Tow-to-port (TTP) operations for offshore floating wind farms: theoretical modelling informed by real-world insights

Paul Watissée, Jade Gregor, Christian Langholz Carstensen, Thibault Vanheeghe, Ilmas Bayati

pwa@peak-wind.com

Motivation

Can duration of TTP operations be accurately estimated?

TTP is the **current proven solution** to perform major component replacement (MCR) on offshore floating turbines. Over a TTP operation, the turbine is first disconnected from its moorings and electrical cables before being towed to a port, where the **MCR is performed at quayside** by an onshore crane.

TTP operations are:

- **Complex** → over 6 marine vessels involved besides the onshore crane
- **Lengthy** → usually take at least 30 days
- **Risky** → mooring lines (ML) and cables disconnected from the foundation
- **Expensive** → 10-15%* of the total lifetime OPEX (8-10%* for bottom-fixed)

As floating wind matures and gets competitive, estimating TTP operations duration helps **mitigating risks and uncertainties**…

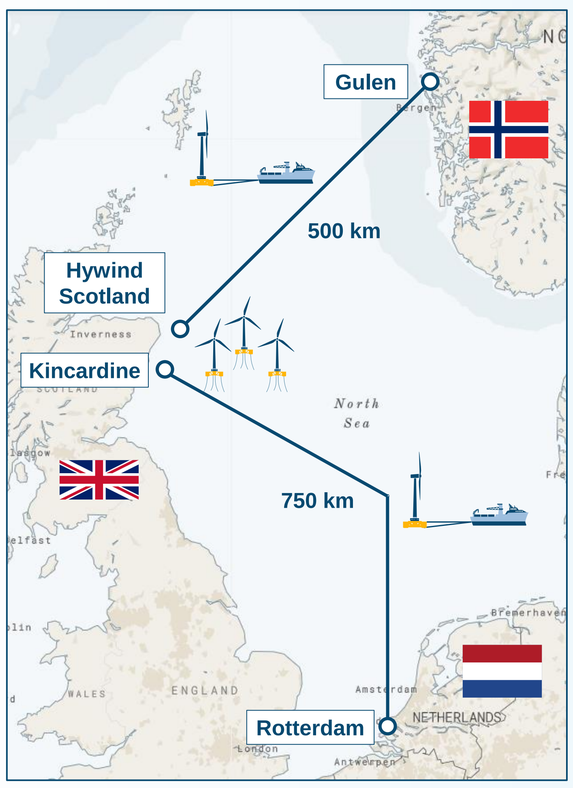
… at early stage …
Compute precise OPEX and availability figures

… and during wind farm operation.
Overall planification of a TTP operation
Procurement (vessels, tools, components, etc.)

Methodology

7 TTP operations were performed on utility-scale projects (as of December 2024):

- 2 at Kincardine – 2022 & 2023
- 5 at Hywind Scotland – 2024



Sea Impact data

- Sea impact is a **market intelligence platform** that tracks and analyses vessels' AIS data.
- Sea Impact first tracked the 2 TTP operations that occurred at **Kincardine wind farm** (2022 & 2023). The following information has been deducted:
  - **Overall process** of a TTP operation, with identified steps
  - **Effective time** of each step
  - **Weather limitations** of each step

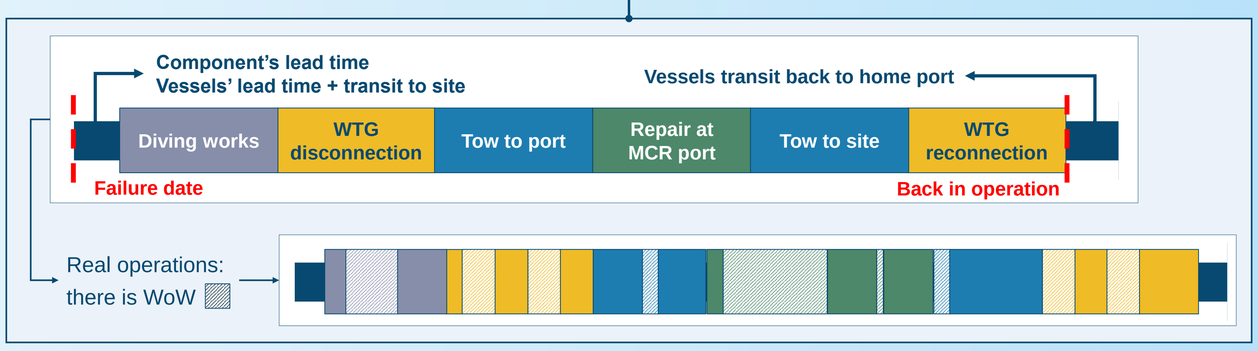
PEAK Wind's in-house TTP tool

→ **PEAK Wind's in-house tool estimates the wait-on-weather (WoW) associated to each step of the TTP operation**

Because **each step is limited by weather** (wind speed, wave height), some WoW must be estimated and added on top of effective times (see conceptual figure below).

