# Physics-informed machine learning for rapid fatigue assessments in offshore wind farms

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## PROJECT AIM

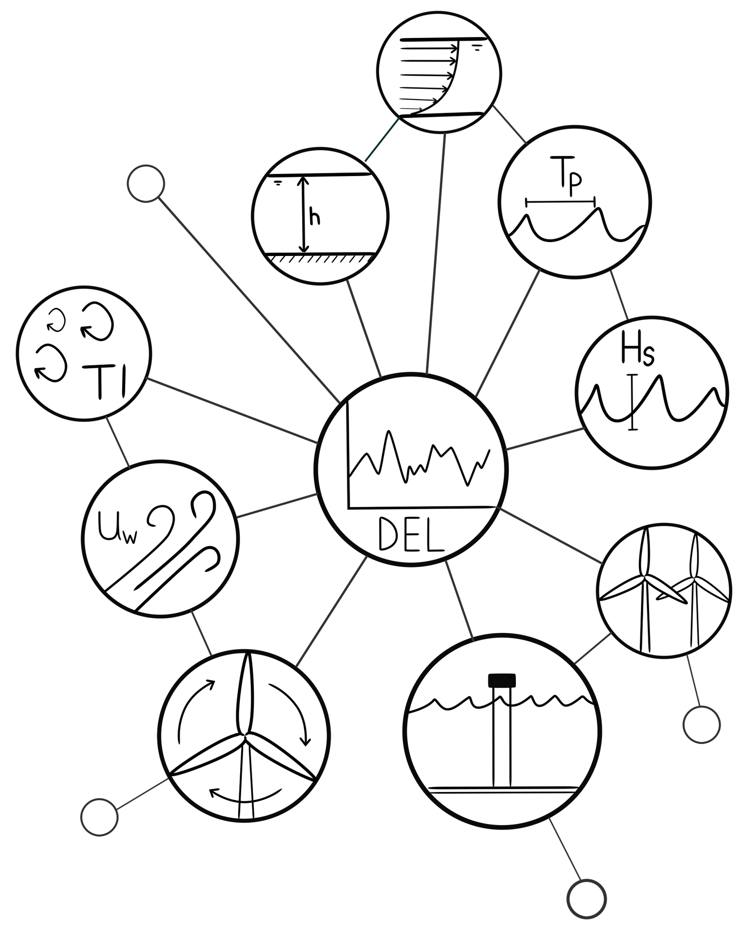
Quickly and accurately determine and forecast offshore wind turbine fatigue using physics informed machine learning, including nonlinear wave loading-induced resonance.

