Energiteknologisk udvikling og demonstration

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Deliverable 3.1: Report on framework

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Preface

This report serves as Deliverable 3.1: "Report on framework" to the EUDP project GASP (Global Atlas for Siting Parameters). The deliverable corresponds to Task 3.2: "To set up the framework to efficiently quantify fatigue loads from normal IEC siting parameters". This report is prepared by EMD International A/S in accordance with the project plan and time-schedule for GASP.

1. Introduction

A fast and efficient framework to quantify fatigue loads is critical to ensure the progress of GASP work package three (WP3). This report briefly describes the established framework which is built around the successful "load response" technology developed at EMD International A/S.

2. The framework

The objective of WP3 is: "to translate the siting parameters from work package two (WP2) to IEC standards and provide the atlas of recommended turbine class for the globe". This clearly defines the input wind climate parameters to this framework in accordance with the IEC 61400-1 standard [1]: Mean wind direction (θ), mean wind speed (U), turbulence (σ), wind shear power law exponent (α), air density (ρ), and flow inclination (φ). These wind climate parameters are estimated across the entire globe in WP2 and converted to characteristic values (IEC standard values) in Task 3.1 (led by DTU). The characteristic values are:

- Directional frequency in bins of 30 degree or less, $P_\theta(\theta)$
- Wind speed distribution per direction, $f_U(U|\theta)$
- Characteristic 90% quantile of turbulence given wind speed and direction, $\sigma_{c,90}(U|\theta)$
- Characteristic mean value of wind shear given direction, $\alpha_c(\theta)$
- Characteristic average value of air density[1], ρ_c
- Characteristic flow inclination, φ_c

Site-specific fatigue loads are calculated based on the characteristic wind climates using the response surface technology developed at EMD International A/S. The technology is based on an accurate multiple linear regression surrogate model calibrated by using a central composite experimental design. The theoretical background to the technology is covered extensively in [2], which also quantifies and validates its accuracy for the current purpose of estimating fatigue loads across a wide range of characteristic wind climates. A vital part of WP3 has been to implement the methodology on EMD's high performance computer in order to allow global coverage of fatigue load assessments within the timeframe of the GASP project.

3. Turbine class recommendations

To provide accurate turbine class recommendations it is essential that representative turbine models are considered. Load response models are prepared for three generic turbine models: The 1.5MW WindPACT turbine [3], the 5MW reference wind turbine by NREL [4] and the 10MW

[1] Taken as the average value for wind speeds above rated.

reference wind turbine by DTU [5]. Each model is simulated in the aero-servo-elastic code FAST [6]. Subsequently, the fatigue loads are estimated on the representative set of load bearing components outlined in Table 1. The fatigue strength of each component is modelled by typical Wöhler exponents (m) used for welded steel details ($m = 4$), cast steel details ($m = 6$) and blade composite materials ($m = 10$). Collectively, the chosen components reflect the overall path of the wind loads from acting on the blades until being reacted by the foundation, and they represent varying sensitivities towards the dominant input wind climate parameters. This is illustrated by Figure 1 for the 5MW turbine by NREL.

Table 1: Wind turbine components

Component	Description	Notation	Type	Wöhler exponent
Blades	Blade root flap-wise bending	RootMyb1	DEL	10
Drivetrain	Low speed shaft torque	LSSGagMxa	LDD	6
Nacelle	Yaw bearing tilt	YawBrMyp	DEL	4
Tower	Tower bottom fore-aft bending	TwrBsMyt	DEL	4

Type refers to either "damage equivalent load (DEL)" or "load duration distribution (LDD)".

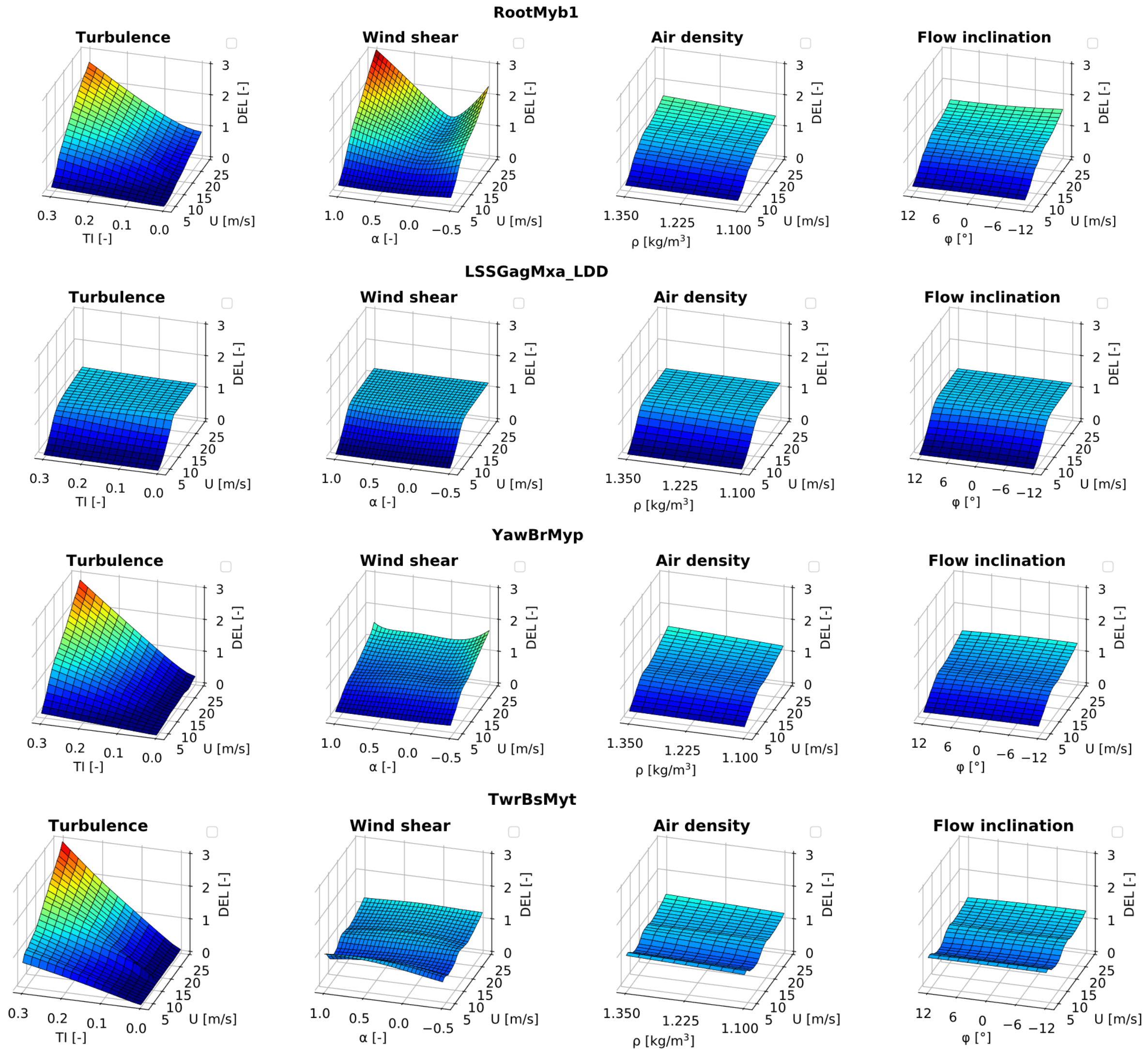

Figure 1: Fatigue load sensitivity of the 5MW turbine by NREL. The response to turbulence is given in terms of turbulence intensity (TI) to account for the increasing scale of the absolute turbulence with increasing wind speed.

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