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Poster n°

Added turbulence empirical model for a single tidal turbine

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• Introduction

Tidal turbines are deployed in cluster arrangement for commercial electricity production as shown in Figure 1. The energy extraction by tidal turbines in a highly turbulent stream condition attenuates the KE and induces fatigue loading on the downstream turbine in form of a wake (Fig. 2). The turbulent intensity in turbine wake is the contribution of turbine generated and ambient turbulent flow. Accurate estimation of turbulent intensity is essential to optimize turbine placement and energy production in tidal parks. This single turbine study provides a basis for a generic model for turbine interaction in a park.

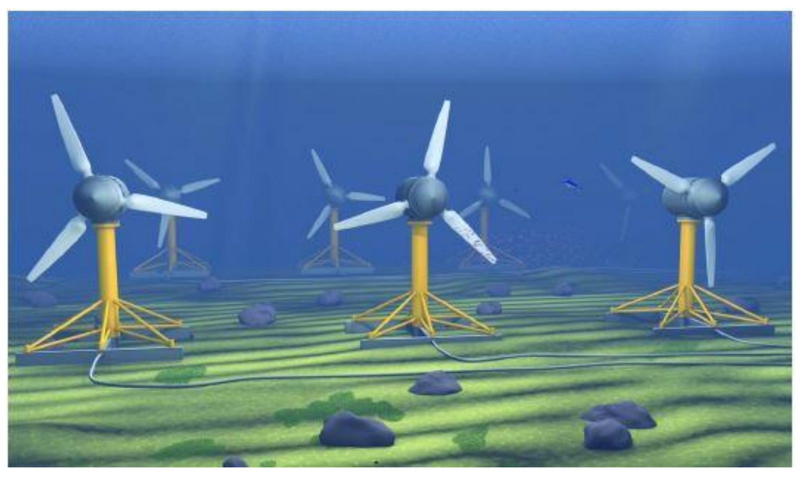

Figure 1: TST array layout © Bereau Veritas

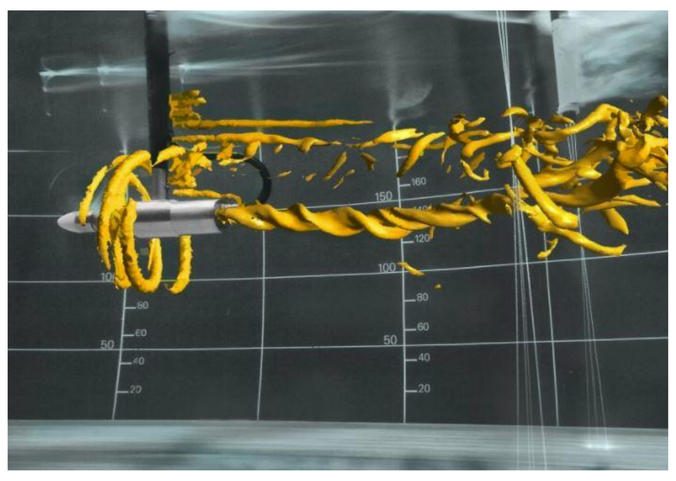

Figure 2: Turbulence in TST © CMERG

• Method

The turbine is represented as a porous disc using the Actuator disc method (ADM). ADM applies a uniform thrust force to the disc region that creates a momentum exchange similar to a real turbine. A 20m diameter rotor is studied in an ideal channel replicating the Alderney Race stream conditions. A turbulence source term is added to the standard k-ε turbulence model to augment turbulent production. The full-Width Half Maximum(FWHM) method is used to estimate the wake radius at 3σ (Fig. 4). The empirical model is developed from curve fitting to estimate (1) the turbulent wake radius and (2) added turbulent intensity.