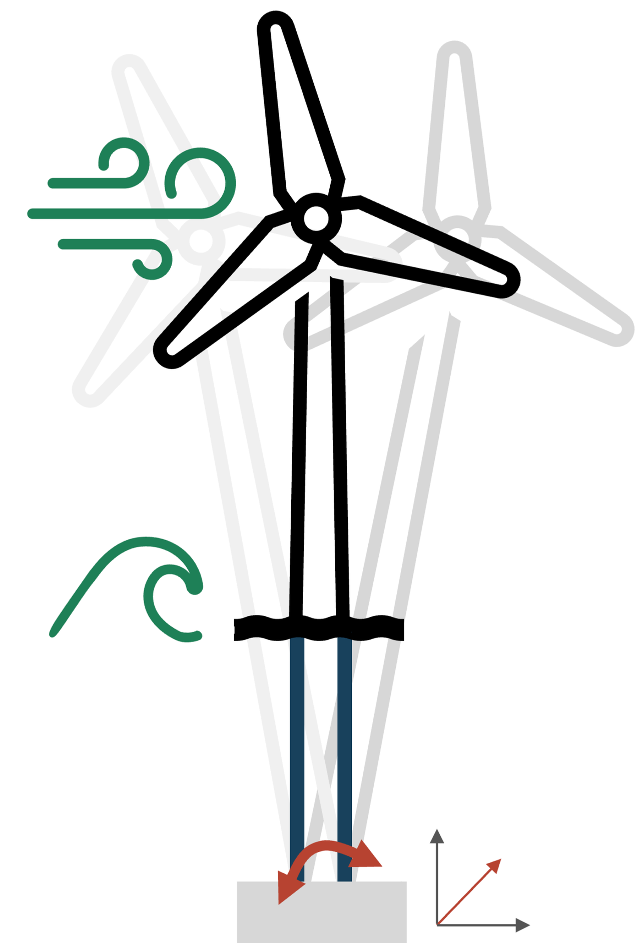
## RATIONALE

There is a need for efficient and accurate damage / fatigue estimations of offshore monopiles throughout the structure lifespan, thus supporting maintenance and decommission decision making, yet this is currently computationally expensive.

## APPROACH

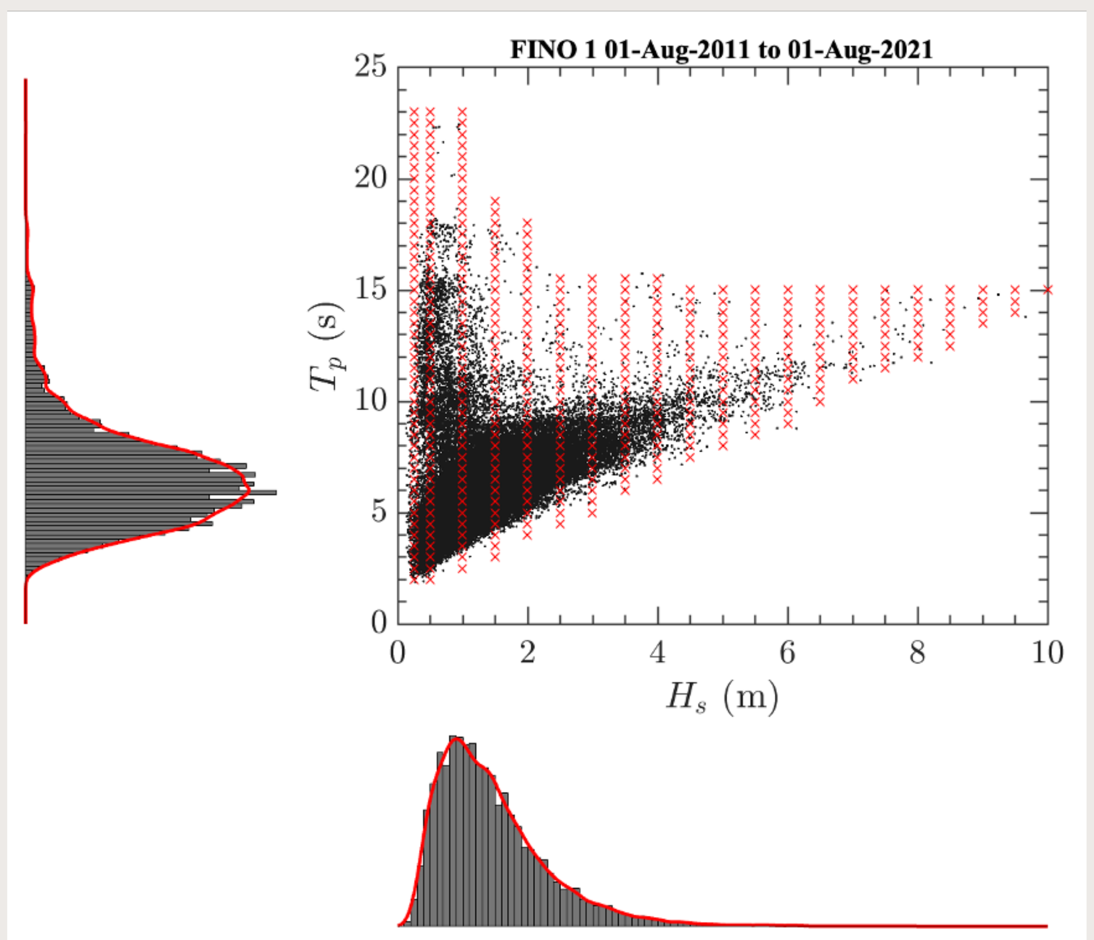
A meta-model is developed based on convolutional neural networks to determine the monopile damage that encompasses an extensive range of environmental conditions recorded in the North Sea, for both operational and parked turbines.



