

ENERGY

Calibration of a numerical model with experimental data and evaluation of a simplified aerodynamic model for the Pelastar TLP

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- Background
- DNV GL certification of floating wind turbines
- Numerical modelling of the Pelastar TLP model tests
- Simulation results
- Conclusions

Background

- DNV GL performs independent analysis as a part of the Project Certification process for offshore wind farms.
- Design of floating wind turbines require analysis of coupled response to wind and wave action.
- Two types of software is used in the industry/research:
 - Onshore WT software
 - Offshore O&G software
- Simplified modelling is sometimes necessary



Certification of the Pelastar demonstration project

Application of DNV-OS-J103: Pelastar TLP demonstration project

- Floating wind turbine demonstration project in UK
- Funded by Energy Technology Institute (ETI)
- Glosten Associates' Pelastar TLP design
- Supporting Alstom's 6 MW Haliade turbine
- DNV GL performs certification of the design against DNV-OS-J103
- The project is currently in Front End Engineering Design (FEED) phase



DNV GL code comparison

- SIMA (SIMO/RIFLEX) HAWC2 BLADED ORCAFLEX
- Collaboration:
 - DNV GL in Copenhagen Hamburg Høvik
 - Glosten Associates
- To be presented at OMAE 2015 in St. Johns, Canada



Numerical modelling of model test

Model tests: MARIN ocean basin

- 1:50 scale model tests
- MARIN stock wind-turbine:
 - Froude scaled wind to represent the mean thrust, RPM and TSR of the full scale NREL 5 MW turbine
 - Torque matched only in idling conditions
 - Fixed blade pitch to obtain correct thrust (not same as NREL controller)



SIMO/RIFLEX: Substructure model



- Undisturbed wave kinematics
- Morison coefficients based on DNV-RP-C205
- Minor adjustments to match natural periods

SIMO/RIFLEX: Simplified vs. full rotor







Calibration of drag coefficient for simplified rotor



Results:

- Model tests
- Full rotor
- Simplified rotor

Simulation results: Parked turbine

- Wsp = 25.6 m/s
- Hs = 6.6 m
- Tp = 13.5 s

- Simplified and full rotor model give similar results
- Both models compare well to model tests
- Differences in excitation of pitchbend frequency



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Simulation results: Parked turbine

- Wsp = 29.7 m/s
- Hs = 8.2 m
- Tp = 14.4 s

- Simplified and full rotor model give similar results
- Both models compare well to model tests
- Differences in excitation of pitchbend frequency



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Simulation results: Turbine in operation

- Wsp = 22.3 m/s
- Hs = 4.5 m
- Tp = 11.8 s

- Surge motion: Full rotor compares better to model tests
- Simplified model overestimates forward surge motion



Simulation results: Turbine in operation

Model test Full rotor Simplified Wsp = 9.2 m/s 6 <u>1e8</u> 40000 Tower base kNm 20000 $S(\omega)$ (kN2m2/s/rad) • Hs = 1.7 m 5 4 -20000 ■ Tp = 8.7 s -40000 3 -60000 2 -80000 . ₩ 1 -100000-1200000.0 2400 2420 2440 2460 2480 2500 0.5 1.0 1.5 2.0 10000 800000 Uncertain wind 700000 Line1 - Tension kN 9000 $S(\omega)$ (kN2/s/rad) input 600000 8000 500000 Simplified model 7000 400000 300000 6000 overestimates 200000 5000 100000 forward surge 4000 2420 2440 2460 0.0 0.5 2480 2500 1.0 1.5 2.0 motion 1.0 1.6 1.4 0.5 $S(\omega)(m^2 *s/rad)$ 1.2 0.0 Surge (m) 1.0 -0.50.8 0.6 -1.50.4 -2.0 0.2 -2.5 L 2300 0.0 2350 2400 2450 2500 0.0 0.5 1.0 1.5 2.0 Time (s) ω (rad/s)

Simulation results: Standard deviations

- SURGE: Full rotor model closer to model tests in all cases
- Small differences between simplified model and full rotor in parked cases



Conclusions

- The analysis models captured significant responses seen in model tests
- Wave response captured with minor adjustments to analytical Morison coefficients
- Full rotor model gave the best reproduction of the surge motion in model tests
- Simplified modelling gave good representation for parked/survival cases
- Further testing with turbine in operation will give deeper insight

Thank you!

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SAFER, SMARTER, GREENER

DNV GL Standards for floating wind turbines

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- DNV-OS-J103 Design of Floating Wind Turbine Structures was published in 2013
- Can be downloaded for free on <u>www.dnvgl.com</u>
- Developed through a Joint Industry Project (JIP) during 2011 – 2013
- GL-IV-2 Guideline for the Certification of Offshore Wind Turbines with extension for floating wind turbines published in 2012
- The two standards are to be merged in 2016