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Modular Simulation Platform for Integrated Energy Systems

Tobias Meyer

Fraunhofer IWES

Why do we need a new simulation platform?

Engineering in wind energy is dependent on models and simulations, which are specific for each use-case

With systems engineering,
wind farm control,
hydrogen integration,
integrated energy systems,… the scope of our system model is larger than ever
…and the system is continuously changing!

We want to transfer the modularity of a wind energy system to model setup

We want to incorporate data from the physical system

The model shall be system and cloud provider agnostic to allow for long-term usage

The model shall be valid for a long time, system changes shall be tracked and represented in the model

Simulations must be efficient and parallelizable to allow for HPC usage

We want to model the system using automatic submodel interconnections

Established simulation models must be incorporated into the full system model

We want it all!

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Why do we need a new simulation platform?

What we want

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We want to model the system using **automatic submodel interconnections**

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We want to incorporate **data from the physical system**

What this means

Individual component models	Component model Management
System structure modeling	Time-based simulation
Simulation management, Optimization	Data Management, data inputs

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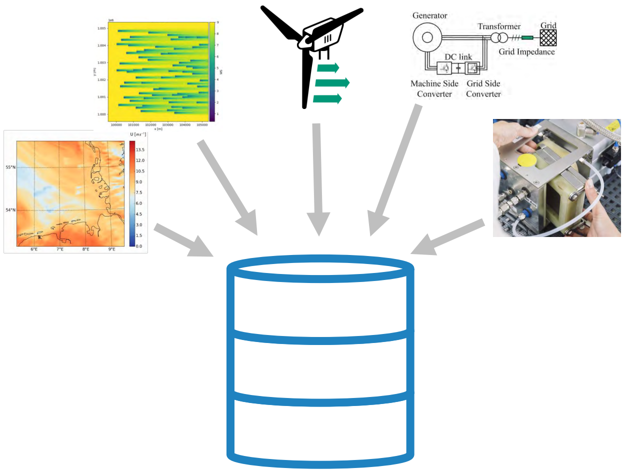
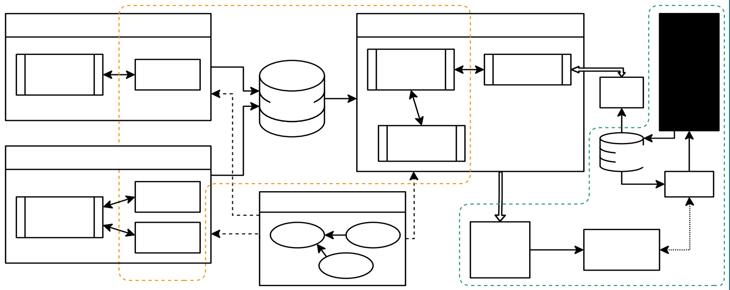
Concept of Simulation Platform

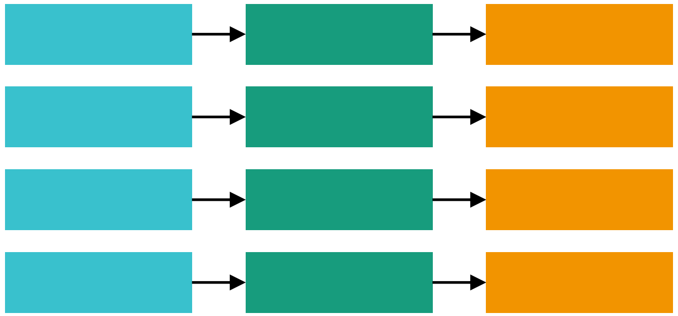
Database of component models



Automatic assembly into full system model



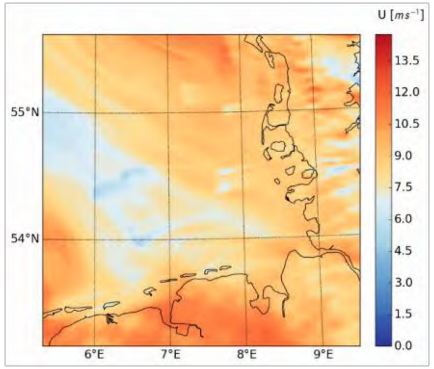
Automatic system simulation and analysis



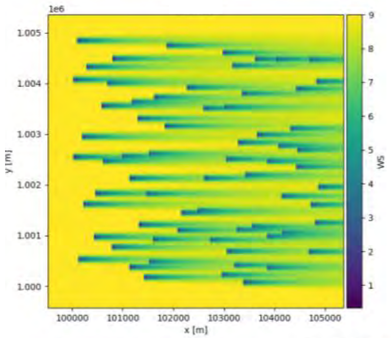
Configuration | Simulation | Evaluation

Library of IWES component models

IWES component models cover the whole spectrum of wind energy conversion



Large-scale wind simulations

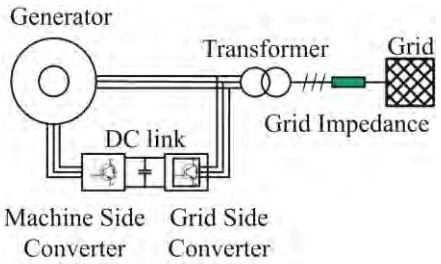


Local wind field in wind farm

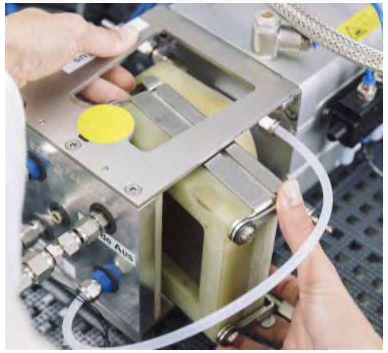
[https://github.com/Fraunhofer IWES/foxes](https://github.com/FraunhoferIWES/foxes)

