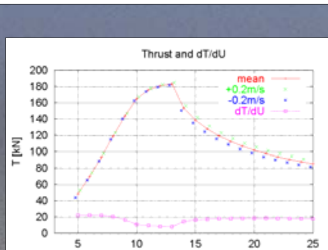

Figure 2. The relation between thrust and wind speed. Quasisteady values follows the red line. The instantaneous gradient is shown with purple and green/blue markers.

The solution

One solution is to decrease the pitch speed, or more precise to decrease the first natural frequency of the rotor-regulator system. This frequency must be lower than the lowest tower tilt frequency to ensure stability. The slower pitch motion however causes very poor performance related to fluctuations in power output and rotational speed.

A special new non-linear gain in the controller ensures the low natural frequency for small variations in rotor speed but increases pitch activity for larger variations. This is sufficient to ensure a fine performance of power and rotational speed combined with a stable tower motion.

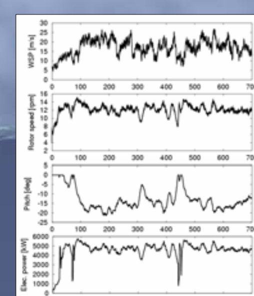

Figure 3a.

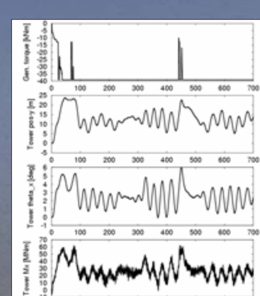

Figure 3b. Results for a floating turbine with a modified controller operating at 18m/s is shown in Figure 3a and 3b. The pitch motion is slow enough to ensure a stable tower motion and still ensures a fine performance of power and rotor speed variations.