

Optimizing Offshore Wind Farms with WindSim: Wake Effects, Blockage Effects, and the Actuator Disc Model

Introduction

Offshore wind farms play a vital role in global renewable energy targets due to their strong wind resources and limited land-use impact. However, accurate prediction of their performance depends on modelling aerodynamic interactions—especially **wake** and **blockage effects**—which can significantly impact Annual Energy Production (AEP).

WindSim supports both **fast analytical wake models** and advanced **Actuator Disc (AD) modelling**—giving developers flexibility for simple assessments and precise analysis in complex offshore environments.

Wake Effects: A Key Offshore Concern

Offshore turbines, arranged in large arrays over smooth sea surfaces, experience amplified **wake effects**—reduced wind speed and increased turbulence behind turbines. These wakes can lead to **15 to 20% energy loss**, especially in tightly spaced configurations.

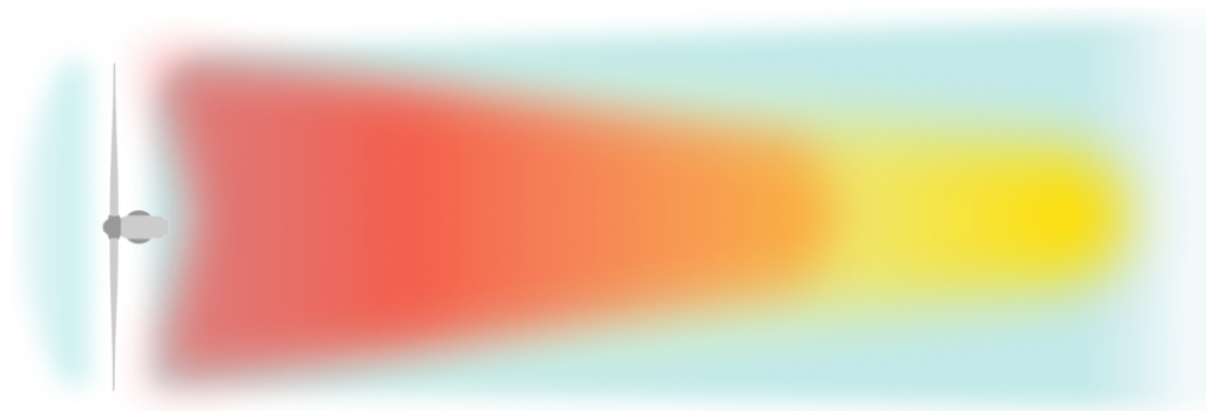


Figure 1 Wake Effects on a Wind Turbine

WindSim's Wake Modelling Toolkit

- **Jensen Model** – A simple linear expansion model.
- **Larsen Model** – Accounts for turbulence in the boundary layer.
- **Ishihara Model** – Includes rotor and atmospheric turbulence impacts.

While fast and useful for preliminary design, these models are limited in accuracy for complex or large-scale offshore projects. This is where CFD and AD modelling become essential.

Blockage Effects: The Often-Ignored Loss

Blockage effects occur **upstream**, as wind slows and diverts around densely packed turbines, affecting all structural elements, and especially the first row. And wake effects from the first row will add to the blockage effect for the second row. This can distort wind speed measurements and result in **overestimated AEP** if not modelled properly.

WindSim addresses this by simulating turbines as aerodynamic obstacles within its CFD environment, capturing both **wake and blockage losses** in a unified system.