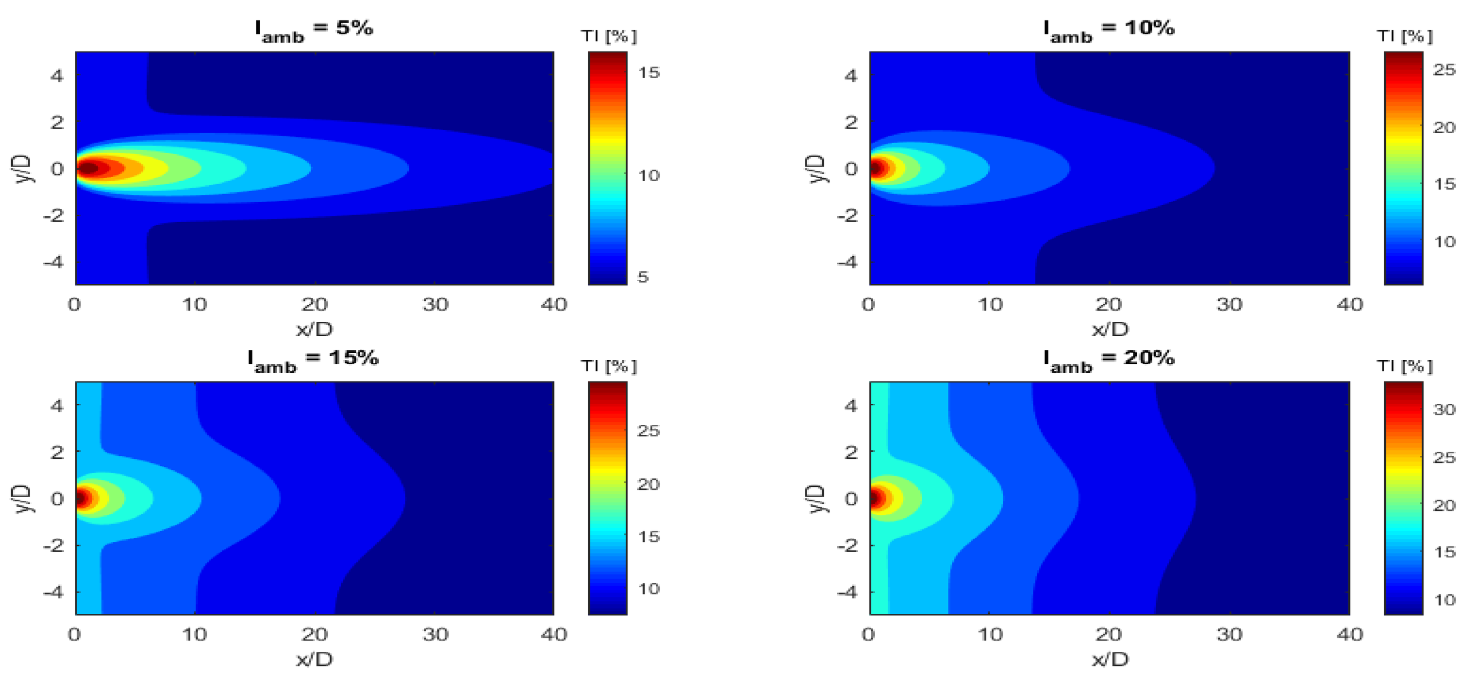

Figure 3: Turbulent intensity contour at different ambient condition showing the effect of added turbulence by the rotor in near wake

• Results

Figure 3 shows the maximum turbulence in the initial near wake account for the contribution of the rotor and mean shear. The Gaussian profile wake expands further and diminish faster at high ambient turbulence due to strong mixing process. Wake turbulence is expressed as:

$$I = \sqrt{I_a^2 + I_+^2}$$

▪ Turbulent wake radius model

The initial wake of rotor size gradually expands downstream according to a power law (Fig. 5). The wake expansion depends on the ambient turbulence intensity (TI) and location downstream. TI increases the wake width but decreases the wake length.

