Digital Twins for an Integrated Design and Operation Methodology for Large Offshore Wind Turbines

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Motivation – Utilize the full potential of offshore wind energy with larger offshore wind turbines

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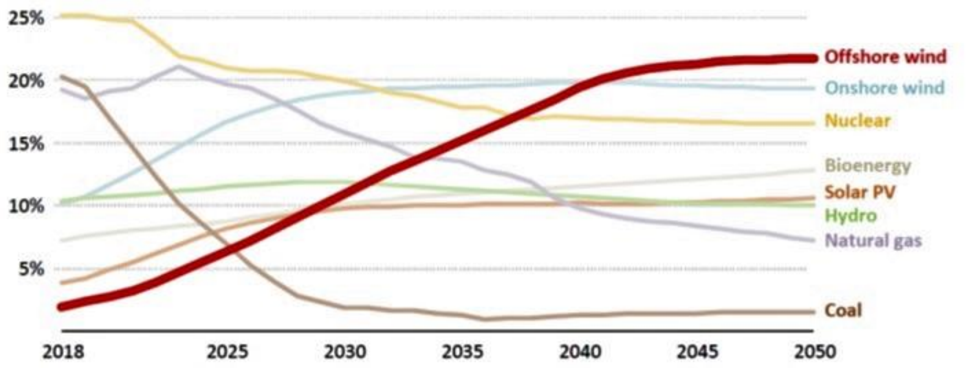
Decarbonisation

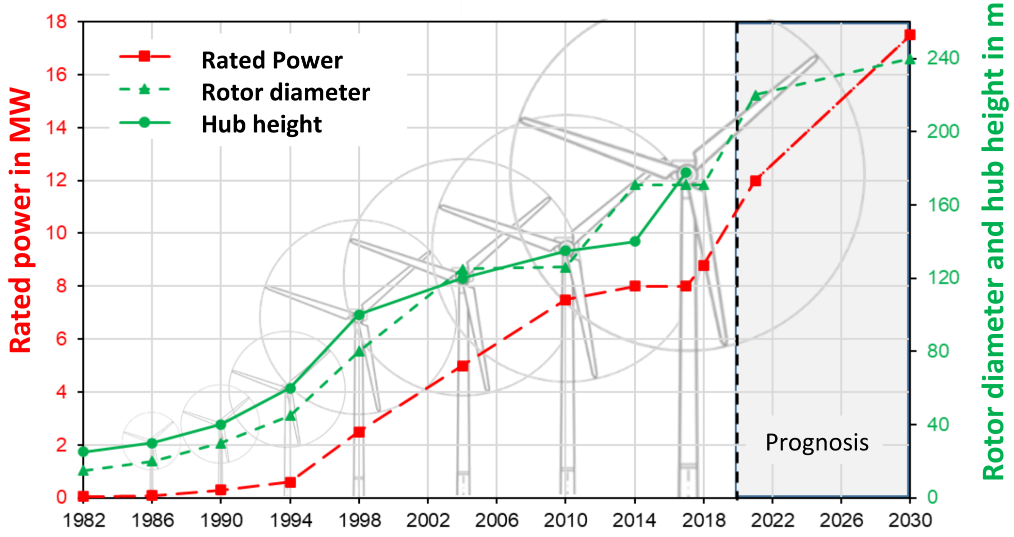
- target: decarbonisation of the energy system in the coming decades
- offshore wind energy is an essential tool
- to realize its potential more efficient turbines are needed

Increasing Dimensions

- advantages
  - more (economically) efficient power generation
  - more continuous power feed-in
  - more cost-effective logistics and maintenance
- challenge
  - simply upscaling not possible due to highly nonlinear interactions which govern the behaviour
  - new integrated approach needed



share of energy produced in the EU (IEA)



development of rotor size

Vision – Use Digital Twins for an integrated design and operation methodology

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Current Approach

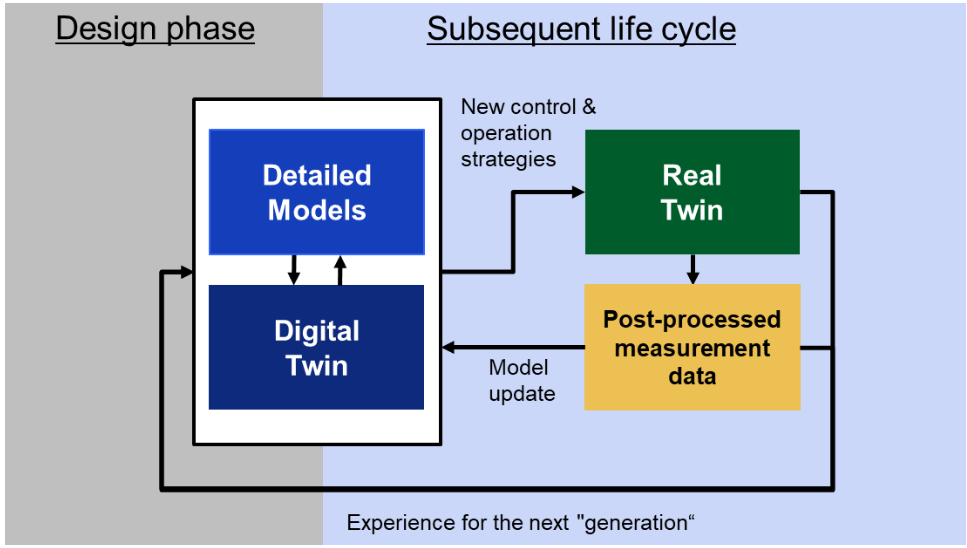
- sequential design
- components considered individually
- usually linear

