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ON THE USE OF PHYSICS-BASED AND DATA-DRIVEN (AI/ML) DIGITAL TWINS FOR OFFSHORE WIND MONITORING APPLICATIONS

(Soiltwin + Supersized 4.0 + INSPIRE)



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AGENTSCHAP
INNOVEREN &
ONDERNEMEN



01/06/2022

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PHYSICS-BASED AND DATA-DRIVEN DIGITAL TWINS

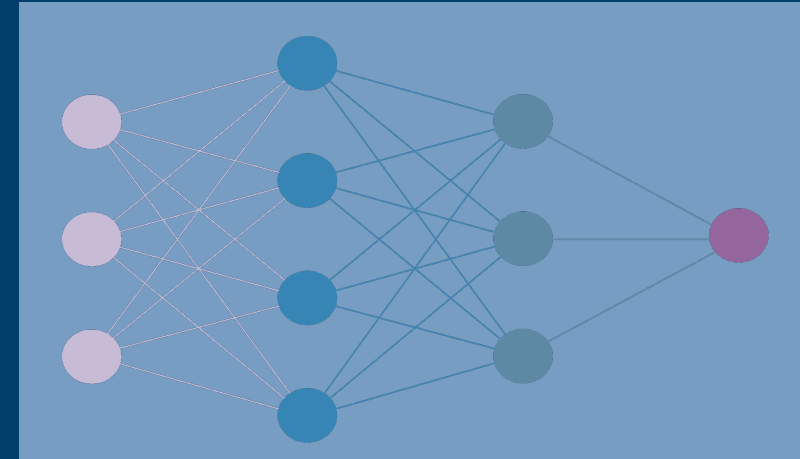
Objective: mimic the physical behaviour

Physics-Based Digital Twins



- **Finite Element Models (FEM)**
 - Model created using analytical equations/FEM + SSI
 - Model can be updated based on short term and/or longterm measurements (unique model per structure)

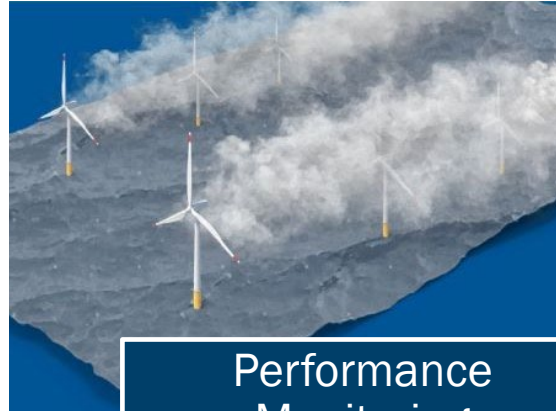
Data-Driven Digital Twins



- **Machine Learning Models (AI/ML)**
 - Model trained using machine learning tools (NN, RFC, SV, PCA,...)
 - Model trained based on sufficient longterm term measurements (model transferred to other structures)

