Project title	Analysis Methodology for Fatigue of Wind Turbine
Project number	TG4-23
Organisation	RISE
Project leader	Anders Wickström, RISE
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Participating companies	SeaTwirl AB

Project description

The main aim of the project is to develop knowledge and deeper understanding of the dynamics and fatigue loads of a vertical axis wind turbine and its interaction with the support structure. Especial the cyclic loads and the potential coupling to the structural dynamic response will be analysed and evaluated. Ultimately the project shall present a design methodology for fatigue assessment of vertical axis wind turbine, with focus on the turbine and its composite material and structure.

A high resolution model will be created by use of a generic method. The Vortex Theory is selected, which is based on the incompressible, inviscid and irrotational flow. It can be used to predict the aerodynamic performance of wind turbines. The advantage of vortex flow is to reduce the flow complexity, and it has been widely used for aerodynamic analysis of airfoils and aircrafts.

Another work package will investigate the cyclic loads acting on the VAWT. A rapid generic simulation model will be proposed, accounting for impact of the cyclic blade loads, centrifugal forces and gravity. The result will be a design methodology for fatigue assessment of vertical axis wind turbines.

The cyclic fatigue loading might be significantly amplified caused by the structural dynamic situation. To evaluate the structural dynamics, the resonance frequencies of the whole floating HAWT will be calculated by FE methods.

The turbine will to a large extent be built of composite materials. Carbon fibre and glass fibre will be used in some combinations. Steel structures will also be used, and special high strength steel will be evaluated if applicable. For all materials, general design criteria need to be evaluated with focus on fatigue properties and strength, also in line with applicable standards

The rigid-body motion of the S2 floating offshore wind turbine due to the wave conditions will be analysed the check for potential resonance with actual wave frequency spectra.

Results

The project has developed knowledge and deeper understanding of the dynamics and fatigue loads of a vertical axis wind turbine and its interaction with the support structure.

The turbine has been modelled in a free wake vortex based code, CACTUS. The results have been compared to CFD high resolution simulations. Although the vortex method predicts higher power (around 16%) and aerodynamic loads compared to CFD, it only requires 0.75 CPU core-hour compared to 28800 CPU core-hour used by CFD. By this method, wind speeds in the operational range have been simulated.

It has been concluded that the blade loads over the azimuth angle are cyclic and can be characterized and represented by Fourier series of order 8 for each selected wind speed, 4, 5, … 25 m/s.

Based on this matrix of wind speeds and Fourier series parameters for the respective load components, a rapid generic simulation model has been created, summarizing the blade loads in a turbulent wind field, blade element by blade element. The impact of centrifugal forces, gravity and rotating bending caused by arbitrary platform inclination are accounted for. The result is a design methodology for fatigue assessment of vertical axis wind turbines. The Fourier series methodology is applicable and relevant for any rotating machinery or turbine.

The methodology has been executed and tested at two spots on the turbine, the strut base and tower base. From the initial structural properties, the fatigue life and integrity has been checked according to wind turbine class 2B and 20 years life.

A finite element model of a vertical-axis wind turbine has created and used to determine the structural eigenfrequencies. The FE-model physical properties are in close resemblance to the “S2” turbine.

A conclusion from the eigenmode analyses is that there is a premium on keeping weights down. Low weight can translate into lower stiffness requirements of the tower. As the tower is made from steel, the weight penalty on increasing tower stiffness is relatively high. High tower weight also results in a larger displacement floating structure. As the entire under-water body is rotating in the SeaTwirl concept, a larger under-water body not only becomes more expensive, it also results in larger frictional losses from viscous water friction.

Part of the project and results is a literature survey and interviewing a blade designer. The result is 13 relevant references. These scientific papers are general with respect to horizontal/vertical axis wind turbines with respect to the material. However, there are differences in the structural response, which is addressed in some papers.

The rigid-body motion of the S2 device due to environmental loads (wind, current and waves) was modelled with a linear radiation/diffraction model including mooring dynamics. The model can be used to estimate fatigue loads due to wave induced acceleration. The device has a resonance peak at 19 s in heave, but the S2 device is starting to see significant response after 16 s. The mooring coupling causes the pitch response to increase after 16 s with a peak around 20 s.

In all, the project has been successful and exceeding expectations in terms of provided results, software, mooring dynamics, references, strength results and general knowledge.

Fulfilment of SWPTC’s goals

In a tangible way the project has addressed the common goal of the SWTPC to build system knowledge to enable development and production of complete wind turbines in Sweden with specific and concrete support for Swedish industry. Results are also applicable to other machineries and wind turbine components.

Deviations from project plan

No deviations from project plan reported.

Publications

No publications but a final report of the entire project and its results is created:
TG4-23-1 Report out, Analysis Methodology for Fatigue of Wind Turbine, Seatwirl

External activities

No external activities.