Vision

- integrated design process
- coupled considerations of all components and environment
- complete life-cycle considered in design

Digital Twin

- basis for design and operation process
- virtual image of the complete wind turbine
- combination of partial models for a dynamic nonlinear model
- demands for this model:
  - coupled
  - real-time capable
  - adaptive
  - individualised



vision of the Digital Twin in operation

Advantages

- entire life-cycle considered in design
- virtual testing of control strategies
- lifetime prediction based an true current state
- condition-based maintenance

Methods – Ensure the applicability of the Digital Twin by using appropriate approaches

Coupled: Mid-Fidelity Methods

- coupling of aerodynamic and hydrodynamic flow and structural deformation by load computation, considering environmental conditions, e.g., soil, scour
- structure: multibody approach, geometrically exact beams for 1D-FEM
- fluid: vortex methods, e.g., unsteady vortex lattice method
- conservation of invariants (energy, momentum) by appropriate time-integration scheme
- consideration of control system for realistic description of turbine

Real-time: Reduced Models

- detailed models reduced before implementation into Digital Twin
- efficient numerical computations
- parallelization
- robust time-integration scheme
- physical instead of empirical models as the boundary conditions are not yet well known (e.g. Prandtl/Ekman layer)
- changes in boundary conditions over time considered (e.g. seabed changes)

Adaptive: Model Updating

- update of the Digital Twin to correctly resemble the current status of the real twin at certain time intervals
- concepts tested either on simulated data or similar structures
- robust monitoring concepts
- consideration of uncertainties
- state-identification and artificial intelligence for structural health monitoring

Application – Combine partial models into one Digital Twin with interdisciplinary research

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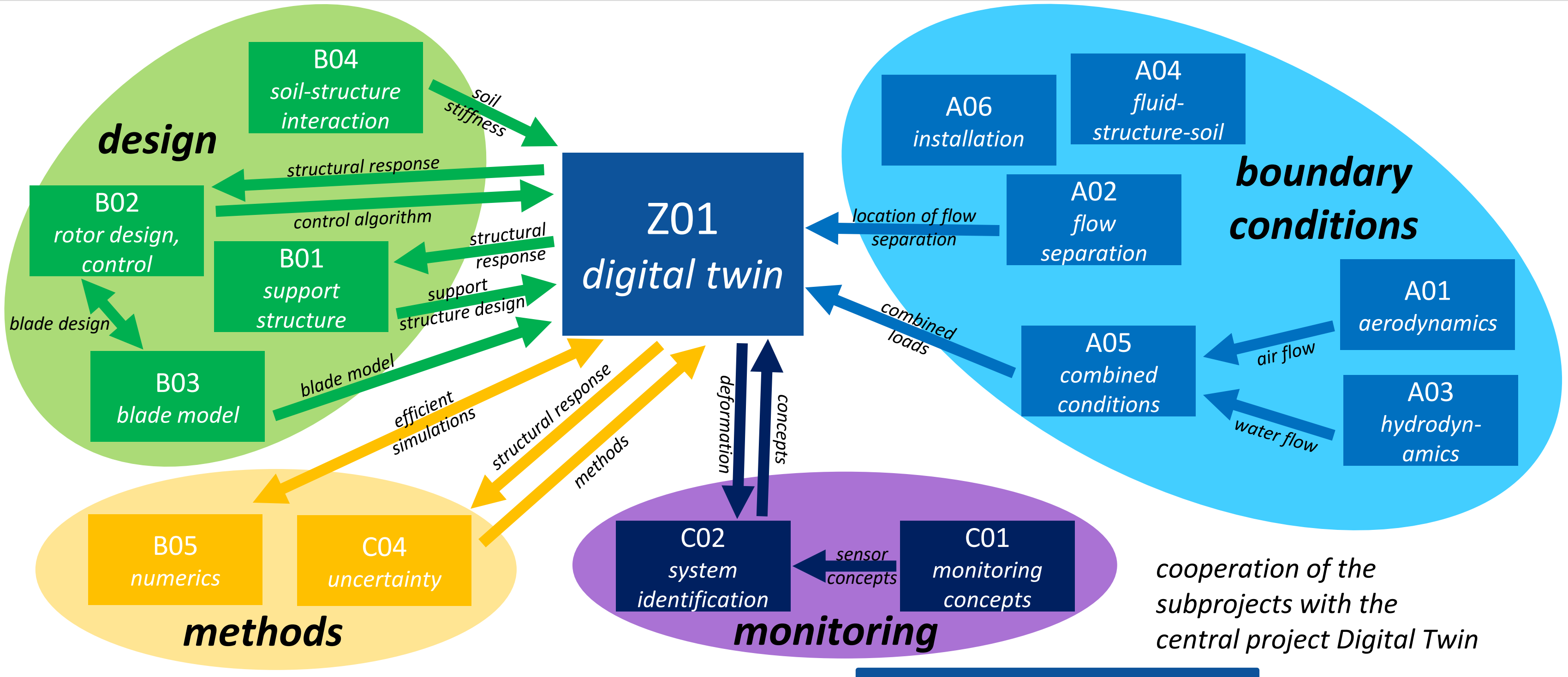
Research Process

- investigation of phenomena and development of detailed models in the areas
  - Boundary Conditions
  - Design Principles
  - Control and Monitoring
- coupling of reduced models into Digital Twin



cooperation of the subprojects with the central project Digital Twin

Project: CRC 1436

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