Reducing Tower Fatigue through Blade Back Twist for a Pitch-to-Stall FOWT

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Introduction

For a turbine mounted on a floating platform, induced turbine loads can be increased by up to 1.6 times those experience by a turbine situated on a fixed base. If these loads cannot be reduced, towers will need to be strengthened which will result in increased costs and weight for both the turbine and platform. Prominent load increases are often seen in the induced tower base fore-aft bending moments. Preventing additional loads from negative damping from occurring on a pitch-to-feather controlled floating offshore wind turbine (FOWT) results in the performance in terms of rotor speed control and regulated power being negatively affected.

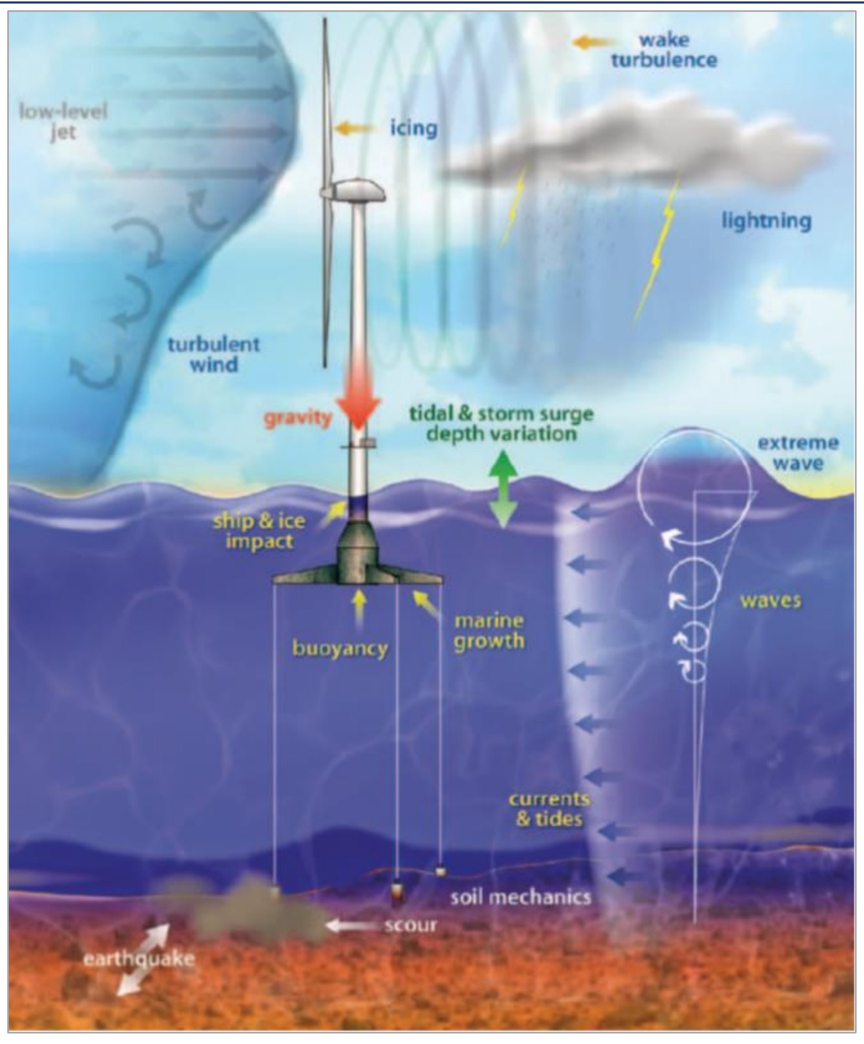

Figure 1. Loads acting on a FOWT*

Aims and objectives

The aim of this project is to specify an ideal set of design criteria for the blade twist profile of a variable-speed variable pitch-to-stall (VSVP-S) FOWT to increase the tower axial fatigue life (TAFL).

Main objectives:

- Select suitable FOWT sizes and types.
- Evaluate and select state-of-the-art methodologies for the assessment and analysis of fatigue loads propagation.
- Define the conditions for the aerodynamic and hydrodynamic models.
- Develop and validate the aerodynamic, hydrodynamic, structural and control models for the analysis of the FOWT.
- Identify, define and create blade models to reduce tower fore-aft responses and perform simulations to derive the dynamic responses.
- Analyse and present the findings in terms of the effects of back twist angle, initiation point and constant pitch angle below rated.

