from **Things**

# Technology for a real-time simulation-based system monitoring of wind turbines
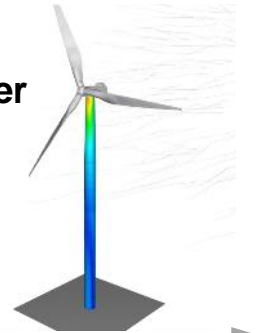
Daniel Zwick, Tomáš Mánik, Asle Heide Vaskinn, Jon Tøndevoldshagen
(all Fedem Technology AS / SAP SE)

EERA DeepWind'2017, 14th deep sea offshore wind R&D conference, 18 - 20 January 2017

SAP

to **Outcomes**

**FEDEM = Finite Element Dynamics in Elastic Mechanisms**

**FEDEM WindPower**

**Engineering and analysis services**

1980    1990    2000    2010    2020
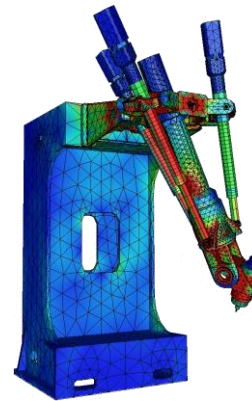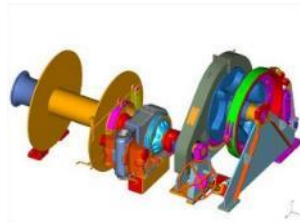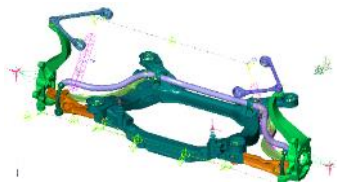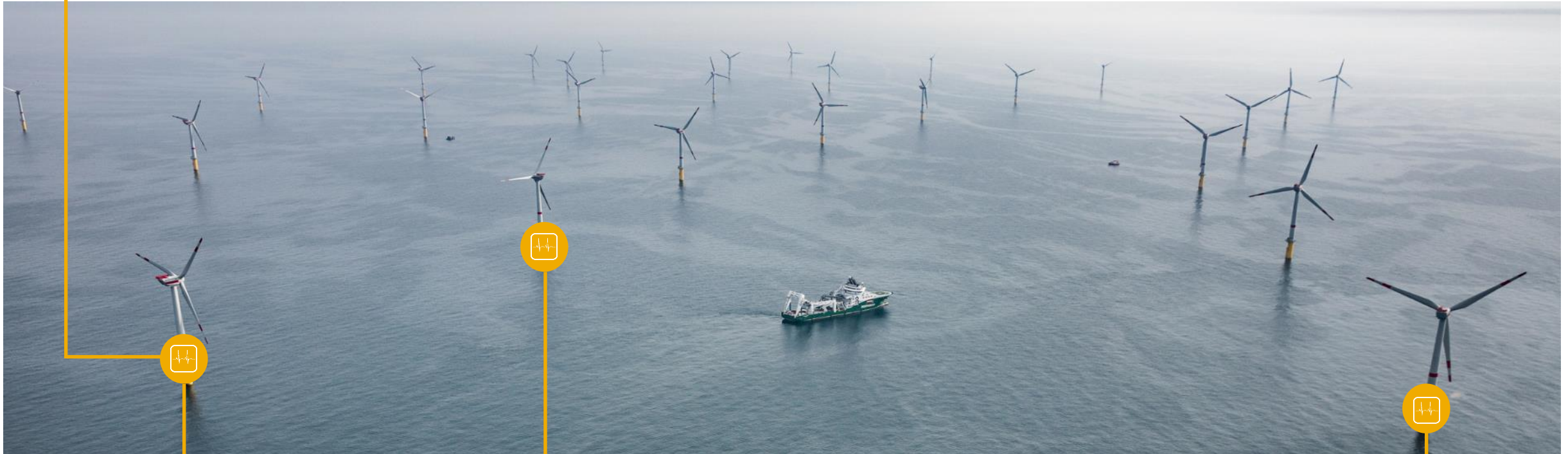
**Fedem (Technology) AS**