USE CASES OF AI/ML IN OFFSHORE WIND

PM, CMS, SHM, Control



Performance
Monitoring



Condition
Monitoring



Structural Health
Monitoring



Control



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TWINs FOR OFFSHORE WIND MONITORING APPLICATIONS

USE CASE 1: AI/ML FOR FLEETWIDE LOAD/LIFETIME PROGRESSION MONITORING

SUPERSIZED 4.0



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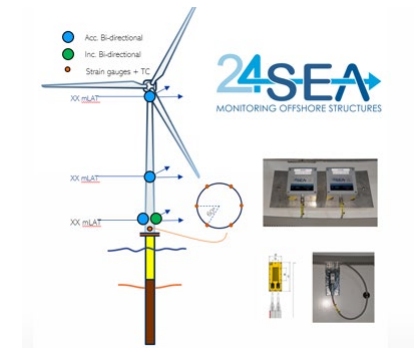
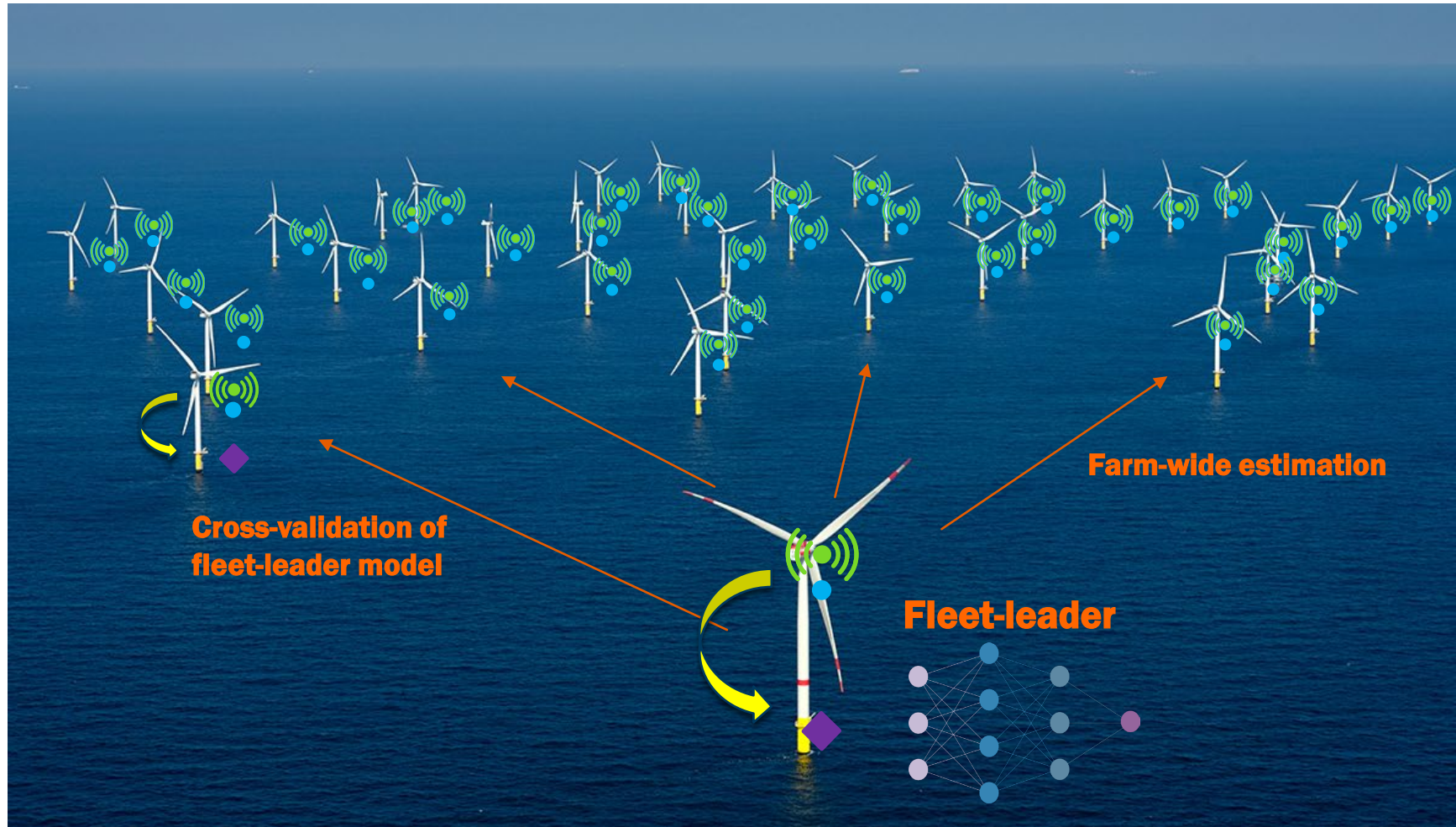
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VRIJE
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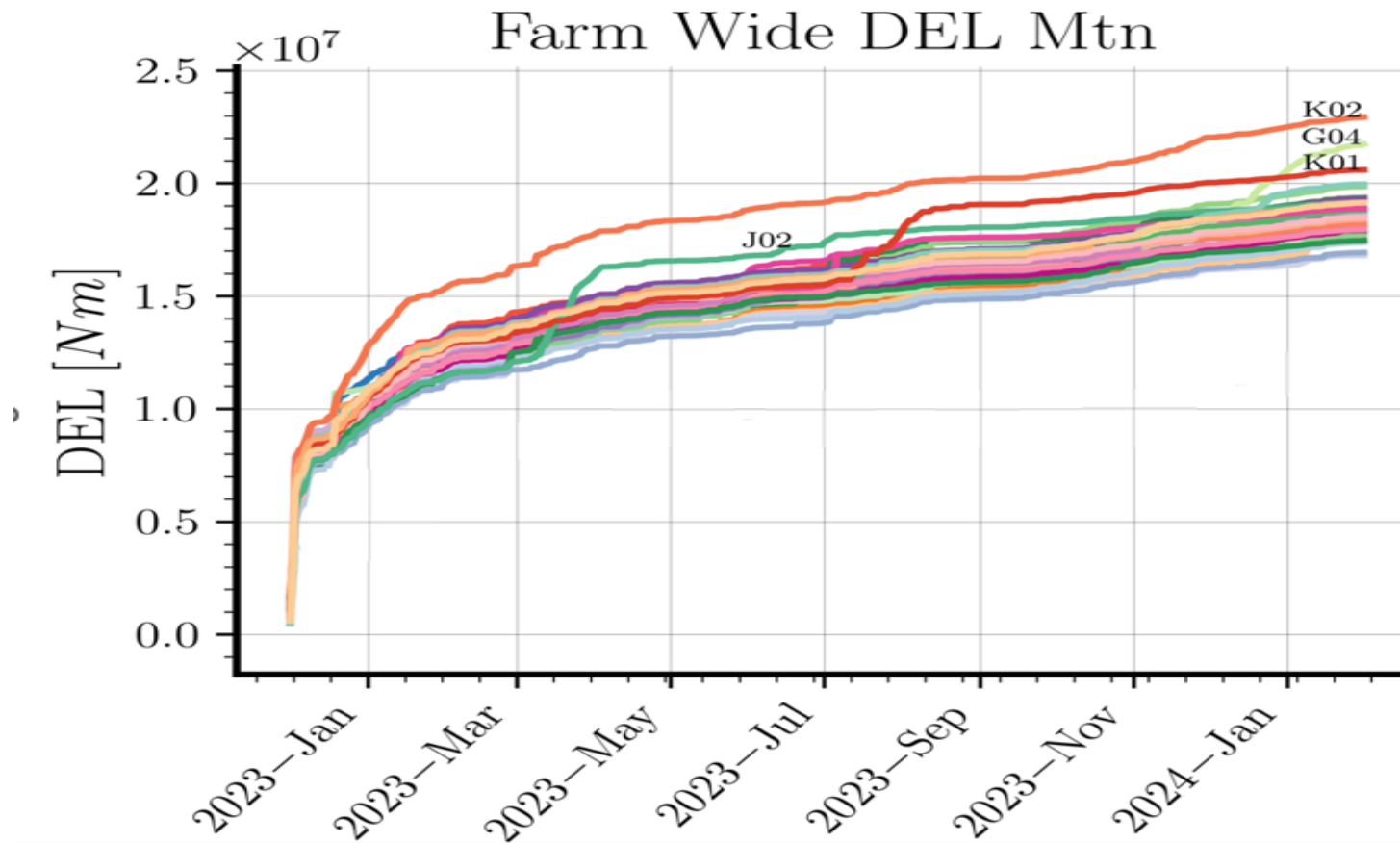
FARMWIDE LOAD MONITORING