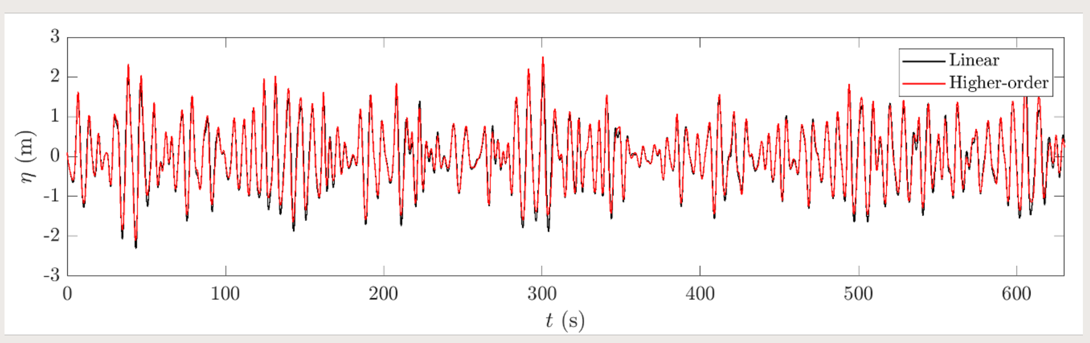



## (1) ENVIRONMENTAL CONDITIONS

Produce an industry accessible environmental conditions library for customised non-linear wave kinematics.



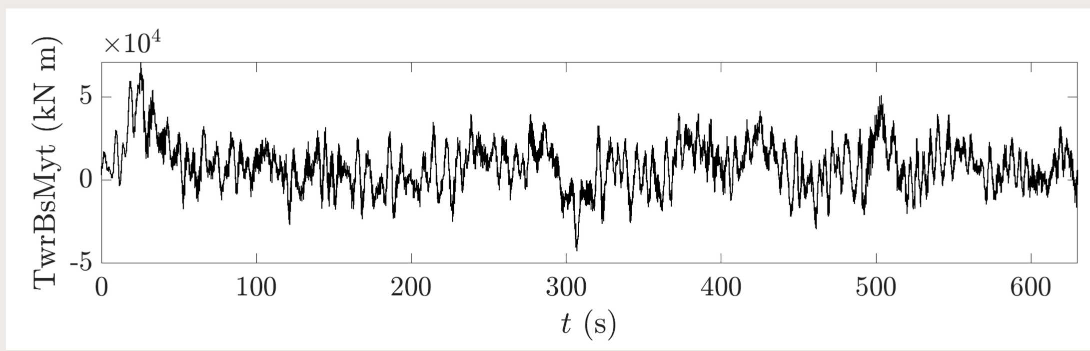

*Peak wave period ($T_p$) and significant wave heights ($H_s$) measured (black dots) at the North Sea research platform FINO1. Red crosses indicate conditions numerically simulated for the library.*