**SAP SE acquires Fedem Technology AS**
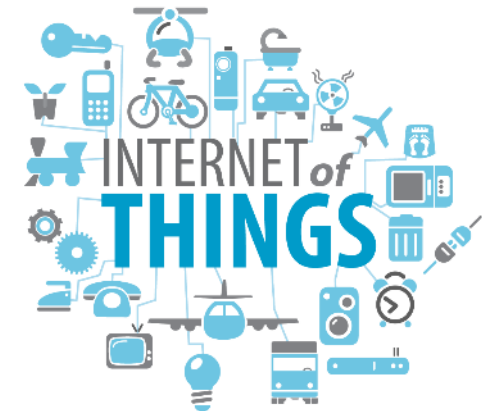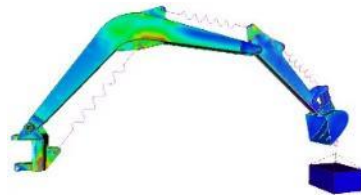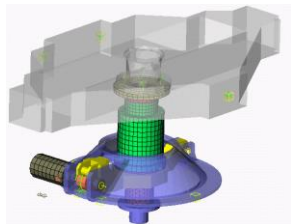
**Our vision enables Digital Inspections of Wind Turbines based on real-time Digital Twins**



**Real-time Monitoring Stress & Fatigue**

**Transparency about remaining useful-life**

**Detection of degradation/ changed physical behavior**

Goal: optimizing **power production** as well as minimizing **structural DAMAGE** under operation

| Design | Operation | Maintenance |
|---|---|---|

**Design**
- Documented state of the system at any time combined with adaptive control systems may reduce the need for conservative safety factors.

Reduced **CAPEX**

**Operation**
- Continuously adapting the control strategy to maximize energy production while optimizing structural loading and condition.
- Recording accurate and reliable history of structural response enables cost-efficient prolongation of life beyond design lifetime.

Increased **INCOME**

**Maintenance**
- Preventive actions may be selected based on detailed insight into the development of structural integrity over time.
- Adaptive maintenance strategy can be based on actual accumulated damage and expected remaining life for different parts of the structure.
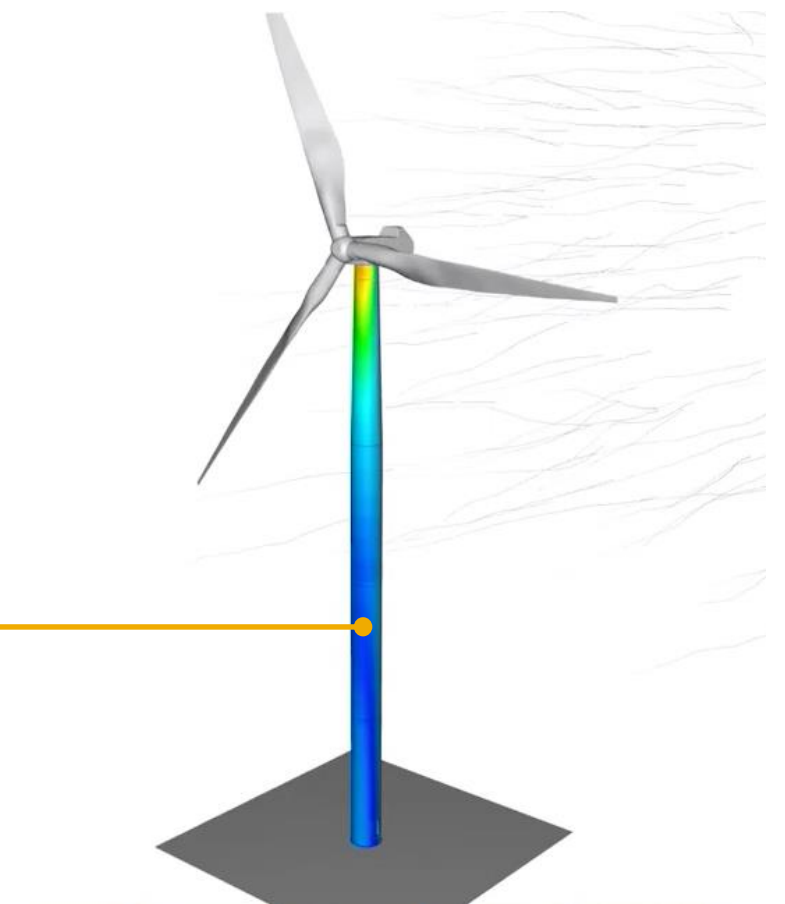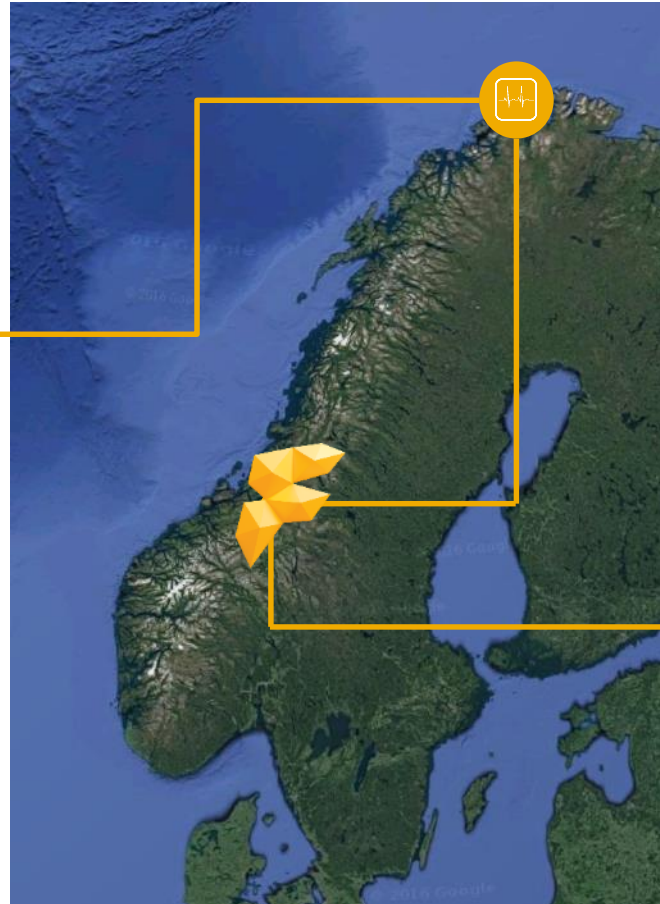
Increased **UPTIME**