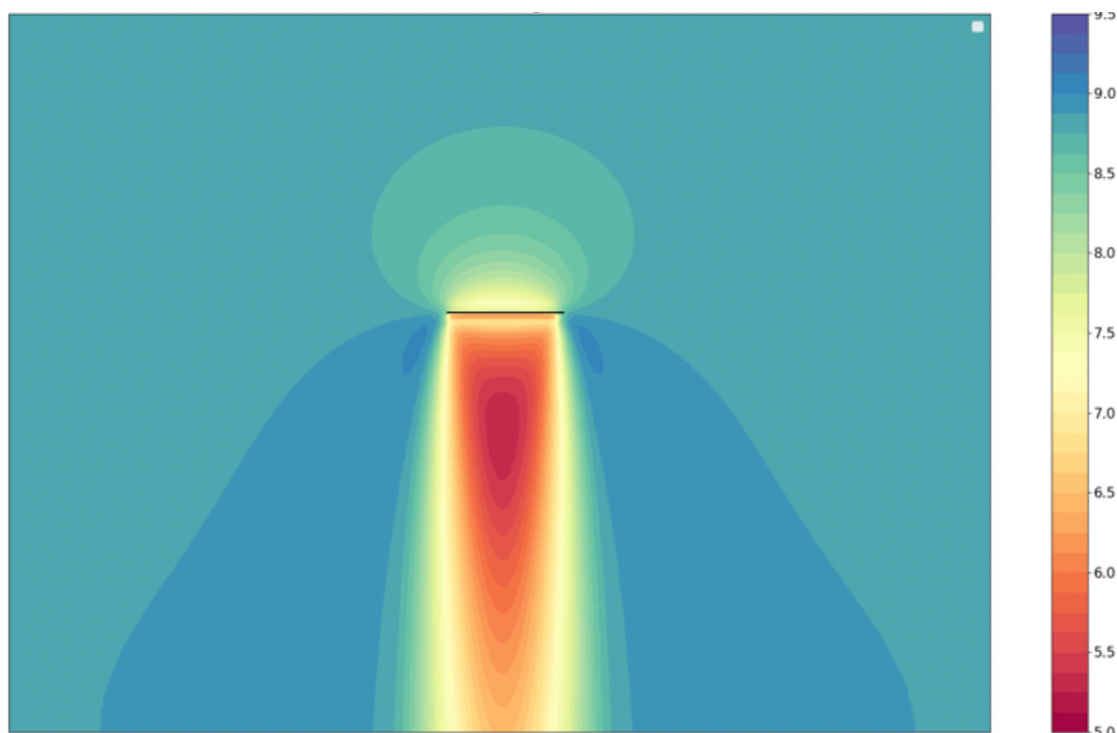


Figure 2 Blockage effects, modelled by WindSim CFD, on a Wind Turbine

The Actuator Disc Advantage

WindSim's **Actuator Disc (AD) model** offers a high-fidelity representation of turbine-induced flow changes:

- **"Old" AD Model** – Applies uniform force based on free-stream wind speed.
- **"New" AD Model** – Uses cell-level computations with local wind speed and induction factors, more closely mirroring real turbine behaviours.

Integrated into WindSim's Terrain and WindFields modules, the AD model generates wind speed deficit maps under various wind conditions, providing a foundation for accurate performance prediction.

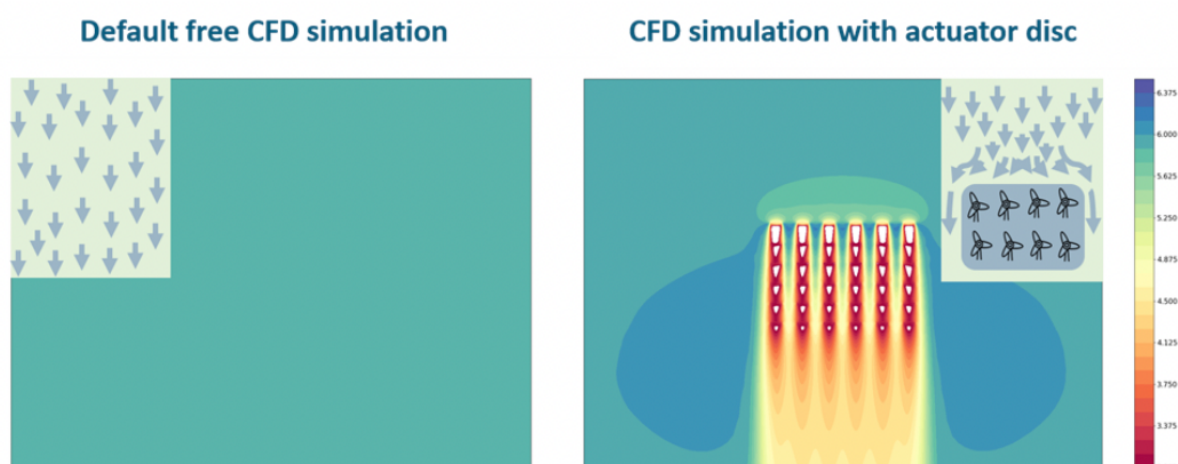


Figure 3 Illustrating WindSim's approach for generating wind speed deficit maps using AD

CFD Workflow for AEP Estimation

WindSim's AEP estimation uses four simulations:

1. Default (no turbines) at high and low wind speeds
2. AD-enabled at high and low wind speeds

These simulations create:

- **Deficit maps** across wind speeds and directions
- **Speed reduction tables** for refined AEP calculations
- **Comparative insights:** Wake-only vs. blockage-included vs. full CFD

In validation studies like Simisiroglou's Lillgrund case (see below), WindSim's **new AD model** closely matched SCADA data and outperformed simpler wake models.

Why It Matters for Offshore Developers

WindSim delivers major advantages for offshore projects:

- **Improved AEP accuracy** by accounting for wake and blockage
- **Validation with real-world data** (SCADA, met masts)
- **Layout optimization** to reduce losses and increase turbine lifetime.
- **Greater financial confidence** through more realistic modelling

As offshore projects grow in scale and complexity—with larger turbines, closer spacing, and high investment—**ignoring blockage or relying solely on wake models can be costly.**

Conclusion

Wake and blockage effects are critical to offshore wind performance. WindSim's integration of Actuator Disc modelling, CFD simulation, and hybrid modelling approaches gives developers a powerful toolkit to maximize energy output and project value. For modern offshore wind development, WindSim puts it all together — offering one of the most advanced and reliable simulation solutions available today.

Ready to learn more?

- 🔗 Curious about the Lillgrund validation study? Find it [here](#).
- 🔗 Curious about wake models? A good comparison can be found [here](#),
- ✉ Contact us at sales@windsim.com or consulting@windsim.com.