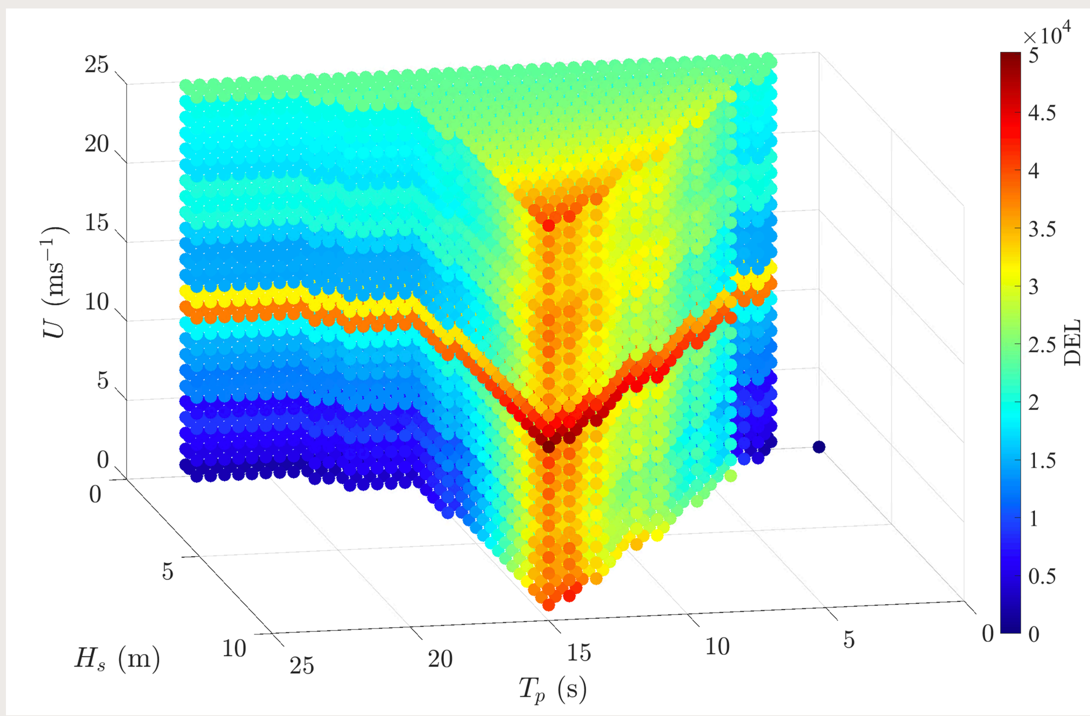

*Example time series of water surface elevations from numerical produced using linear and higher-order boundary element methods.*

## (2) MONOPILE FATIGUE SENSITIVITY

Estimate monopile fatigue for various environmental (ECs) and operational conditions (OCs), and identify critical damage cases.



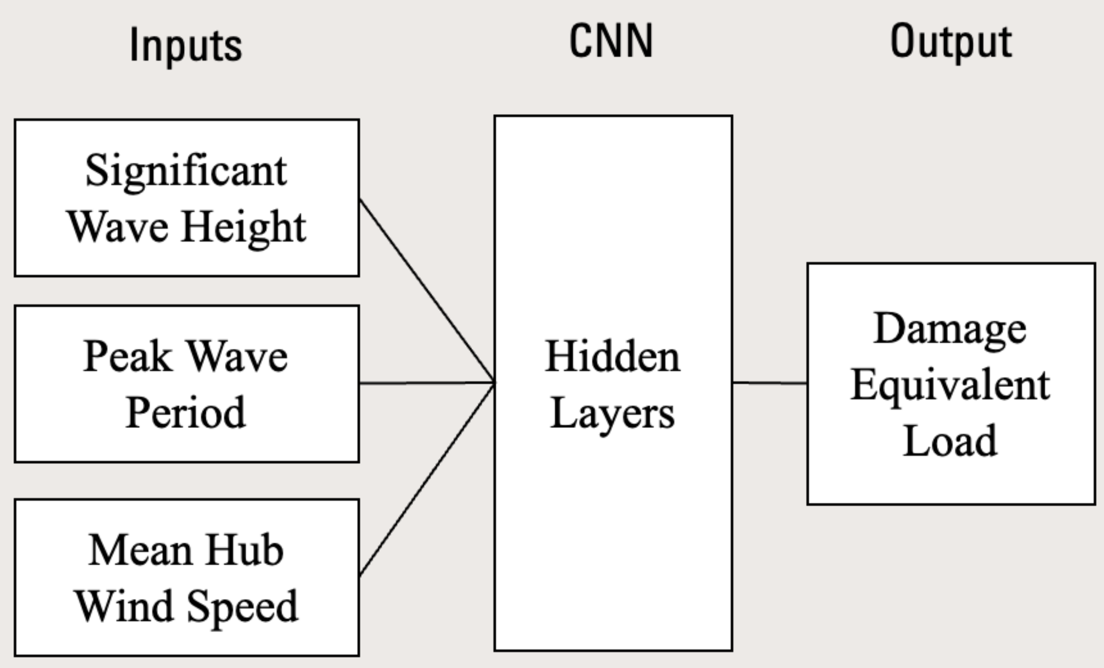

*Example tower fore-aft mudline bending moment output from areo-hydro-elastic-servo simulator (FASTv7). Damage is subsequently estimated using rainflow-counting methods.*