Results and discussion

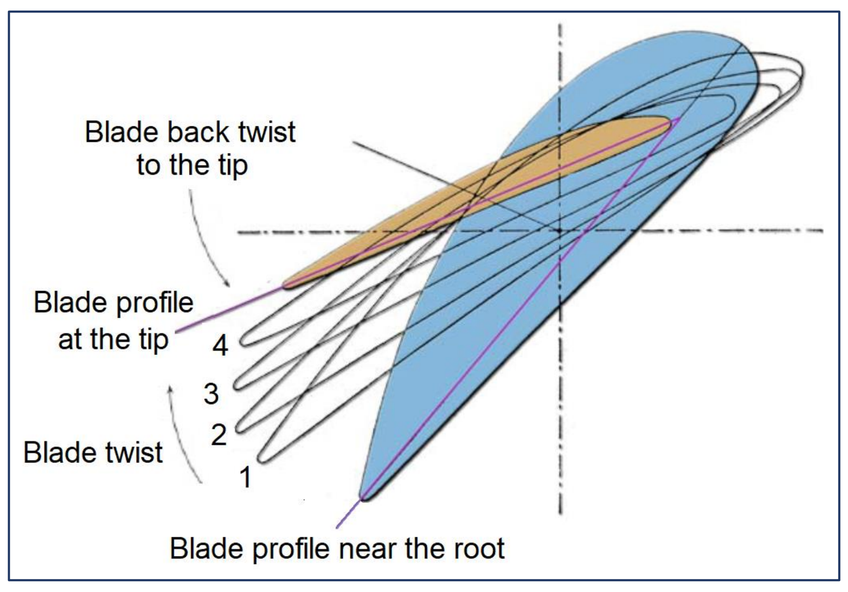

Figure 2. Blade back twist

- Analysis of trends and effects of back twist (BT) angle and initiation point (IP) as measured from the blade root.
- Four BT angles: 3° 6°, 9° and 12° at the tip each at three BT IPs: 75%, 87.5% and 92.75% from the blade root (Fig 3).
- Responses at mean turbulent wind speeds of 8, 13 and 18mps, normalized against a conventional Feather Base Model (FBM) (Fig 4).
- At 8mps the TAFL increased as the BT IP became closer to the tip for all BT angles but the maximum was 6% lower than the FBM, occurring at a BT angle of 12° and IP of 92.8%, power output was also reduced.
- At 13mps an increase of 20% in TAFL was seen for most of the BT profiles with IPs greater than 75%, compared to the FBM.
- At 18mps winds TAFL increased as the BT increased but decreased as the IP approached the tip.
- Reductions in the rotor thrust (RT), platform pitch (PP), blade out of plane deflection (OoPD) & flapwise bending moment (BFBM) ranges, caused increases in the TAFL at 8 & 13mps.
- At 18mps no correlation in PP range and TAFL was apparent.