Aeroelastic wind turbine

http://www.mowit.info



Electrical drive train subsystem



Electrolyzer system

Co-Simulation for Tool Independency

Co-Simulation with FMU

FMI is a standard interface for simulation models

Can be exported from over 100 software tools

Dynamic simulation in time domain

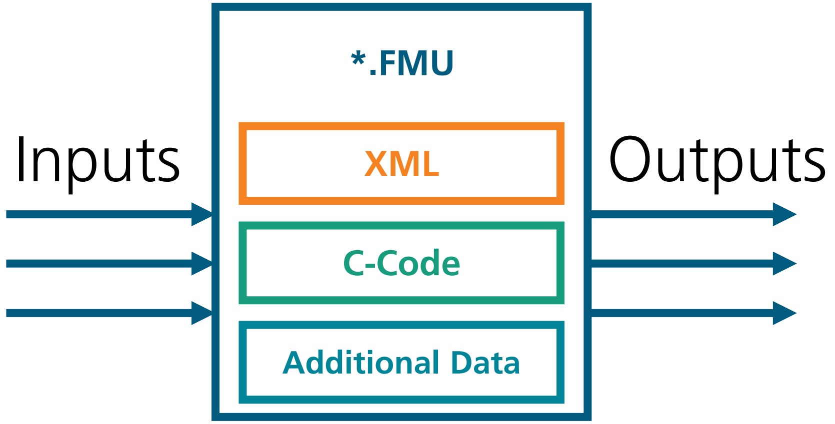
Problems with FMUs:

- No instruction of how to build model interfaces
- No additional information e.g., what is described by the signal?

Coupling on physical level more intuitive?

Standardized interfaces for model inputs and outputs?

- → Currently working with power bonds to solve this issues
- Power bonds give a basis for physical model coupling



https://fmi-standard.org/

Model Interface Design Guideline

Power Bonds and Multi-Signals

How can we ensure compatibility of component models?

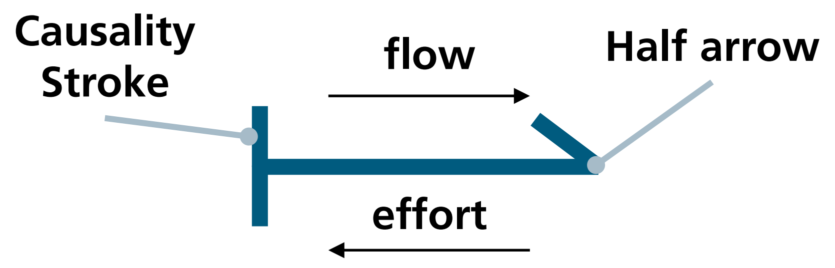
Power Bonds

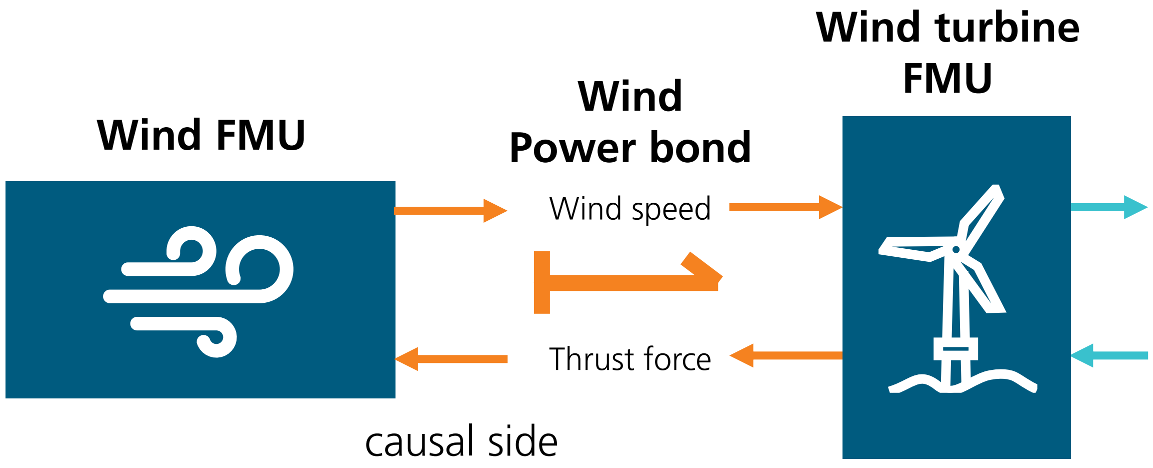
- Define standard interfaces for all power domains
- Power is split into effort (a potential) and flow (energy carrier)
- They have opposite causality
- Physical coupling is ensured in this way

→ Power Bonds help us to define interfaces, which are then implemented in submodels

