Note on Engineering Details

No: DWM-JBF-extern-001, Rev. 2

Title: **Interpretation of Section 7.1.3 Drive train dynamics**

Ref.: GL Wind “Guideline for the Certification of Wind Turbines”, Edition 2003 with Supplement 2004, Section 7.1.3 and “Guideline for the Certification of Offshore Wind Turbines, Section 7.1.3”, Edition 2005

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Key Words: drive train dynamics, resonance, eigenmodes, modeshapes, natural frequencies

This revision has been issued to include the GL Wind Technical Note 068 “Requirements and recommendations for implementation and documentation of resonance analysis”, Revision 1, dated 24.09.2007.

Resonance analysis

1. Motivation

The transformation of global loads is state of the art technique for generating extreme loads and load spectra used within the design assessment of all machinery components. The simulation model which is used for global load assumptions simplifies the drive train and its components because the today used aero-elastic codes do not provide the possibility to model the drive train more detailed.

To make load assumptions for components load spectra in most instances a static drive train model is used for the transformation of global loads. This means that dynamic properties of drive train components are neglected. The static transformation method is only admissible if no system resonances are excited in the operation range of the wind turbine. Therefore a resonance analysis is essential.

2. Requirements of Guideline for the Certification of Wind Turbines, Edition 2003 with Supplement 2004 and Guideline for the Certification of Offshore Wind Turbines, Edition 2005

2.a) The requirements given in section 7.1.3 shall ensure that drive train parameters used within the global load assumptions match to the properties and design of the wind turbine’s machinery components. State of the art aero-elastic codes represent the drive train as a simplified mechanical model, e.g. two mass oscillator. It has to be documented that the global dynamic behaviour of a detailed drive train model and of the simplified drive train model are comparable. This is to provide security for global load assumptions used within the design assessment of e.g. rotor blades, tower and foundation. This has to be demonstrated for the B-Design Assessment. It is recommended to perform this investigation for the C-Design Assessment to guarantee a cost effective wind turbine

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development and certification process. Because state of the art aero-elastic codes consider torsional behaviour of drive train only a reduction to a pure rotational drive train model is permissible but not recommended.

2.b) Furthermore section 7.1.3 requires the consideration of the dynamic behaviour of drive train for determining design loads. If the design assessment of machinery components is based on load spectra that have been generated via static transformation of global loads a verification by means of a resonance analysis is necessary. Therefore a detailed drive train model shall be analysed that includes all major drive train components e.g. main shaft, torque arm support incl. elastic bushings, main bearings, gearbox shafts, bearings and toothings, high speed coupling, and generator. The resonance analysis should consider torsional and translational degrees of freedom. A limitation to a rotational model is not recommended. This resonance analysis is necessary for the B-Design Assessment.

Enclosed please find:

GL Wind Technical Note 068 "Requirements and recommendations for implementation and documentation of resonance analysis", Revision 1, dated 24.09.2007, 6 pages

Hamburg, 24.09.2007

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GL Wind Technical Note 068

Requirements and recommendations for implementation and documentation of resonance analysis

Revision: 1 **Date: 24.09.2007**

Germanischer Lloyd Industrial Services GmbH
Business Segment Wind Energy

Reference [1] „Guideline for the Certification of Wind Turbines", Edition 2003 with Supplement 2004, Germanischer Lloyd WindEnergie GmbH, Hamburg

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1 Inducement

In section 7.1.3 of the Guideline [1] it is stated that the dynamic behaviour of the drive train, i.e. rotating components and elastic linking of these components, shall be considered in a suitable manner for determining design loads of machinery components.

Furthermore the reduction of the complex drive train system and the determination of the drive train parameters used within the global load assumptions, i.e. in most simulation codes a single rotational stiffness and a single rotating mass, shall be presented for the assessment of the machinery components.

Therefore two actions are required.

1. The dynamic behaviour of the wind turbine needs to be analysed using a detailed simulation model of the drive train.

2. The model parameter representing the drive train in global simulation model need to be verified by the dynamic properties of the machinery components.

2 Scope of assessment

(1) For the assessment of the dynamic behaviour of a wind turbine the real design is simplified into a simulation model. State of the art techniques use multi body and finite element approaches to display the real machine. In both cases the result is a mechanical model of the wind turbine which might include non-linearities, e.g. force-elements representing gear meshes and bearings, as well. The dynamic behaviour of these models can be numerically analysed in frequency and time domain. The analysis in frequency domain requires a linearised model, which means that a certain state has to be chosen for determining Eigenfrequencies and Eigenmodes of the model. These information are required for performing a resonance analysis. The same model can be used for determining of loads by analysis in time domain, too.