$$r_w = r/r_0 = 7.41 I_a^{0.3} \left(\frac{x}{D}\right)^{0.384}$$

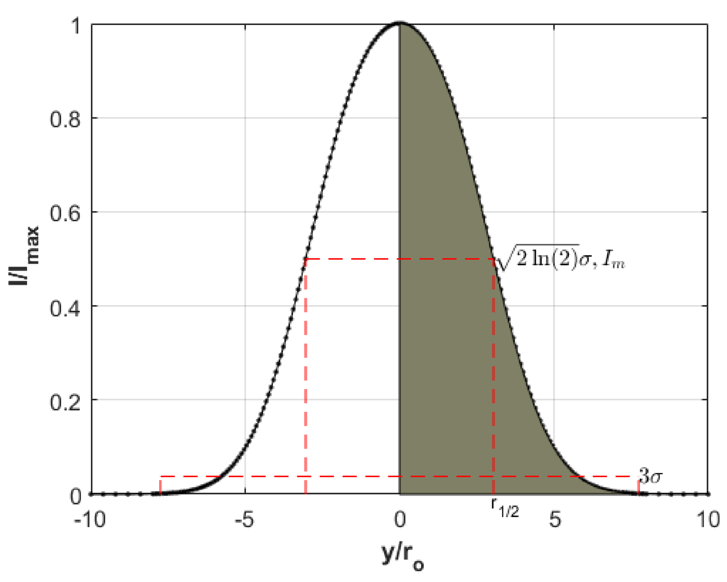

Figure 4: Turbulent wake radius estimation at 3σ

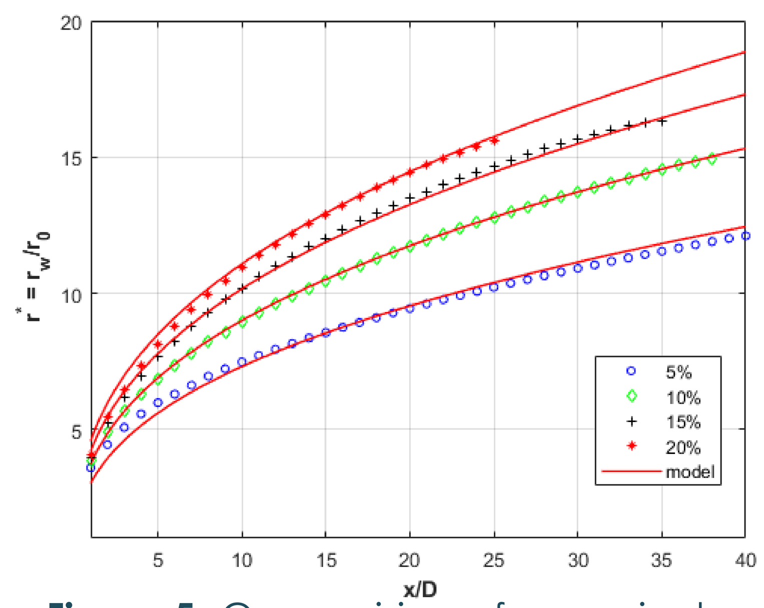

Figure 5: Comparision of numerical and empirical turbulent wake radius

▪ Added turbulence model

The near wake region is dominated by the mean shear and turbine generated turbulence. Figure 6 justifies that the major turbulence source in the near wake is attributed to the rotor. The added turbulence is largely influenced by the turbine characteristics rather than the ambient turbulence. The model is expressed as:

$$I_+ = a(x/D)^{-b} \qquad a = 0.16C_T^{4.83} + 0.179, \quad b = 0.68I_a + 0.472$$

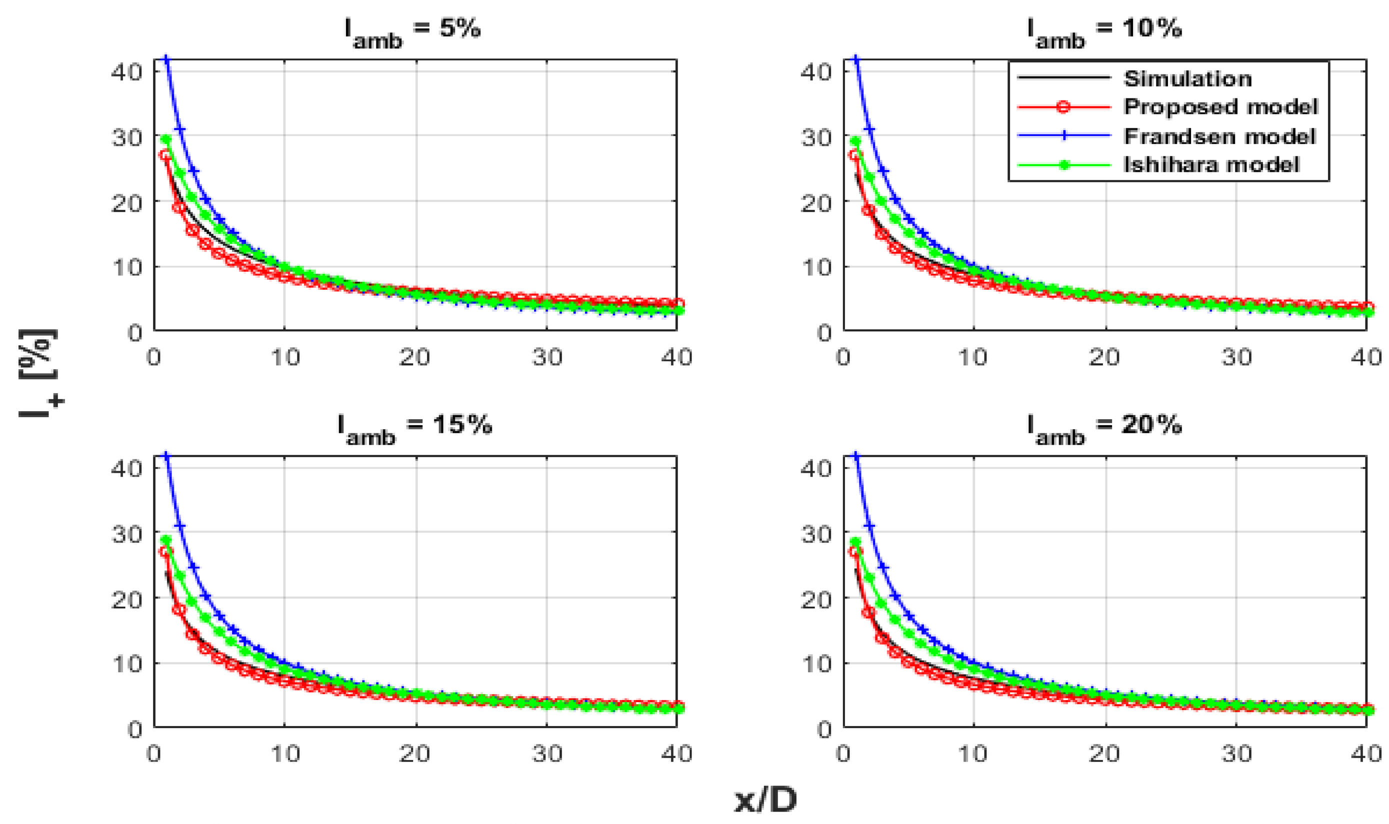

Figure 6: Comparision of Centerline added turbulence intensity with existing models for wind turbine.

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