Inputs and assumptions to the model:

- **Hourly wave height and wind speed** data (at site, along towing route and at port)
- **Effective times**, depending on project-specific information (towing distance, #mooring lines per WTG, water depth, etc.)
- **No delays** across the TTP operation



Validation

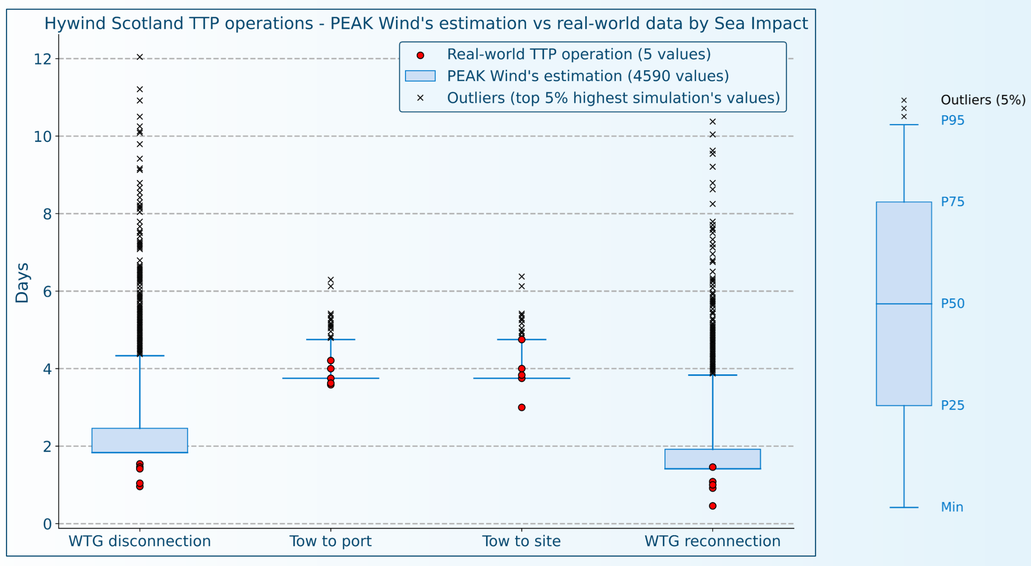
To validate PEAK Wind's model based on Kincardine, let's compare it with the latest 5 TTP operations at Hywind Scotland.

TTP process at Hywind Scotland – consistent across the 5 operations

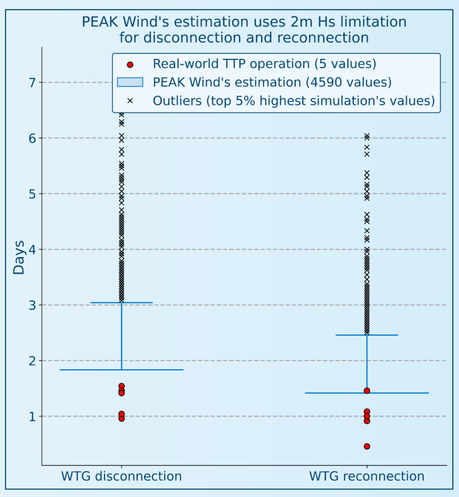
Preparation works had different scope than diving works at Kincardine
→ no comparison will be made with PEAK Wind's model

Repair at MCR port: WTG were kept at MCR port due to a full retrofit campaign carried out on WTG while secured at quayside → project-specific consideration

TTP #	1	2	3	4	5	PEAK Wind's estimate
Time at port	46 days	56 days	53 days	43 days	37 days	5 days (in average)

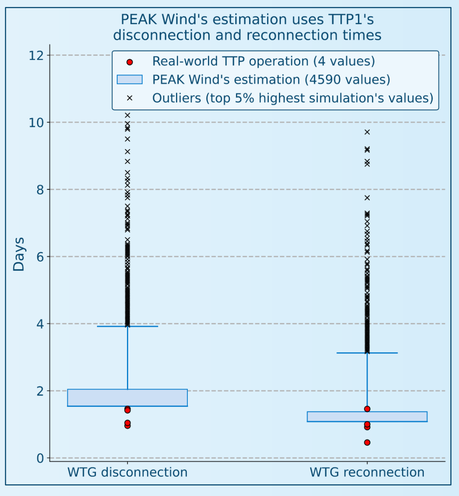


Results are satisfactory for the towing operations, but **WTG disconnection and reconnection times are overestimated**. Let's try 2 sensitivities: first adopting a 2.0m Hs limitation seen at Hywind Scotland (vs 1.5m as default seen at Kincardine), and second using Hywind Scotland's TTP1's disconnection and reconnection times as assumptions to estimate the 4 other TTP operations.



Results are still **overestimated.**

→ Wave height limitation is therefore not a key factor here, as the **limiting factor seems to be the effective time** deduced from Kincardine TTP operations.



Results are **slightly better.**

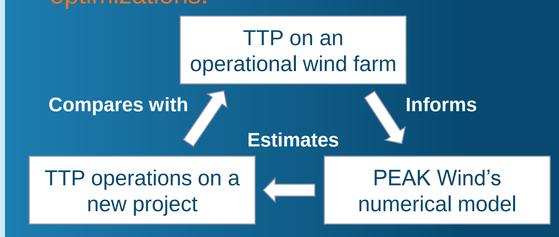
→ The default effective times for WTG disconnection and reconnection in PEAK Wind's model from Kincardine are overestimated. The **assumptions need an iteration** to reflect new industry standards as operations mature.

Conclusions

TTP operations were **split in several steps.** The model could accurately estimate part of them (towing operations in particular).

TTP operations are still immature: 7 TTP operations on utility-scale so far. Operations at Kincardine and Hywind Scotland differed, and this may be due to the WTG type, floater design (semi-submersible vs SPAR), ML type, etc.

→ As these TTP operations happen and mature, a continuous iteration process is needed to capture the latest operations optimizations.



PEAK Wind's model does not capture **project-specific considerations** such as delays or extended time at port.

→ Deep engagement with project is needed to capture these considerations and better estimate total duration of TTP operations.

TTP is the proven technology for floating wind MCR, but other solutions are emerging: an **in-situ MCR** was performed at Kincardine in Summer 2024.

→ In the future, TTP operations may be replaced by more efficient, faster, easier and cheaper solutions.

** Figures obtained within PEAK Wind's involvement on numerous projects across the globe*