(2) State of the art load assumptions for wind turbines already use a hybrid simulation model using multi body and finite element approaches. This model generates load assumptions for the design of wind turbines components. For parameterisation of this global model the dynamic properties of rotor blade, tower and drive train are required. The dynamic properties of rotor blade and tower are evaluated within the design assessment of these components. This Technical Note 068 shall clarify the certification requirements for the assessment of the dynamic properties of the drive train within the assessment of the machinery components.

(3) The dynamic behaviour of the drive train depends mainly on mass and stiffness properties of the major components within the drive train. Varying drive train configurations cause variations of these properties. Hence a new analysis becomes necessary if different types of the following components are installed in the same type of a wind turbine:

- Gear box
- Rotor blades
- Elastic gear box support
- Generator coupling

3 Model build-up

(1) To make the dynamic behaviour of the drive train accessible a single simulation model is required which includes all major drive train components.

(2) In the following major drive train components are listed which shall be considered at least:

Major drive train components	Minimum requirements for modelling structure of components	Minimum requirements for modelling degrees of freedom of components
Rotor blades	rigid body	edge wise and flap wise
Hub	rigid body	torsional
Main shaft	rigid body; elastic recommended	torsional
Low speed shaft coupling	rigid body	torsional
Gear box housing	rigid body	torsional
Planet carrier	rigid body	torsional
Gear box shafts	rigid bodies, elastic recommended	torsional; axial recommended
Gear box gears	rigid bodies	torsional; axial recommended
Elastic gear box support	rigid body	torsional
Brake disc	rigid body	torsional
Generator coupling	rigid body	torsional
Generator	rigid body	torsional
Elastic generator support	rigid body	torsional

(3) Each major drive train component shall have individual degrees of freedom.

(4) Stiffness properties of shafts, couplings and gear meshings have to be considered.

(5) The assessment shall include a description of the model build-up and the model parameters used.

4 Dynamic properties of drive train

(1) To verify the drive train model parameters used within global load assumptions the detailed drive train model shall be analysed. In most cases these parameters are "resulting drive train stiffness" and "moment of inertia of generator rotor".

(2) For the assessment of the resulting drive train stiffness between hub and generator an analysis of the static equilibrium of the system can be performed by applying a static torque on the hub and fixation of generator.

(3) Depending on the model build-up and simulation possibilities other assessment techniques are permitted.

5 Resonance behaviour of drive train

(1) To exclude operation of the wind turbine in resonance conditions the resonance frequencies and the exciting frequencies are of interest.

(2) For the assessment of resonance frequencies a modal analysis is required.

(3) For the evaluation of potential resonances a simulation in time domain is recommended.

(4) The evaluation of drive train resonances shall be done by means of Campbell-diagrams, natural modes and energy distributions.

(5) Excitation frequencies which shall be taken into account are rotor speed, speeds of gearbox shafts and mesh frequencies. Depending on the drive train design additional exciting frequencies may occur.

(6) The relevant speed range for resonance analysis is given by the possible operation states during power production. Drive train resonance behaviour should be analysed between minimum operation speed n_1 and maximum operation speed n_3 (cf. Section 2.2.2.5 in [1]).

(7) Other analysis methods shall be defined in consultation with GL Wind.

6 Requirements for documentation

(1) The documentation shall give a reference to the wind turbine configuration analysed, i.e. wind turbine type and grid frequency.

(2) A listing of type information of all major components and relevant drawing numbers is required.

(3) The relevant frequencies should be named according to the following table.

Frequency identification	**Symbol**	**Orders that should be analysed**
Normal Frequencies	f_N1, f_N2, f_N3, ...	-
Exciting Frequencies (shafts)	f_E1, f_E2, f_E3, ...	Rotor shaft: 1P, 2P, 3P, 6P Gearbox shafts: 1P, 2P
Exciting Frequencies (gear meshes)	f_ZLSS_0, f_ZLSS_1, ..., f_ZIMS_0, f_ZIMS_1, ..., f_ZHSS_0, f_ZHSS_1, ...	Fundamental frequency, 1st and 2nd harmonic

(4) The results of modal analysis shall be documented in Campel-diagrams. The scaling of the axes need to be adapted to the relevant frequency ranges.

(5) The assumptions for parameterisation of drive train model for global load assumptions have to be compared to the results obtained by means of the detailed model.

7 Literature

[1] „Guideline for the Certification of Wind Turbines“, Edition 2003 with Supplement 2004, Germanischer Lloyd, Hamburg

[2] „Guideline for the Certification of Offshore Wind Turbines“, Edition 2005, Germanischer Lloyd, Hamburg

[3] Weidemann, H.-J., „Schwingungsanalyse in der Antriebstechnik“, Springer Verlag, Berlin 2003

[4] Dresig, H., „Schwingungen mechanischer Antriebssysteme“, Springer Verlag, Berlin 2001

[5] Laschet, A., „Simulation von Antriebssystemen“, Springer Verlag, Berlin 1988

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