# Fedem wind demonstrator 2016

- **Havøygavlen, Finnmark, owned and operated by**

  ARCTIC WIND

- **NORDEX N80 equipped with motion sensors since March 2016**

- **Data feed to server and digital twin representing state of system in real-time**

- **Online application for data access**

- **Partially funded by Innovation Norway**

# Strain gauge verification

- **Comparison of physical and virtual strain gauges at tower bottom**

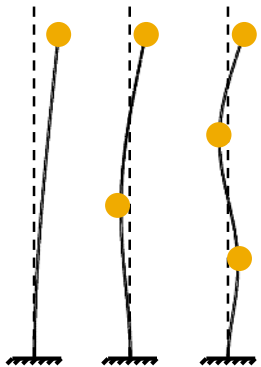- **Demonstrator limited to first order movements of the tower structure based on IMU at tower top**
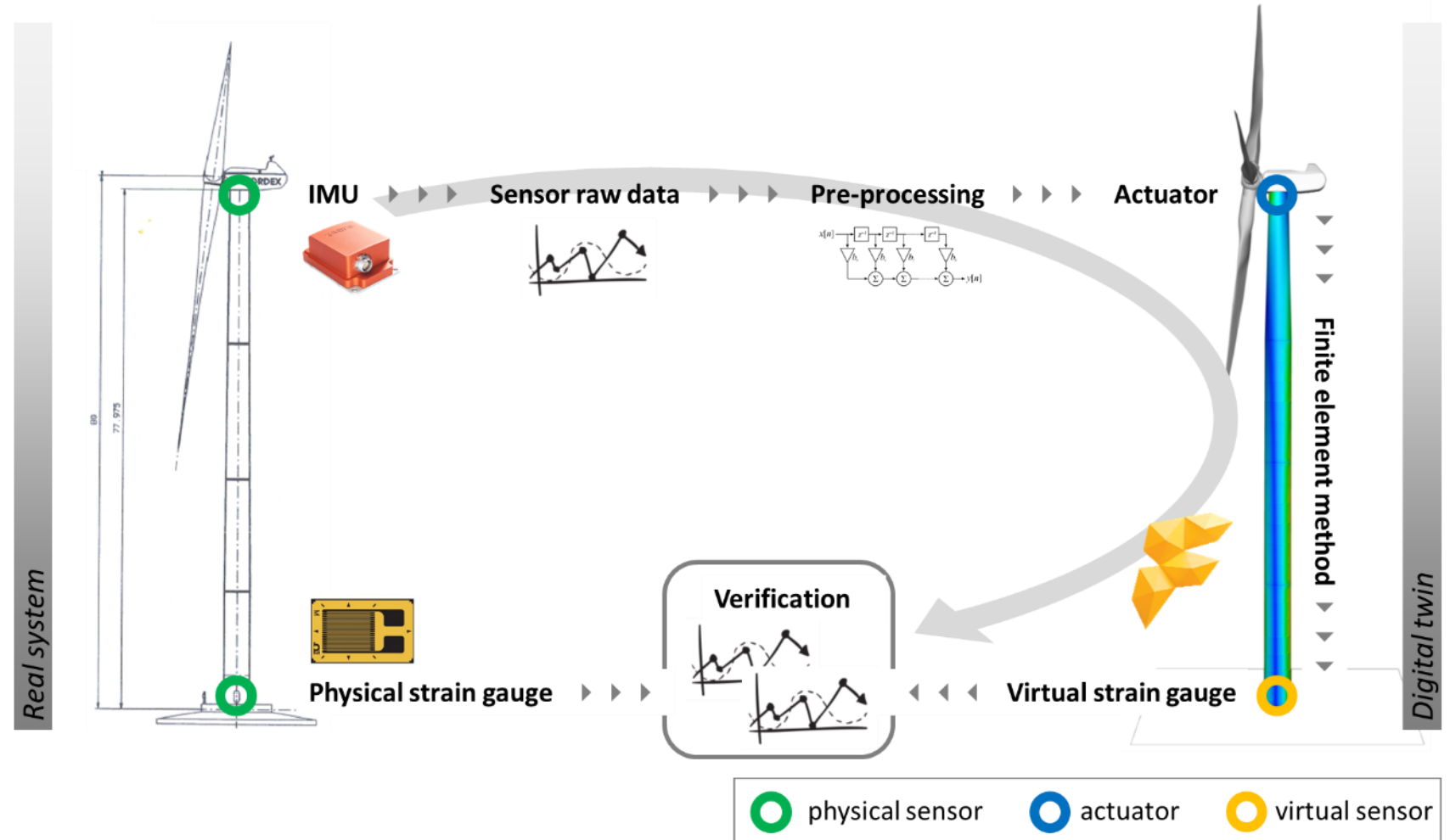
# Strain gauge verification

- **Production to stop scenario**

- **Tower structure oscillates in its first eigenmode for several minutes**

- **Data compliance in both amplitude and period achieved by virtual strain gauges**