TRAINING AND VALIDATING MACHINE LEARNING MODELS



FARMWIDE LOAD MONITORING

Typical Result



The operator gets a direct quantification on fatigue life progression of every turbine within the windfarm

- Potential Root causes higher fatigue rates
 - Rotor unbalance issues
 - Parked conditions
 - High number of start-stop events
 - ..

DATA-DRIVEN DIGITAL TWINS

INSPIRE
Sustainable Blue Economy Partnership



Sustainable Blue
Economy Partnership

USE CASE 2: Integrated wind-
hydrogen power plant



Integrated wind-
hydrogen power plant



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LEARN FROM DATA

SCADA 1-sec & CMS

67 turbines



LiDARs

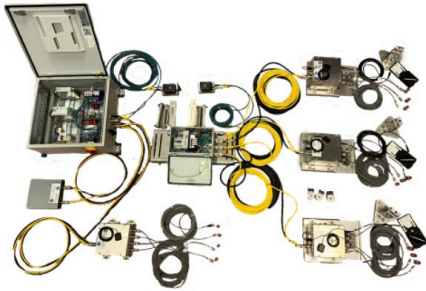
2 turbines long-term
(SeaFD & Beforecast)

1 moving around in
the cluster
(Cloud4Wake)



CMS instrumentation

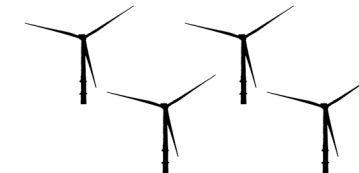
20 kits



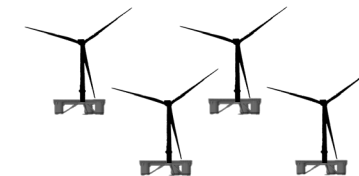
Offshore Integrated Power Plant



Set points based on
demand



Wake



Floating



Integration

WAKE MODEL CALIBRATION USING AI METHODOLOGY

Environmental sensing

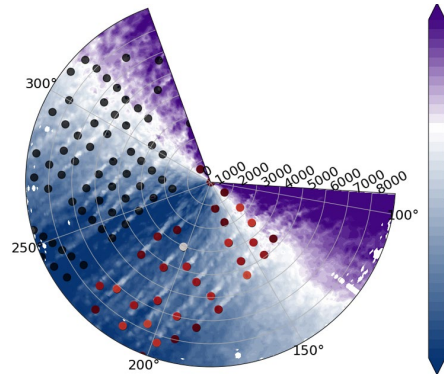
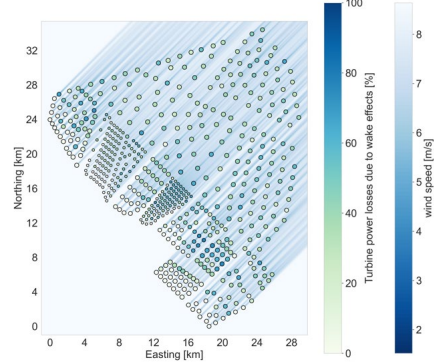
3D wind field



Rain, wind speed, humidity, pressure, temperature



D van Binsbergen et al. (2024)
Wind Europe
[Best poster award]



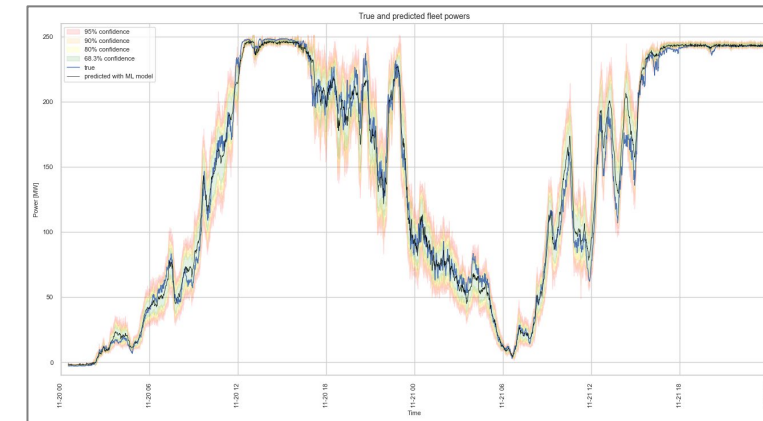
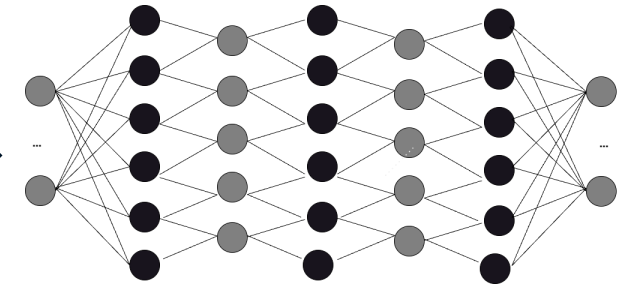
Simulation

