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

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Accurate and efficient assessment of offshore wind turbine monopile fatigue is required to inform maintenance and decommissioning decision making. Although, direct field-based measurements are limited and current industry standard modelling approaches are often devoid of fully non-linear waves, thus omitting critically important resonance effects. Here, numerical modelling is combined with machine learning to develop a meta-model capable of rapidly estimating monopile damage and fatigue. Fully non-linear wave kinematics were numerically modelled using higher-order boundary element methods to represent conditions recorded in the North Sea. These environmental simulations were implemented within numerical areo-hydro-servo-elastic engineering modelling of a reference turbine (NREL 5MW) with monopile foundations, for both operational and parked turbine configurations across a range of incoming wind conditions. The modelled fore-aft tower base bending moments are used to estimate of the corresponding structural damage using rainflow-counting methods, enabling identification of conditions associated with the largest damage loads. These data are applied within the development a meta-model based on convolutional neural networks to provide rapid assessment of monopile damage associated with any given environmental and operational condition.