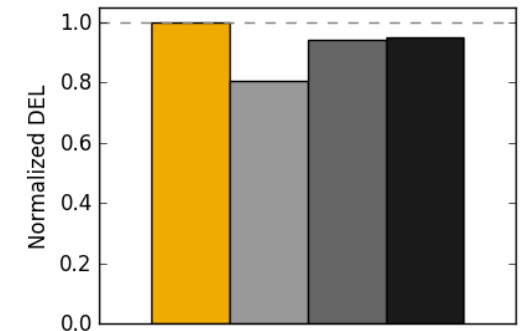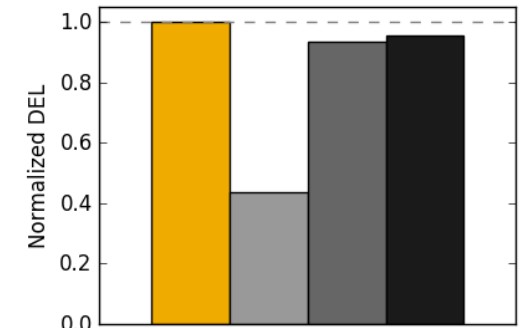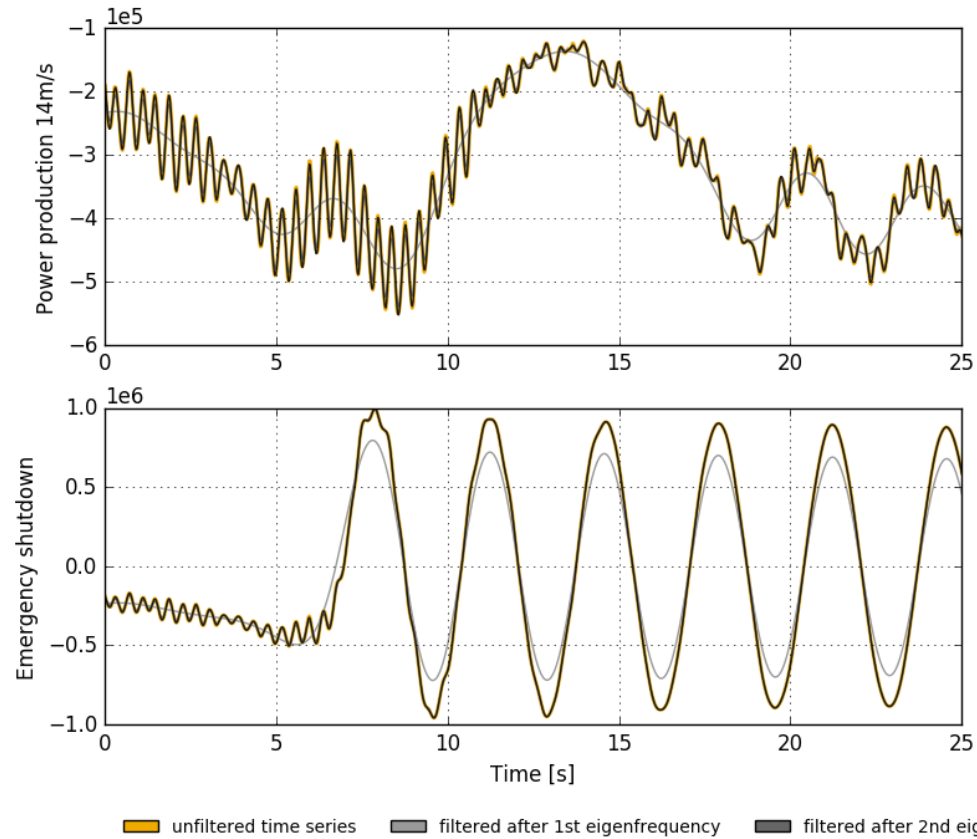