Multi Signals

- Modelling of controller connections
- Exchange of information





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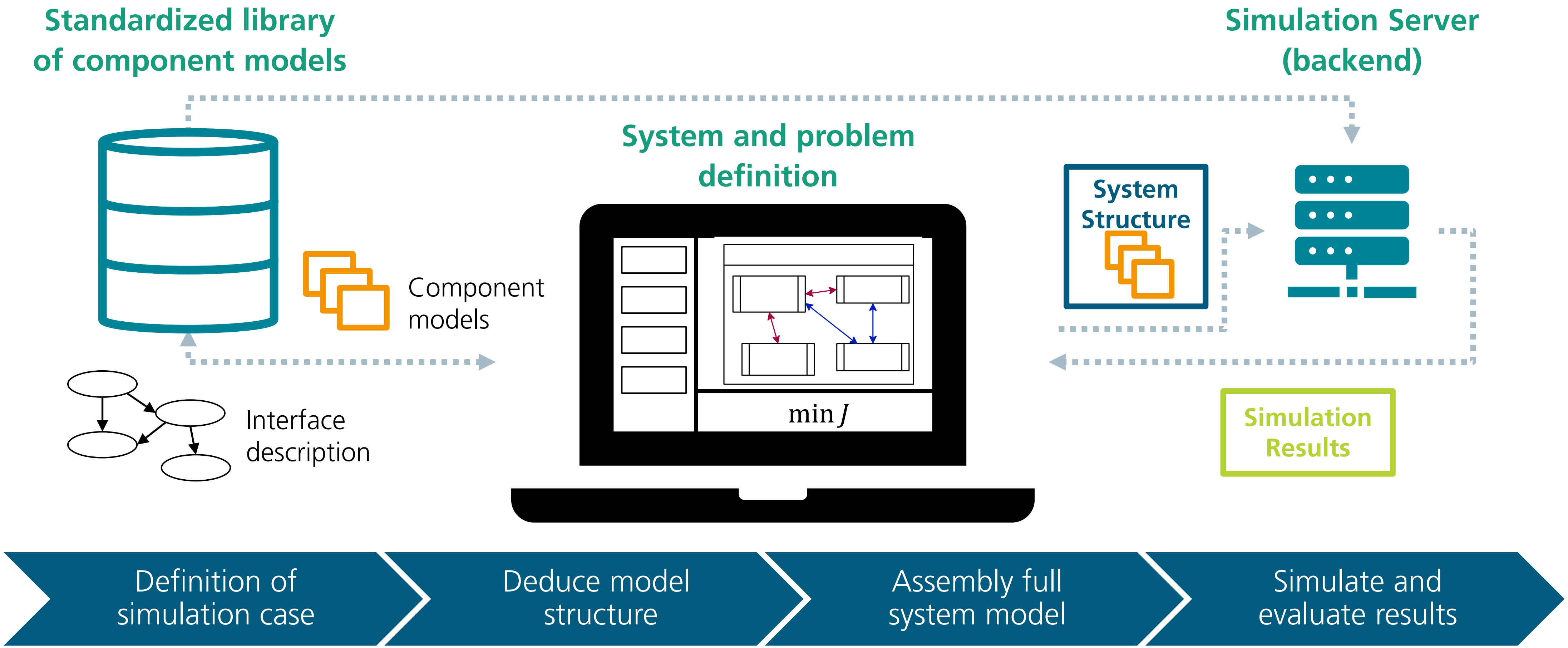
Usage Concept of Simulation Platform



Example for an Integrated Energy System

System modelling is made easier

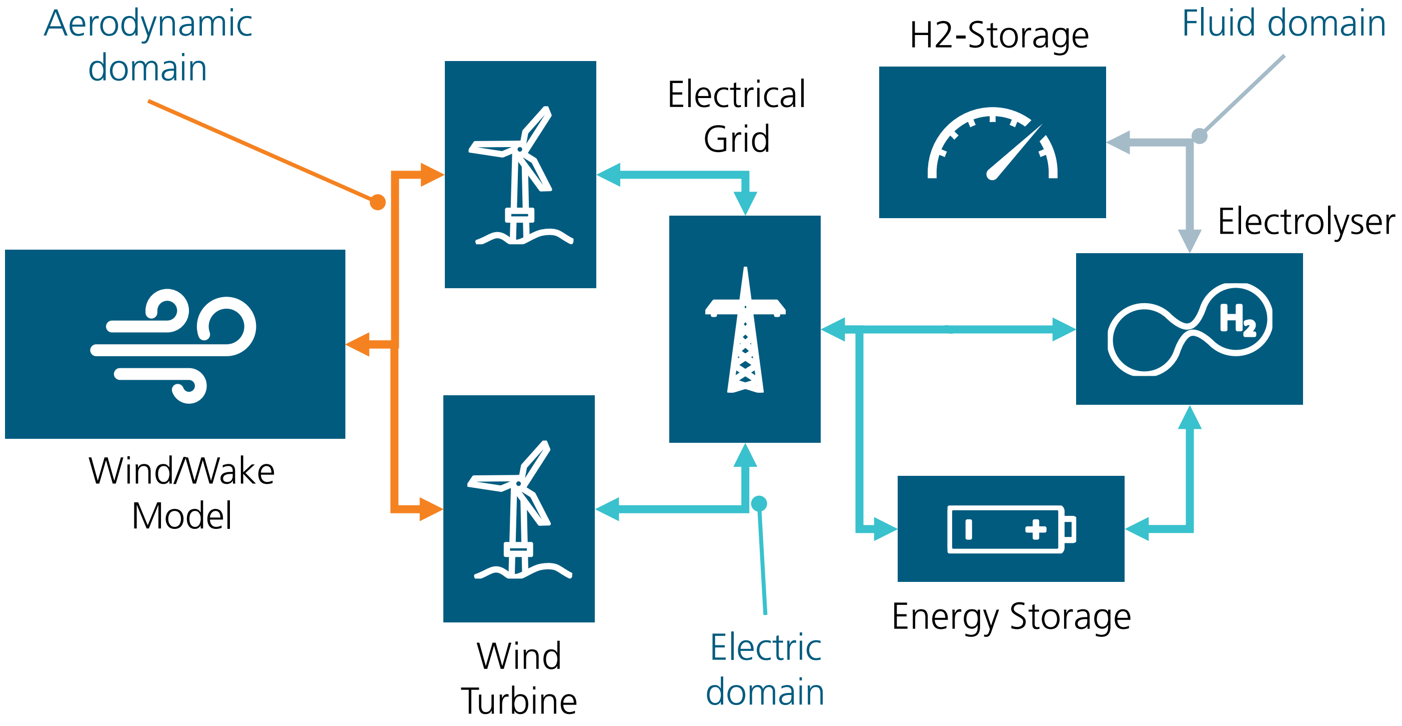
Mindset in simulation platform: Think of Energy flow