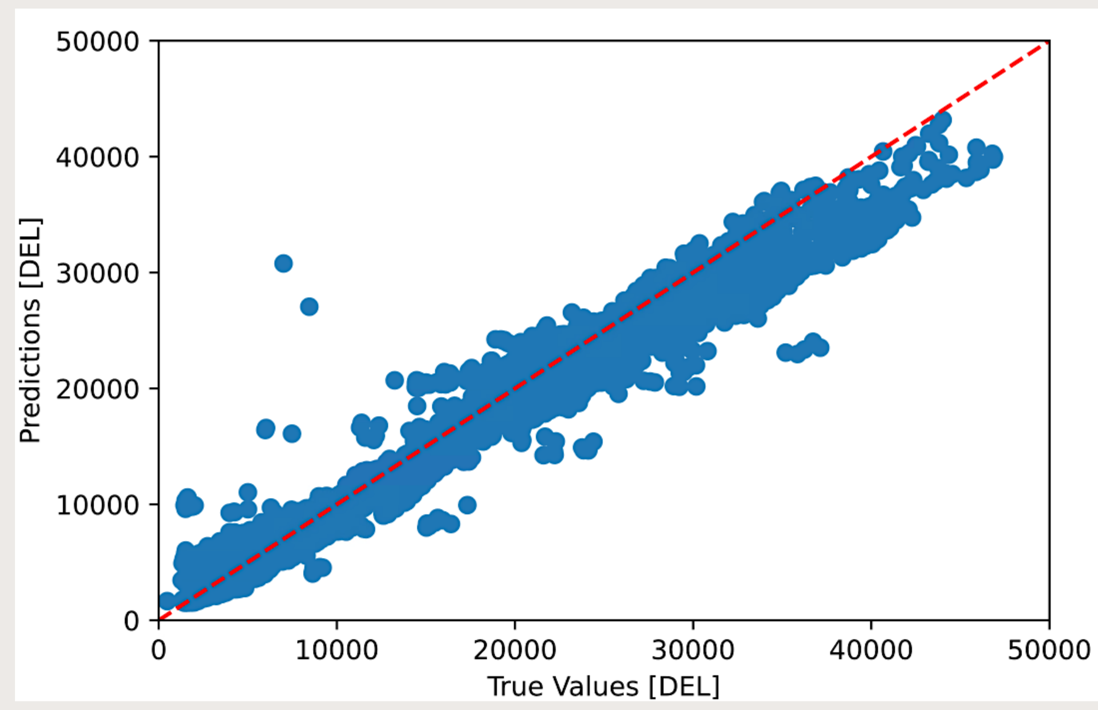

*Monopile Damage Equivalent Load (DEL) for simulations based on the NREL-5MW monopile wind turbine during operational conditions.*

## (3) RISK FORECAST MODEL

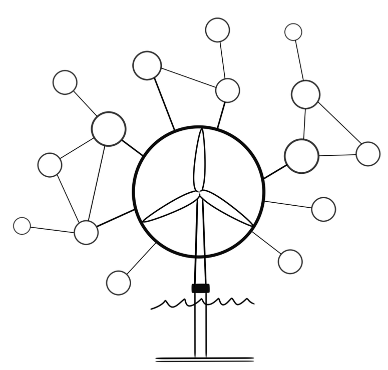
Develop a predictive physics-informed machine learner for lifetime fatigue damage of offshore wind turbine monopiles.




*Convolutional Neural Network (CNN) model architecture for monopile Damage Equivalent Load (DEL) prediction for various ECs and OCs.*




*Test data results for the machine learning model.*



## ONGOING RESEARCH

- Acquisition of experimental and field data to validate model results.
- Further model development to calculate accumulated fatigue and implement into lifetime assessments.
- Upscale research outputs to a wind-farm scale for turbine specific evaluation.

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