### Digital Twin for improved management of wind farms

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Web-page: https://www.ntnu.edu/energy/wind-power



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### What is a Digital Twin?

A digital twin is defined as a virtual representation of a physical asset enabled through data and simulators for real-time prediction, monitoring, control and optimization of the asset for improved decision making throughout the life cycle of the asset and beyond.

**A. Rasheed, O. San, and T. Kvamsdal**. Digital twin: Values, Challenges and Enablers From a Modelling Perspective. *IEEE Access*, 8: 21980-22012, 2020.

### Digital Twin (Oracle)

- Virtual Twin: Creation of a virtual representation of a physical asset or a device.
- **Predictive Twin:** Physics based, data driven or hybrid models operating on the virtual twin to predict the behavior of the physical asset.
- *Twin Projection:* Integration of insights generated by the predictive twin into operations and processes.

## How DT makes a difference



Information transfer during *design* Decision support and operation control throughout operation phase. Faster and better simulation models enabling *Predicitive Twins* 



 $\mathbf{u}_t(\boldsymbol{\mu},\boldsymbol{\kappa}) = \mathbf{F}(\mathbf{u};\boldsymbol{\mu}) + \mathbf{\Pi}(\mathbf{u};\boldsymbol{\mu},\boldsymbol{\kappa})$ 









### Digital Twin: An enabler for holistic approach



# Examples of Applications

- Wind farm and environment
- Advanced wake models and farm control
- Short term asset management
- Leading blade edge erosion
- Degradation of bearings and gears
- Fatigue monitoring
- Cable health monitoring
- Blade damage monitoring
- Power electronics health monitoring

### Wind farm and environment



Fluid-Structure Interaction Simulation

Surrounding terrain or ocean

Micro wind model

Shortwave

Longwave radiation

# Advanced wake models and farm control

- Wake effects important for fatigue damage
  - Should be included in design analysis
- Accurate engineering models accounting for these effects needed
  - Enable local load mitigation and park control/power optimization
  - · Should be verified with CFD and full-scale measurement
- · Shortcomings existing wake models
  - Yaw misalignment, wind shear profiles, account for 6DOF of floating wind turbine, atmospheric turbulence, wind-wave interaction.







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### Short-term asset management







#### Ahead of / during severe weather events:

- Varying production and demand
- Possibly large downtimes:
- Knowledge gap:



- Limited accessibility



# Degradation of bearings and gears

#### Monitor

- Acoustic emission
- Environment
- Detoriation of lubricant

#### Model

- Contact loads
- Environmental stress crack growth
- Corrosion
- Electrochemical migration









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# Fatigue monitoring

- Collect sensor information at few locations
- Use machine learning / statistics to extrapolate fatigue loads at other locations of interest



# Cable health monitoring

#### Monitor

- Mechanical loads
- Corrosion
- Environment

#### Model

- Stress and environmental driven crack growth
- Residual capacity





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# Power electronics health monitoring

- Reduced downtime by condition-based maintenance
  - Serves as decision support to riskbased maintenance for optimal cost/risk ratio.
- Digital twin for estimating state-of-health
  - Real-time measurements
  - Digital model translates usage into deteriorating stresses
  - · Lifetime model keeps count on stresses
- Demonstrated real-time system in laboratory







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### Concluding remarks

- A catalysator for collaboration
- The foundations behind a digital transformation

# Digital Twin: A catalysator for collaboration



### Digital Twin Digital Thread

https://www.challenge.org/insights/digital-twinand-digital-thread/ Digital twins and digital threads are the foundations behind a digital transformation

They **both** enable new ways to assess practices, processes, and product concepts in a virtual environment.

Simply stated the *digital twin* is the current representation of a product or system, mimicking a company's machines, controls, workflows, and systems.

The *digital thread* meanwhile is a record of a product or systems lifetime, from its creation to its removal.

**Both** can potentially have huge benefits for operating models, revenue stream and relationships in the future.