- Separation of energy domains
- Based on Power Bonds

Abstractions removes handling all inputs and outputs of models

Define the questions to be answered, e.g.

- What components do I need to support my energy needs?
- What is the best mix and what is available?
- Is my system robust enough?



Definition of simulation case → Deduce model structure → Assembly full system model → Simulate and evaluate results

Meta data and Ontologies

Model interface description

Interfaces are documented in an ontology

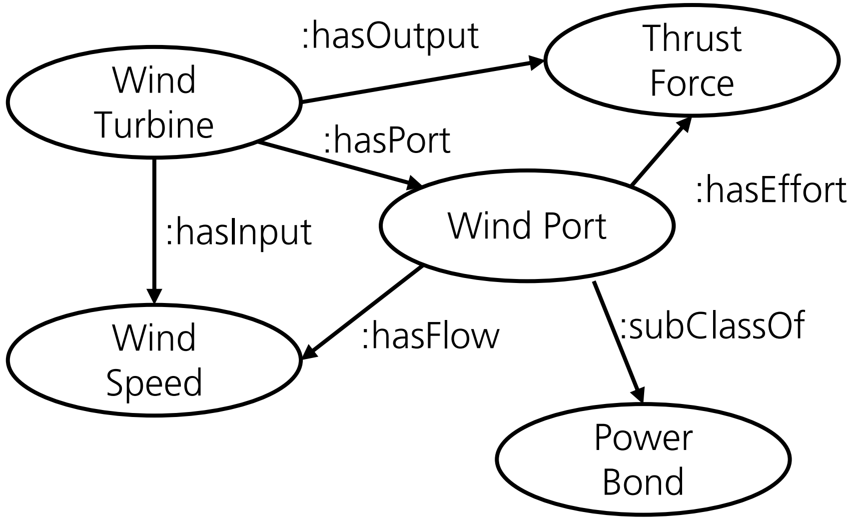
System structure and meta-information are combined

Every FMU model interface is described in ontology

Meta data definition

Unique identifiers for simulation variables with definitions

This makes distinguishment of data possible for efficient post processing



Definition of simulation case → **Deduce model structure** → Assembly full system model → Simulate and evaluate results

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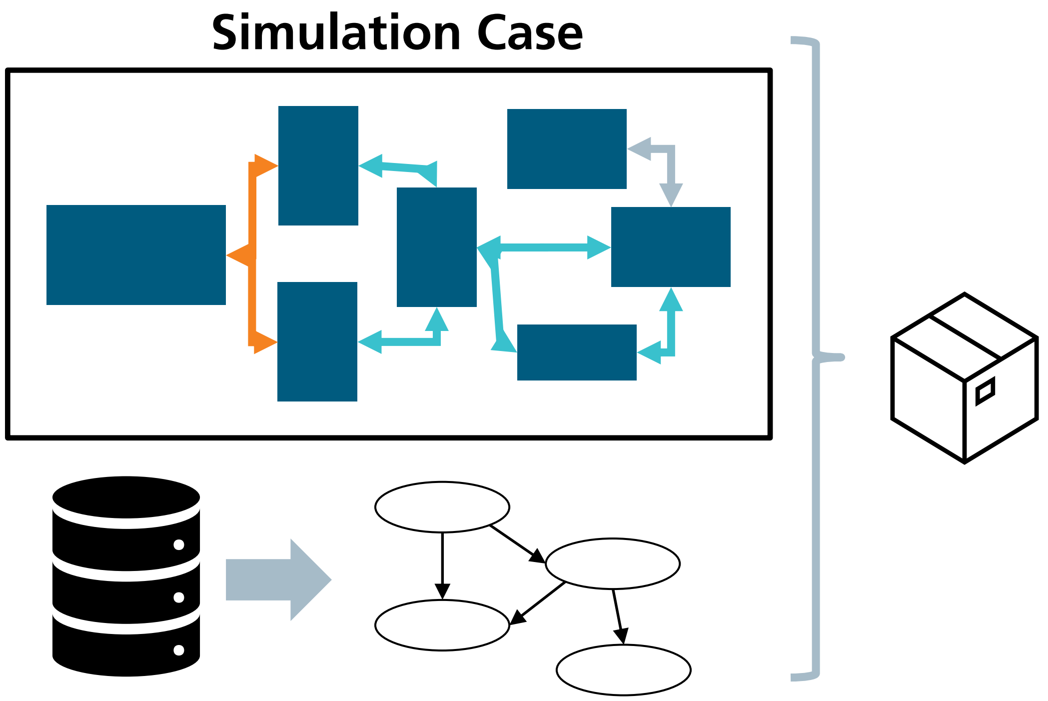
Combination of multiple systems into one simulation model

