Nacelle slippage of a multi MW wind turbine: Influence of different braking models for the yaw system

M-G Kim, J Sünkel, P H Dalhoff, P Gust

presenting author: Moo-Gyn Kim*
co-authors: Jörn Sünkel**, Peter Dalhoff*, Peter Gust***

Affiliations/Organisation:

* Hamburg University of Applied Sciences, Berliner Tor 5, 20099 Hamburg, GERMANY

** Nordex Energy GmbH, Langenhorner Chaussee 600, 22419 Hamburg, GERMANY

*** University of Wuppertal, Gauss Strasse 20, 42119 Wuppertal, GERMANY

1. Introduction

High wind speeds with yaw misalignment coupled with faults in the control system of the wind turbine can lead to high yawing loads on the yaw system. The yaw system's braking torque is generally designed to withstand these yaw loads and to hold the nacelle in a given position. Circumstances in which the aerodynamic yaw loads are higher than the yaw system's braking torque can occur due to the following reasons:

- abnormal load conditions occur which were not considered in the considered design load cases
- reduced brake efficiency due to mechanical failures, brake wear or environmental influences
- because of economic purposes the braking torque is designed lower than specified

In these cases, the nacelle will slip and turn around the tower axis. These situations can lead to damages on the yaw system and its components which – in most yaw system design - includes hydraulic regulated yaw brakes, yaw drives, mechanical brakes on the yaw drives and the yaw bearing. Nacelle slippage can be one of the issues responsible that the yaw system has such a high failure rate compared to other mechanical components of multi MW wind turbines [1; 2]. In extreme load conditions high nacelle rotation speeds due to slippage can also have an impact on the fore-aft bending moments in the blade root section or on the rotor torque due to gyroscopic forces.

Due to the high environmental influences on the braking capabilities, yaw brakes and the mechanical brakes on the yaw drives are sometimes specified with a braking capability of plus-minus 20%. As the braking capability is inconsistent during the service life time of the yaw system, high uncertainties on the general operation conditions of the wind turbine are present. These uncertainties should be considered during the design stage, as it can lead to different loads and dynamics during aforementioned nacelle slippage conditions.

Therefore, the work objective is to investigate the load behaviour on the yaw system and other wind turbine components during nacelle slippage situations by means of multi body system simulations of an existing 3.3 MW wind turbine. To consider the uncertainties in the braking capability, simulations with different braking torques and also with different braking models are made correspondingly.

2. Approach

The multi body system model of the yaw system is modelled in detail and incorporated into a multi body system model of a wind turbine based on an existing 3.3 MW wind turbine. The wind turbine is modelled and analysed with the aerodynamic load simulation tool Samcef Wind Turbines, whereas the detailed yaw system has been modelled in the multi body system-tool Samcef Field. To consider the stick-slick effects on the yaw brakes, the brake function is modelled with the coulomb model. Load simulations has been carried out with selected load cases defined in the IEC 61400-1 standard [3]. The loads and dynamics are briefly discussed and then compared to simulations with different braking models and different friction coefficients. For the discussion of the loads the blade root section, the rotor shaft torque and the tower top has been considered. Nacelle and yaw drive rotation speeds are compared and discussed.

3. Main body of abstract

The load case under consideration is power production plus occurrence of a fault, there the fault is a single stuck pitch drive during shut down procedure which leads to an aerodynamic imbalance and therefore to a peak on the yaw loads before the wind turbine can shut down completely. As expected the slippage of the nacelle limits the tower top torque to the designed braking torque of the yaw system. Whereas the fore-aft bending moment on the blade root section and the rotor torque experiences an increase in loads during nacelle slippage.
Comparing the different brake coefficient and thus the braking torque, the influence on the fore-aft bending moments and the rotor torsion as well are minimal. Whereas the rotation speeds of the yaw drives are up to 90 times higher during nacelle slippage if the braking torque is reduced by 25%. Analysing the simulations with different yaw brake models, there is not much of a difference on the loads and overall dynamics between the constant braking model and the stick slip braking model.

4. Conclusions

This paper presents the dynamics and loads in situations, where the rotor-nacelle system of a state of the art onshore wind turbine slips around the tower axis. The influence of nacelle slippage on the fore-aft bending moments on the blade root sections, rotor torque and on the tower top torque are briefly discussed. Different braking torques have been considered as well as the different braking models.
The influence of nacelle slippage on the loads of the rotor torque and the fore-aft bending moments in the blade root sections are not considered crucial for their own design. Then comparing different brake coefficients on the yaw brake the load difference on the other wind turbine components are minimal whereas the difference in the rotation speeds of the yaw drives are vast. Analysing the influence of the stick slip effect on the loads or the dynamics didn’t show any crucial differences compared to the brake models with constant braking torque.

5. Learning objectives

This work clarifies in some regards the uncertainty of the loads- and dynamics behavior on wind turbines during nacelle slippage situations. The influence of different braking capabilities of the yaw system during slippage of a state of the arte onshore wind turbine by means of multi body system simulations are shown. For design load cases, where the aerodynamic yaw loads are higher than the braking torque of the yaw system, additional design parameter considerations for the yaw system are stated.

References

[1] Wilkinson M and Hendriks B 2009 Reliawind Reliability focused research on optimizing Wind Energy systems design, operation and meintenance: tools, proof of concepts, guidelines & methodologies for a new generation Tech. rep.

[2] Spring M, Sepulveda, M, Davies P. and Gaal G. 2015. Top 30 Chart for wind turbine failure mechanisms EWEA 2015 Annual Event *Conference Proceedings*

[3] International Electronical Commission 2005 IEC 61400-1 Third edition Wind turbines - Part 1: Design requirements. *Standards*