# Digital Twin for the Floating Offshore Wind Industry

AS | MOSLEY
OFFSHORE SIMULATION

## OBJECTIVES

A consortium of AS Mosley, Fugro and the University of Strathclyde was awarded a grant as part of the Floating Wind Technology Acceleration Competition, administered by the Carbon Trust with funding from the Scottish Government.

The purpose of the project was to demonstrate a digital twin approach to track mooring line fatigue on a Floating Offshore Wind Turbine (FOWT) as an enabler for a risk-based inspection regime.

> *"Tracking fatigue over the whole life of the FOWT, allows inspections to be performed only when necessary. This provides significant cost-savings and reduces health & safety exposure."*

## CHALLENGE

Floating offshore wind turbines (FOWT) are subject to complex static and dynamic loading from wind, waves and current, so accurate real-time monitoring of loading on mooring lines to prevent damage is essential.

The fatigue design of components is commonly assessed through numerical modelling of models of representative load cases, but numerical models have inherent conservatism built-in.

Load cells can be used to track mooring line loading, however they have a track record of being unreliable in offshore environments whilst being costly.

## SOLUTION

Using digital twin technology combined with non-intrusive real-time remote monitoring of actual loads offered an ideal solution.

The monitoring system considered only robust and reliable sensors which can be mounted on (and preferably within) the floating hull: accelerometers, gyroscopes and satellite positioning. The resulting position and motion signals were converted to mooring line tension cycles using transfer functions generated from a simulation model of the FOWT that characterised its response in various wind and wave conditions.

Mooring line fatigue was calculated by the digital twin using the industry-standard S-N Curve method, but also using a new peridynamic method, which gives a comprehensive assessment of fatigue damage progression.

Tracking fatigue over the whole life of the FOWT, allows subsea inspections to be performed only when (and if) necessary. The elimination of unnecessary subsea inspection yields significant cost-savings as well as reduced health and safety exposure.

CASE STUDY

# Digital Twin for the Floating Offshore Wind Industry

## SOLUTION - SIMULATION MODEL

A simulation model of the Hywind Scotland 6 MW FOWT design was created to simulate its response to a variety of environmental conditions. The simulation response was tailored to match the measured FOWT response as closely as possible using available measured data.

A method of calculating the mooring lines tensions was demonstrated based on virtual sensor packages measuring FOWT motion and position.

The sensor packages considered during the verification phase were relatively low-cost and included MEMS-based accelerometers and gyroscopes as well as a commercially available satellite positioning receiver. The analysis demonstrated that the noise performance of such units was adequate to determine fatigue rates in the mooring lines.

A sensitivity study of differing wind and wave directions as well as increasing significant wave height suggested. that a lookup table of motion-to-tension transfer functions should be derived from simulations with 10° compass direction intervals and 3m significant wave height bins. This was shown to give accurate fatigue predictions for this scenario.

The analysis method was applied to a limited set of field data recorded on one of the Hywind Scotland FOWTs. The mooring line tensions were calculated from the FOWT motions for comparison against measured tension readings from six load cells installed in the mooring lines at the connection to the hull.

## ANOMOLOY DETECTION

Anomaly detection of mooring failure scenarios and events was also demonstrated using the monitoring system.

By processing the measured signals continuously, problems with the mooring system can be identified in a timely manner – safely and remotely. To demonstrate this, simulations were performed for four identified failure scenarios or events relevant to operation of a FOWT: 1) Trawler snag loading; 2) Mooring line anchor slippage; 3) Broken mooring line bridle and 4) Loss of floater ballast.

The data was processed in real-time in segments of 10 minutes to reduce the measured time series data to an appropriate and manageable set of statistics. By looking for deviations in FOWT position, inclination and dynamic response from predictions of the simulation model – essentially adjusting for prevailing wind and wave conditions – anomalous behaviour of the FOWT was accurately identified. All the selected failure scenarios could be confirmed.

## OUTCOME

Excellent correlation and fatigue matching were obtained at the mooring line connections versus tension extracted directly from the simulation. Typical correspondence for fatigue was within 10%, which is very good for fatigue tracking and excellent verification of the project methodology. Further improvements are expected by using high accuracy GPS measurements in future (i.e. Galileo).

Peridynamic fatigue analysis was conducted on a mooring line component (a triplate) to determine the fatigue life under typical load cycles and how fracture would progress. This was shown to provide not just accurate predictions of the formation of fatigue cracks but also where and how they would progress to failure.

A complete picture of fatigue damage evolution from crack initiation to final failure was obtained - an important input into a risk-based inspection methodology – allowing operators to know what and where to look for fatigue failure and target any subsea inspection work deemed necessary.

Key findings were that the digital twin should:

- Record accelerometer signals from the FOWT.
- Utilise high-accuracy (“differential”) satellite positioning to minimise spurious data.
- Include a feedback loop between the simulation model and the monitoring system to enable full digital twin capabilities.