System structure and meta-information are combined

Meta-information is processed from ontology

Full system model is packaged and augmented with simulation information

➔All information required for an individual simulation is packaged independently



Definition of simulation case → Deduce model structure → **Assembly full system model** → Simulate and evaluate results

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Combination of multiple systems into one simulation model

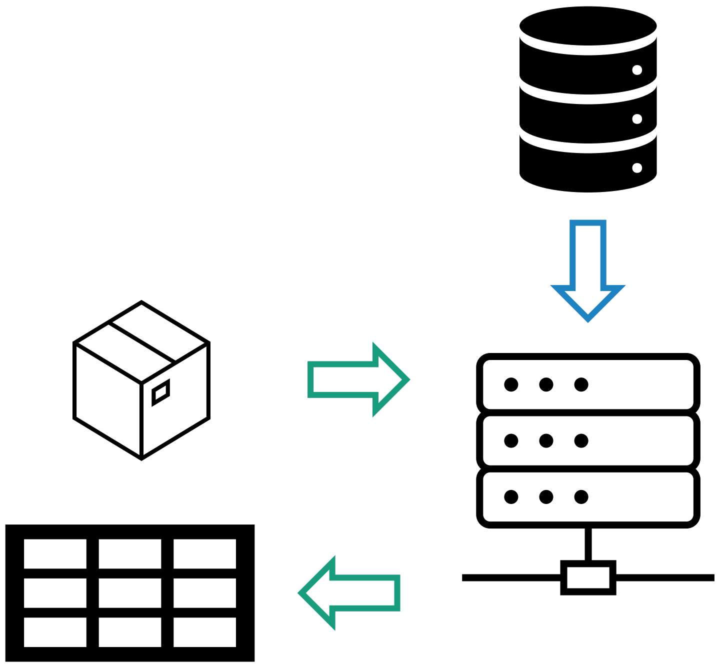
Simulation server receives full simulation package

Models are loaded from the data base

Simulation results are returned

Multiple simulations can be run in parallel
- Highly scalable

➔Structured solution for many simulations

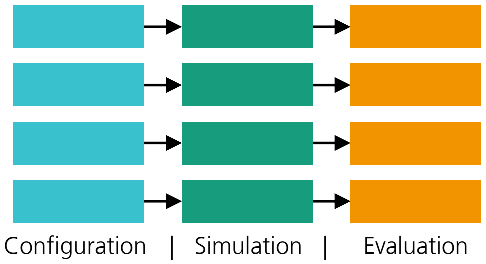


System simulation and analysis

Scenario simulations

„Simulate a wind turbine for wind speeds 2,4,6,…16 m/s and turbulence intensity 10%, 20%.“

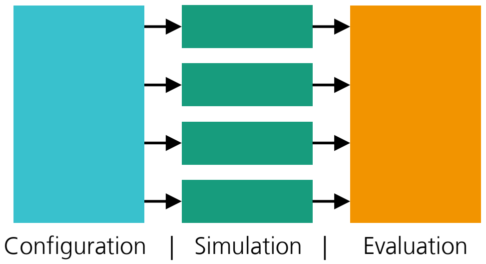
- Deterministic parameter variations
- Manual or specific evaluation of results



Monte Carlo Simulations

„How does an uncertain parameter affect system performance?“

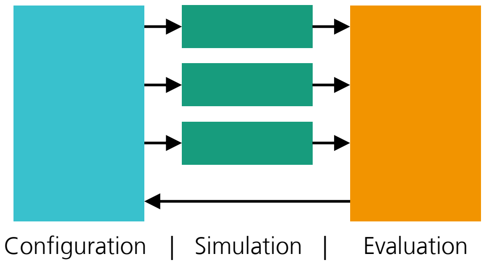
- Stochastic parameter variations
- Automatic post-processing of results



Optimization

„Find operating parameters that yield minimum cost.“

- Automatic parameter variations
- Permanent evaluation of results



Stability

„Does a wind farm work as a full system?“

Functional Safety

„Is the turbine safe?“

Economic feasibility

„Is this a business case?“

➔Multiple methods for configuration, simulation and evaluation allow for flexible usage