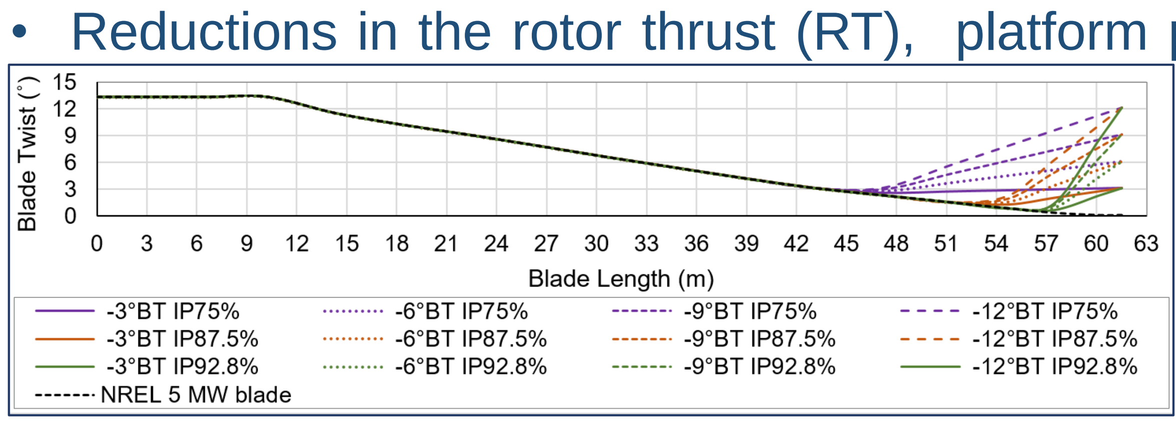

Figure 3. Blade back twist profiles

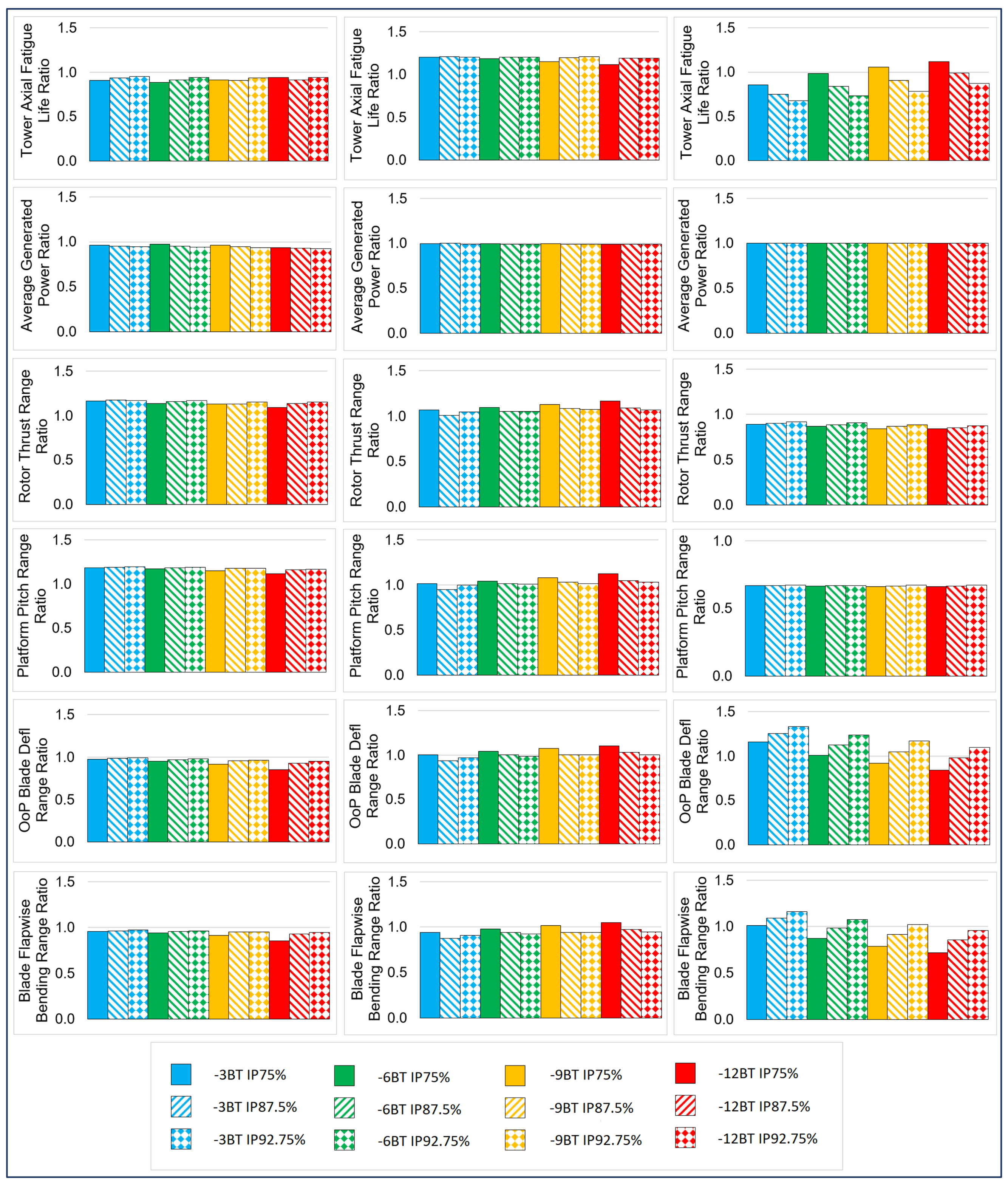

Figure 4. Response ratios normalized to the 'Feather Base Model' at 8 (left), 13 (centre) and 18mps (right) mean turbulent winds.

Conclusions

- TAFL increased for all blade profiles, when operating in 13mps winds, correlating with a decrease in the range of motion for RT, PP, OoPBD and BFBM.
- 18mps no correlation between the PP response and TAFL was apparent, however, a strong correlation seen with OoPBD and BFBM ranges.
- Reducing the OoPBD and BFBM can result in a reduction in the tower fore-aft moment response, which can increase the tower axial fatigue life.
- Achieved by applied changes to the curved blade geometry in terms of a blade BT.
- For the VSVP-S control the negative damping phenomenon was avoided by design.

Future work

Research on a fully developed BT stall blade design would be recommended, to enable an in-depth analysis of all the blade loads as well as the loads on the nacelle and drive train. This would then enable a full assessment of the overall pros and cons of a BT blade for a FOWT with VSVP-S control to be carried out. Benefits of a BT blade and VSVP-S control system on other FOWT types would also be valuable.

* Source: Wind Power Today 2010

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