Hydraulic Yaw System

Stubkier, Søren; Pedersen, Henrik C.; Mørkholt, M.

Publication date:
2012

Document Version
Accepted author manuscript, peer reviewed version

Citation for published version (APA):
1. Introduction
As wind turbines increase in size, combined with increased lifetime demands, new methods for load reduction needs to be examined. One method is to make the yaw system of the turbine soft flexible and hereby dampen the loads to the system, which is the focus of the current paper.

By utilizing the HAWC2 aeroelastic code and an extended model of the NREL 5MW turbine combined with a simplified linear model of the turbine, the parameters of the soft yaw system are optimized to reduce loadings in critical components.

Results shows that a significant reduction in fatigue and extreme loads to the yaw system and rotor shaft when utilizing the soft yaw drive concept compared to the original stiff yaw system.

The physical demands of the hydraulic yaw system are extreme loads to the yaw system and rotor shaft when components.

By utilizing the HAWC2 aeroelastic code and an extended model of the turbine, the parameters of the soft yaw system are optimized to reduce loadings in critical components.

2. Advantages of hydraulic yaw systems
The hydraulic yaw system will operate as a stock suspension system on a car, hence reducing the load away from the wind turbine structure and into the hydraulic system where it can be disposed as heat.

Implementation of the hydraulic yaw system leads to the following advantages:

- Reduced system and different operating modes
- No yaw gear degradation
- Save the cost of the yaw brake
- Well-defined extreme load on the yaw system, component sizes, gear contact.
- Guaranteed same load on all turbines
- Load reduction: Both ultimate and fatigue loads
- Damping by self centering of yaw shaft during operation
- No breakable rotating elements due to gear interaction
- No mechanical braking of the yaw system
- Detection of yaw error based on pressure
- Same pressure as for electrical yaw - hydraulic pitch is utilized.

3. Wind turbine model
The model parameters are based on the data of the NREL 5MW turbine. Model [12] (mass moment of inertia, damping and spring stiffness of the toy system.

The overall parameters and coordinate specifications may be found in table 1 and figure 1.

4. Optimization of Stiffness and Damping
As described the objective of the soft yaw system is to lower the ultimate and fatigue loads on the turbine by letting the wind system move in a controlled manner. The movement is controlled by the stiffness, K, and damping, B, of the system. To find the optimal solution for this, a graphical solution method is chosen. It is desired to minimize both extreme loads and fatigue loads, why the objective is to minimize

\[f(B, K) = M_{\text{extr}} + M_{\text{fat}}\]

where \(M_{\text{extr}}\) is the extreme load on the yaw system and \(M_{\text{fat}}\) is the equivalent fatigue load on the yaw system. \(M_{\text{fat}}\) is based on random counting and Palmgren/Miner partial damage hypothesis.

To find an optimal value of both \(K\) and \(B\) HAWC2 is utilized. All 2491 degrees of freedom, and the total model of the turbine is can be made cheaper with the same energy capture, or the turbine is simply increased in size in order to increase the energy capture, but based on the same structure. A realistic or absolute calculation of price reduction is dependent, not only on the specific turbine, but also on the site locations. Such calculation is not possible before a specific problem is available.

The idea behind the soft yaw system is to be able to optimize, the soft yaw system consisting of eight motor/gear units, which can handle 20 years of operation with the turbine is can be made cheaper with the same energy capture, or the turbine is simply increased in size in order to increase the energy capture, but based on the same structure. A realistic or absolute calculation of price reduction is dependent, not only on the specific turbine, but also on the site locations. Such calculation is not possible before a specific problem is available.

5. Results I
Figure 2 shows the maximum load on the system compared with the maximum angular movement. Notice that the loads decrease when angular movements are below 20 degrees and rise again when the loads angular movements are below 5 degrees. This indicates an optimal solution range.

6. Results II
Figure 3 shows the density of operating area is in the center of the figure. The load spectrum and amplitude is taken from the NREL 5MW turbine.

Figure 4 shows the density of operating area is in the center of the figure. The load spectrum and amplitude is taken from the NREL 5MW turbine.

Figure 5 shows how the cost increases with smaller movements.

7. Load reduction
The poster presented the advantages, turbine soft, optimization and results from the soft hydraulic concept. Further a full scale test rig is presented for further testing. It is concluded that the results from the loads extrapolated over 25 years shows huge reductions in fatigue and ultimate loads on the wind turbine. Especially the fatigue loads on the yaw system is reduced significantly.

On the hardware side duty cycles for a hydraulic yaw system consisting of eight motor/gear units is presented. This is done for a simple model including friction. Finding the right hardware, which can handle 20 years of operation with the presented duty cycles will lead to significant load reductions on the wind turbine structure.

This might increase the cost of the yaw system compared to an original stiff system, but the total cost of ownership for the wind turbine is expected to be reduced significantly.