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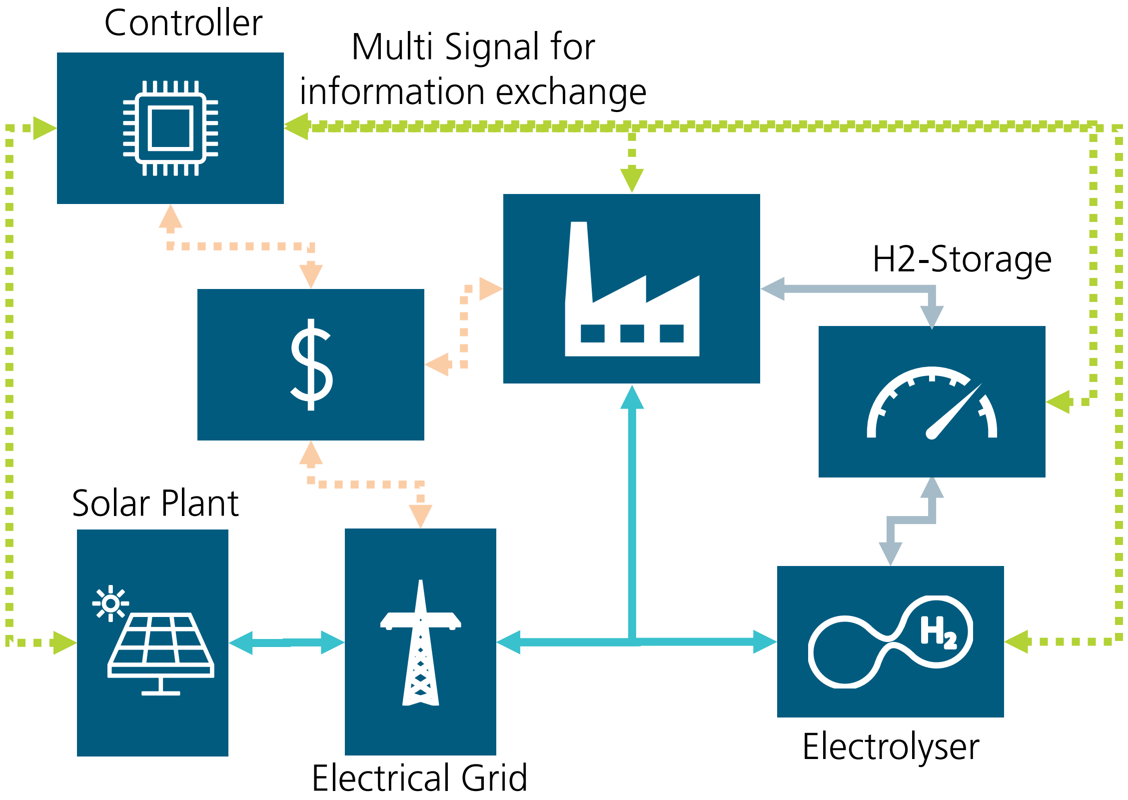
Examples for systems modelling

Energy System for Factory Production Management

Model with many different aspects and parts
- Energy production, factory processes and controllers
- Dynamic simulation in the time domain

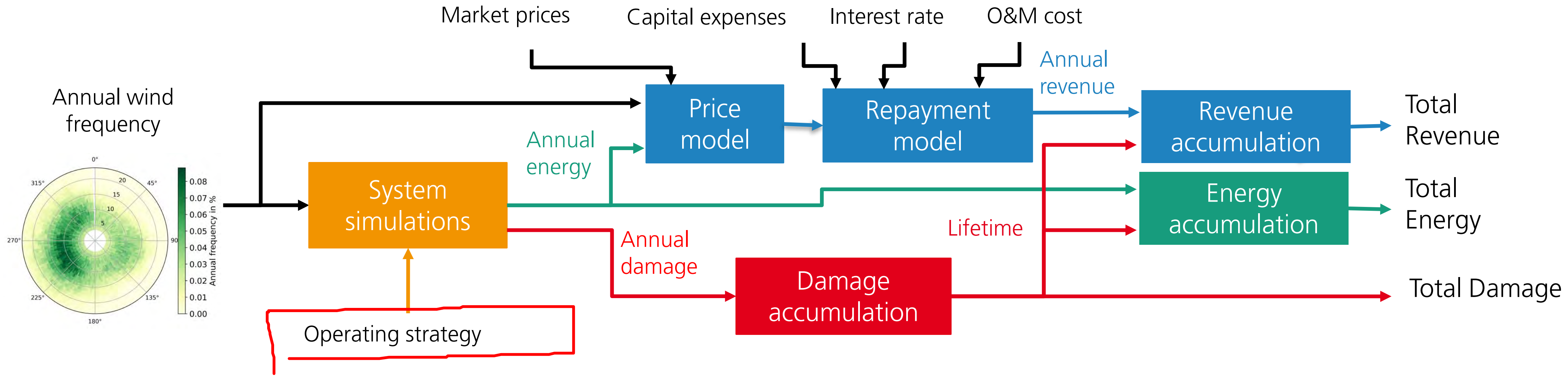
Separation of domains
- Power exchange deals with physical model interaction
  - Ensures coupling is possible
  - Supports model creators
- Information distributions in specific multi signals
- Helps in energy system modelling and gives clear overview for the full model