Transient from production to stop
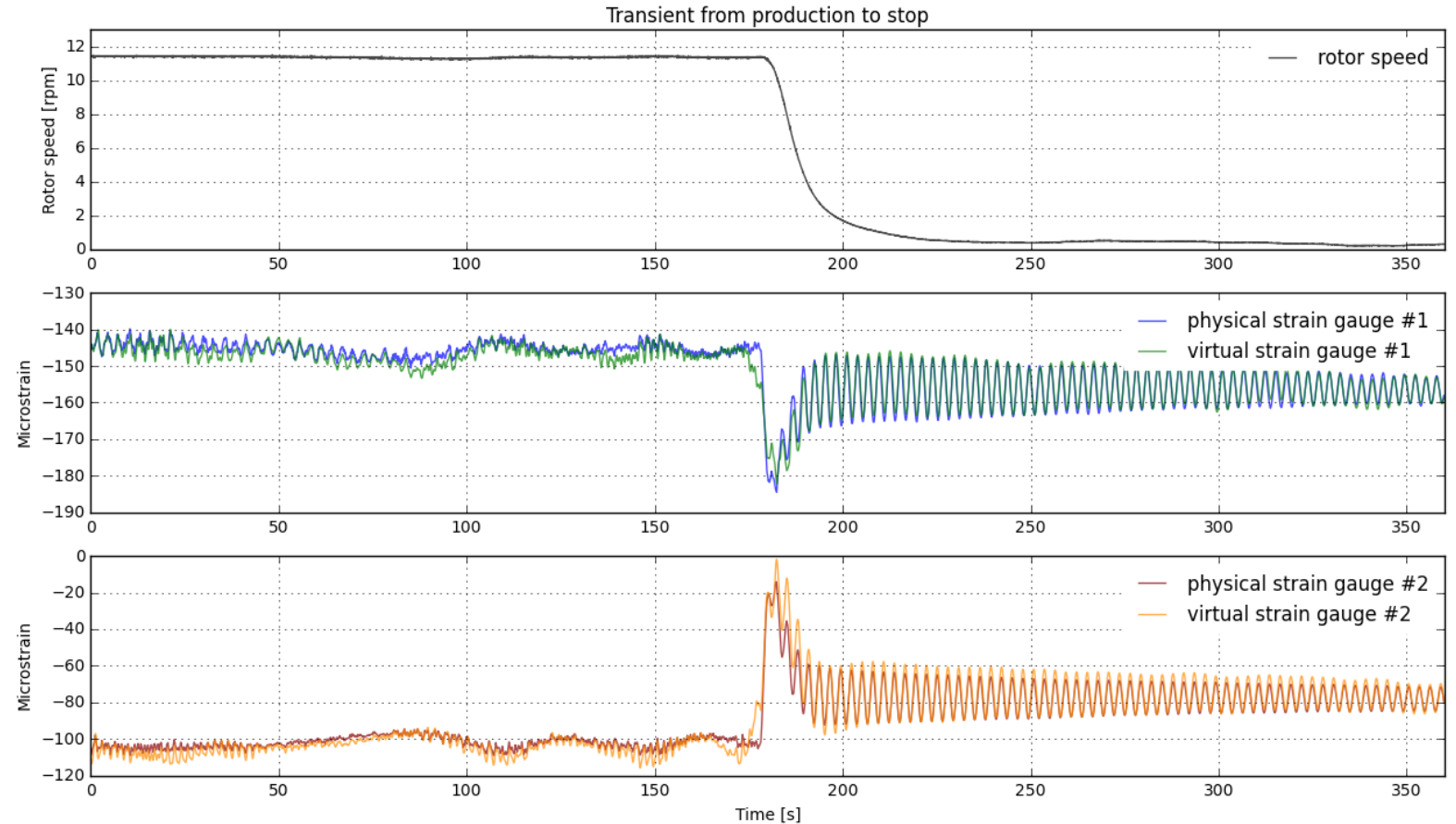
# Fatigue analysis