Validation

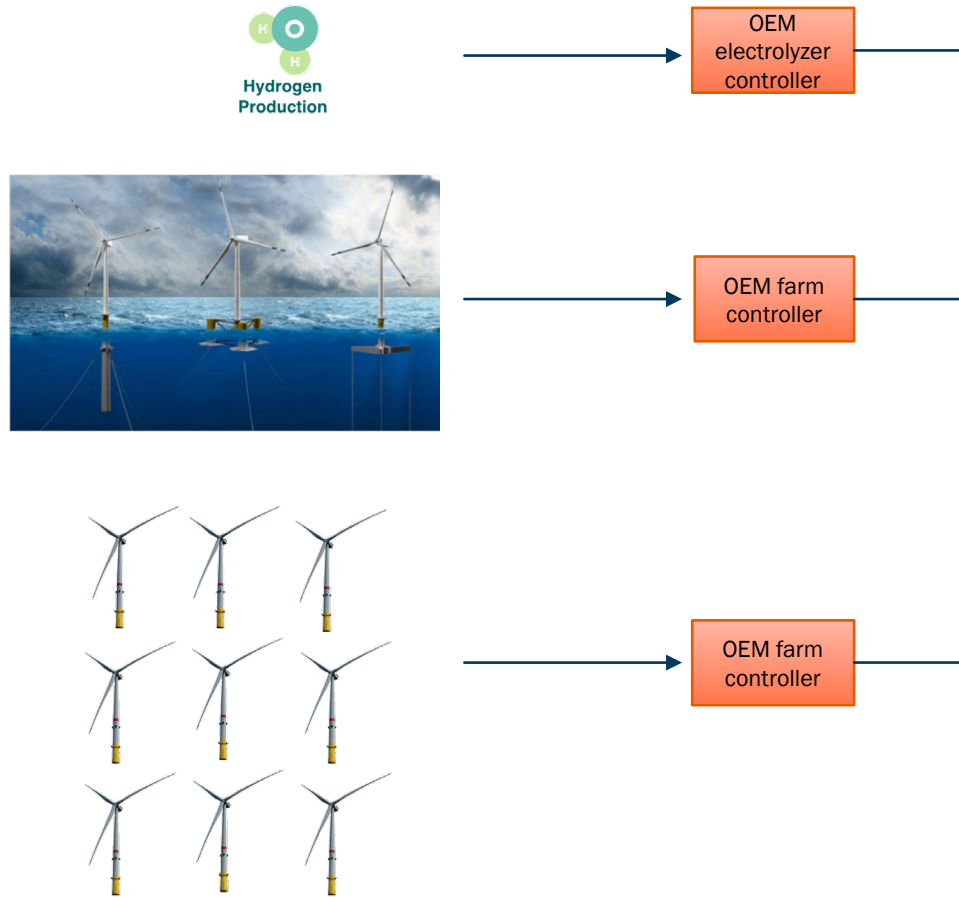
SCADA 1-sec
+
Virtual data

Hyperparameter
Optimization

Train power prediction model



REINFORCEMENT LEARNING FOR INTEGRATED WIND-HYDROGEN SYSTEM



Reinforcement learning



Recommend

Observe

Act

Observe

Physical asset



Simulation model



Insights for

- Balancing electrolyzer stacks (INSPIRE)
- Reducing turbine loads (CORE)
- Maximizing power (CORE)
- Matching demand (POSEIDON)



THANK YOU FOR YOUR ATTENTION

Are there any questions?



NOVELTY DETECTION IN THE SHM DATA OF AN OWT



01/06/2022

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