Simulation setup for optimization
- Optimal control problems
- Decision problems



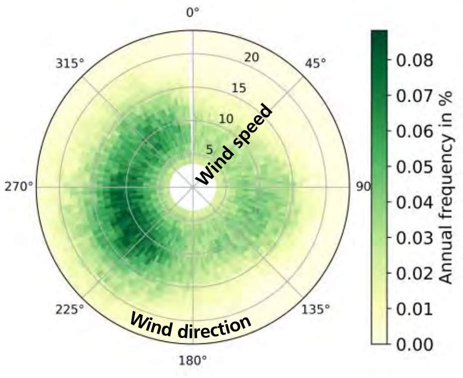
Use case: Operational optimization

Goal: Maximize revenue from existing components
Approach: Model-based optimization for all operating conditions over full lifetime

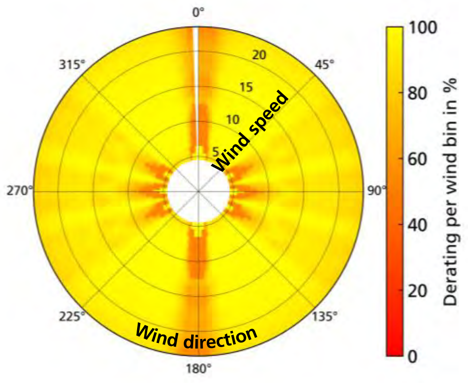


Challenge: Aging of electrolyzer components must be taken into account
Result: Planned operation of all turbines for entire lifetime

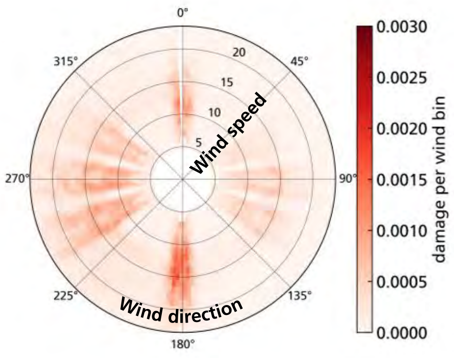
Use case: Operational optimization



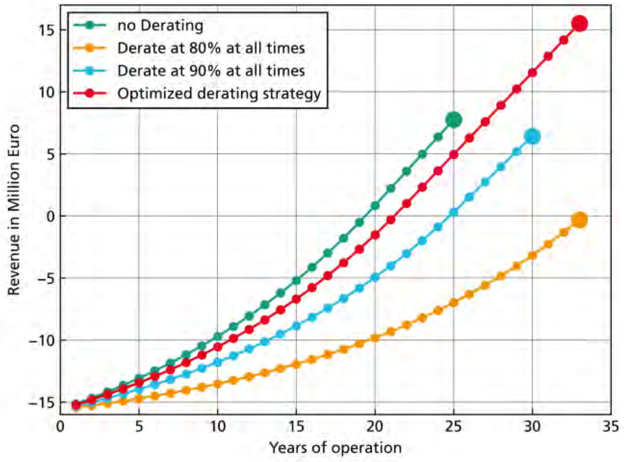
From wind distribution



to planned operation



to planned damage progression



to optimized lifetime, yield and revenue

➔Only the combination of multiple models allows for computation of trade-off between energy and damage
➔Clever planning of operation can yield large increase in lifetime and revenue

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Simulation Platform as Basis

H2Digital

- Meta data management
- Co-Simulation platform connected to meta data
- Connection to data from physical system
- Energy system modelling

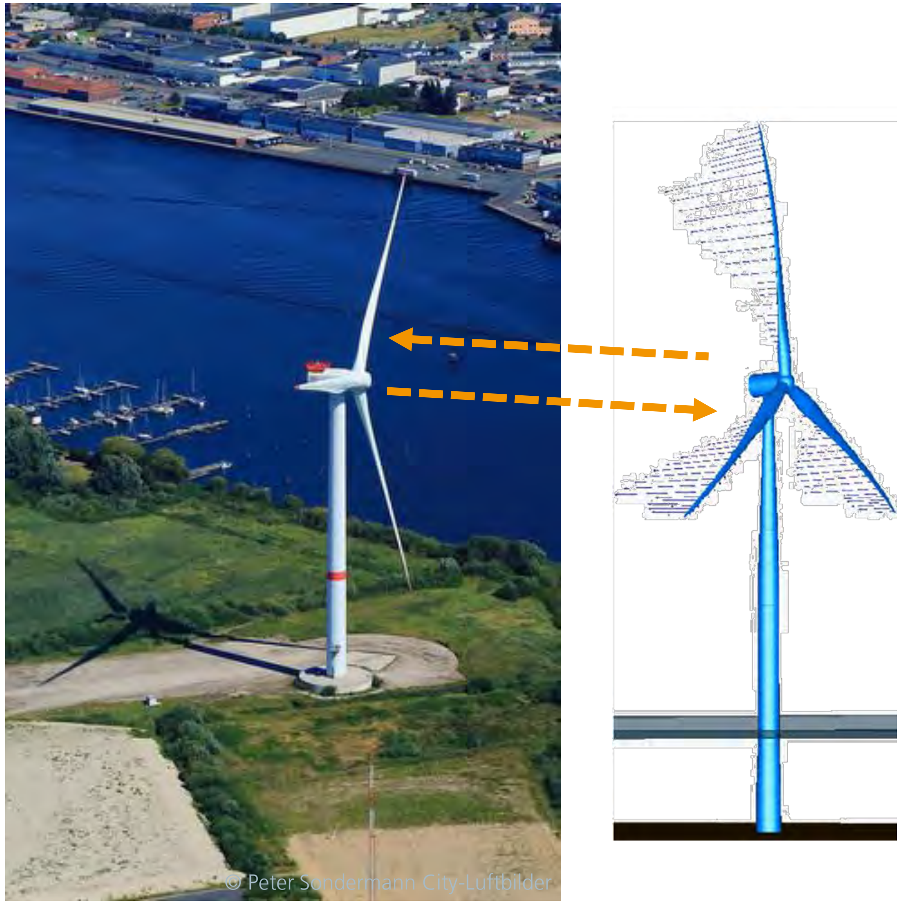
DigiWind – Digital Twin of a Wind Turbine