- **Simulation study on the contribution of structural modes to fatigue**

- **Number of recorded structural modes by sensors determines the accuracy that can be achieved in the fatigue analysis**



Damage equivalent load (DEL) for shear force at tower bottom

unfiltered time series    filtered after 1st eigenfrequency    filtered after 2nd eigenfrequency    filtered after 3rd eigenfrequency
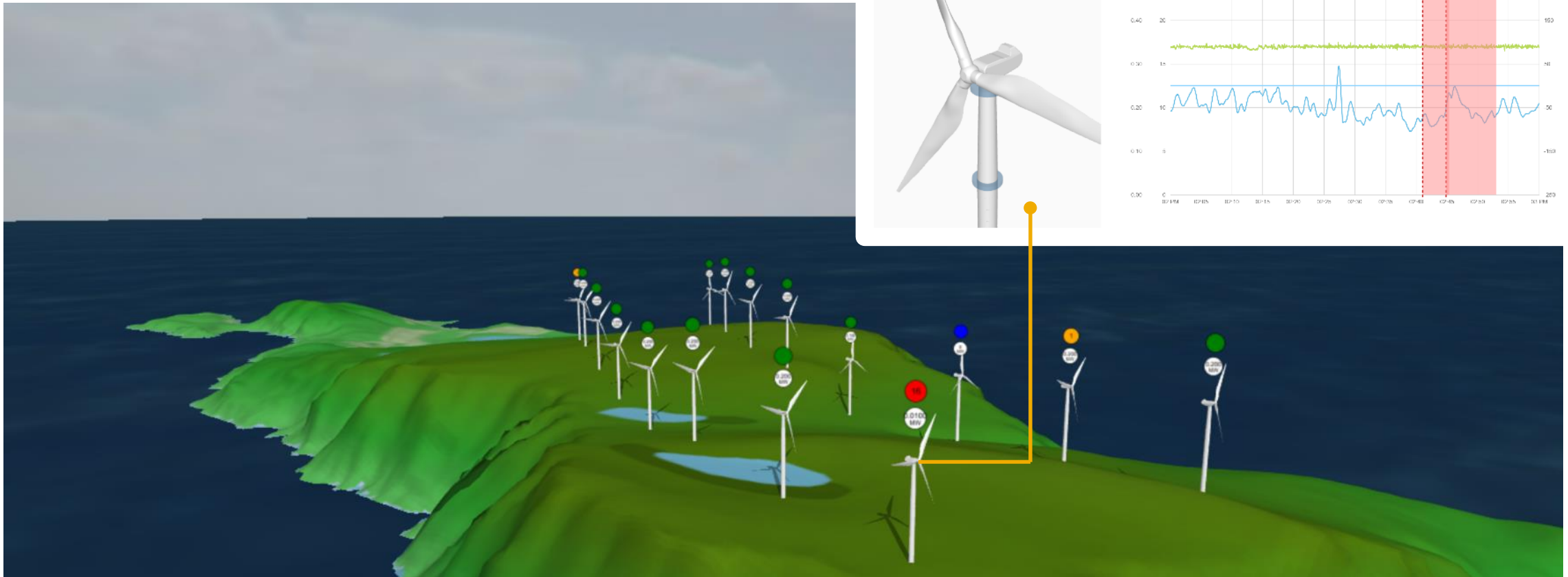
# Simulation studies and further work

- **Bottom-fixed and floating offshore wind turbine**

- **Extending the solution to cover complete wind turbine system**

- **Transferring technology into other industries**
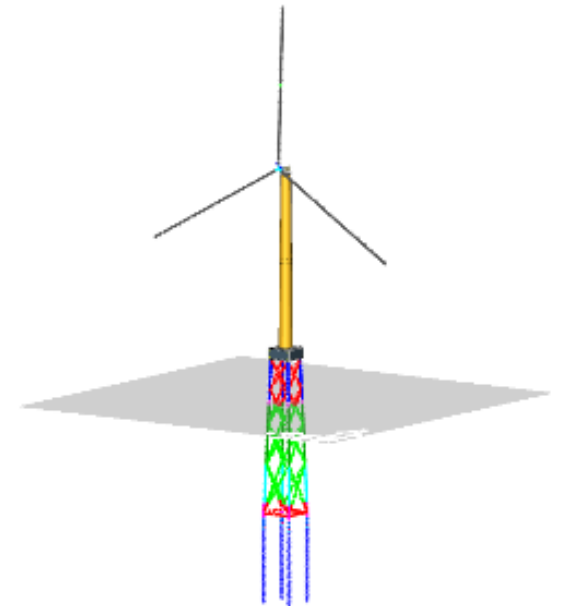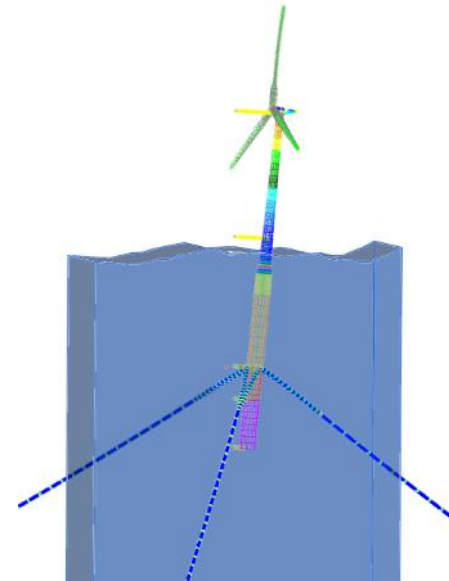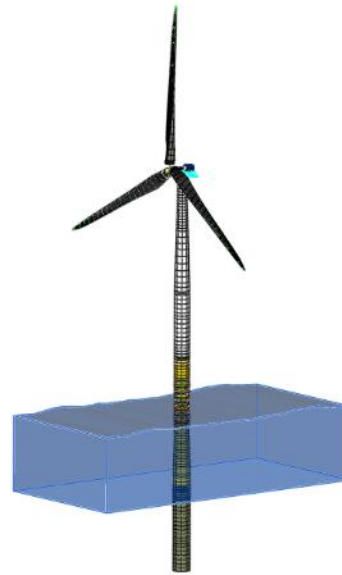
# Digital twin based structural integrity monitoring

from **Things**

**Thank you**

**SAP**

to **Outcomes**