- Setup of a digital twin platform
- Development of digital twin services and applications
- Models from simulation platform are used for digital twin applications

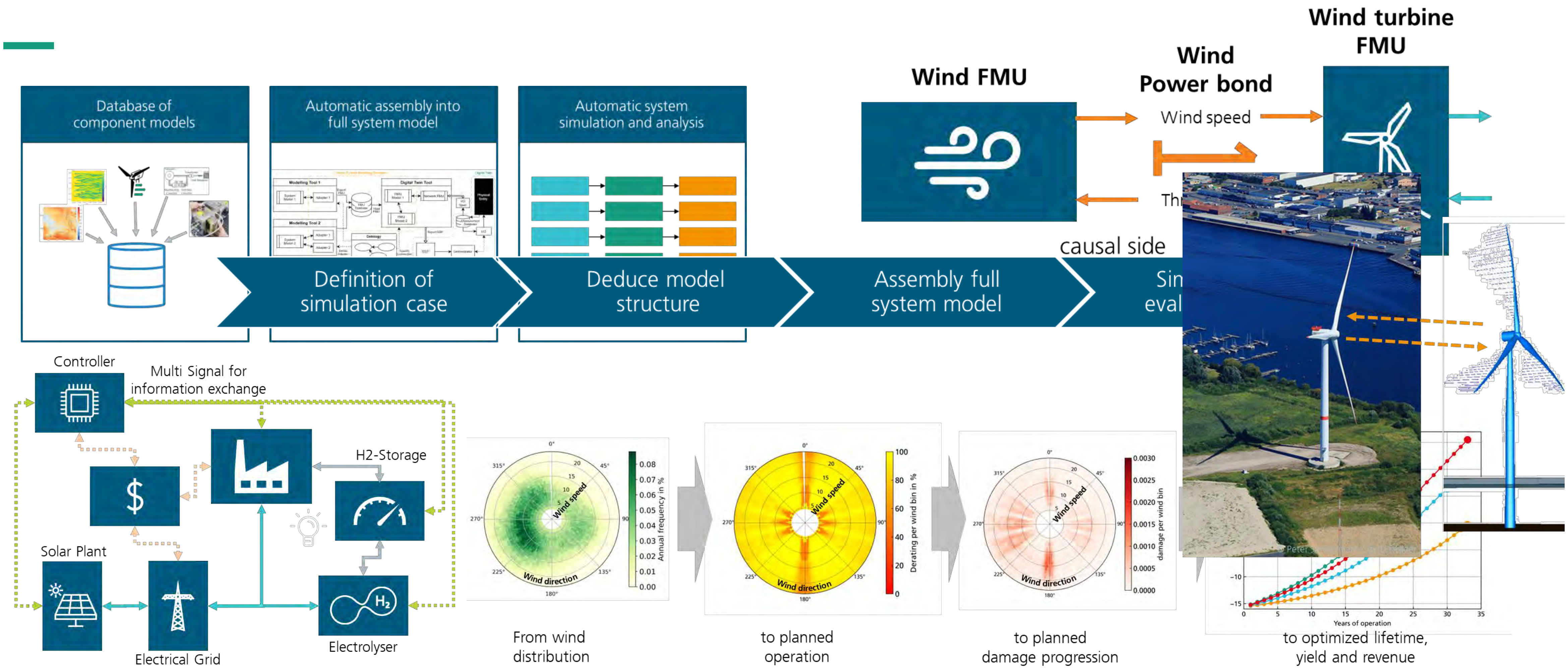
H2-Mare-OffgridWind

- Offshore hydrogen production without grid connection
- Evaluate functionality of a hydrogen-producing wind farm
- Ascertain safety of hydrogen-producing turbines
- Optimal operation concepts for wind turbines with additional hydrogen-specific components

We are building a dedicated simulation tool for large modular systems to tackle these challenges!



Conclusion and Outlook



The simulation platform integrates various models and forms the basis for answering complex questions!

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Thank you for your attention!

Contact

Tobias Meyer
Advanced Control Systems
Fraunhofer Institute for Wind Energy Systems IWES
Am Seedeich 45
27572 Bremerhaven
Germany

Phone +49 471 14290-417
tobias.meyer@iwes.fraunhofer.de

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