Leitprojekt H_2Mare

Fraunhofer IWES

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Systems modeling and optimization of the coupled wind turbine-electrolyzer system

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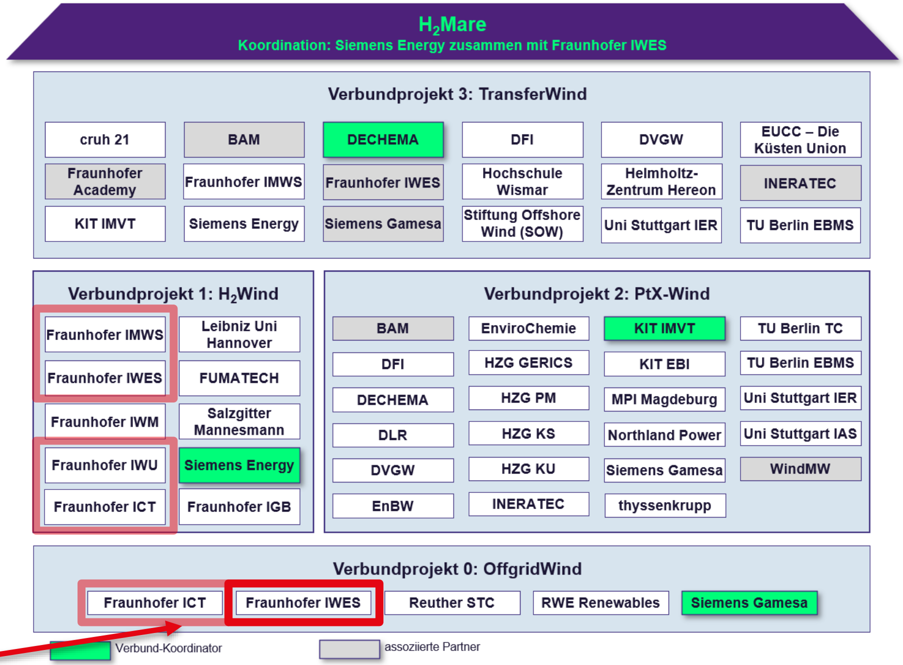
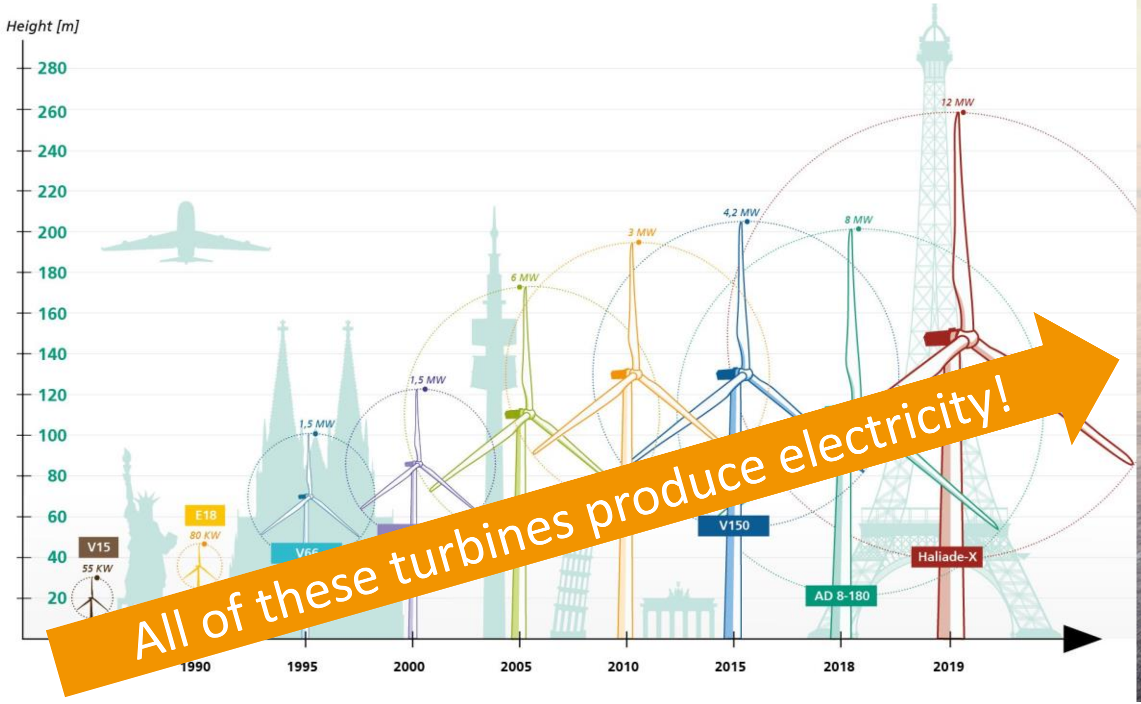
IWES simulation and digitalization works in H2Mare



Contents of this talk are mainly one piece of the entire H2Mare project house!

Wind turbine evolution



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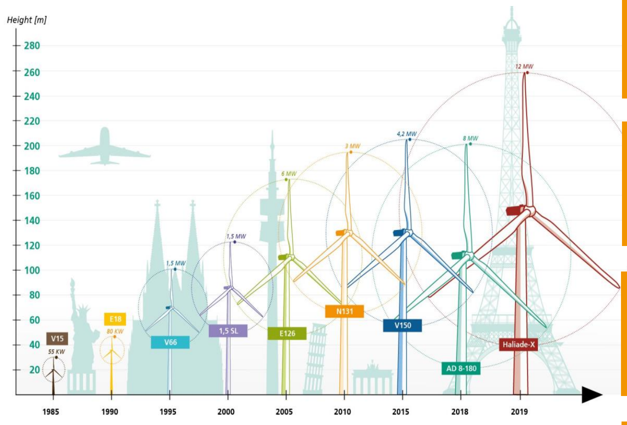
Our challenges



Electricity-producing	Hydrogen-producing
>50 years of development	New technology
Proven electrical components	Electrolyzers in harsh environment
Proven safety systems and fail-safe states	Hydrogen!
Proven operation on wind farm level	Solitary prototypes
Refined operating strategies	Additional fragile and aging components

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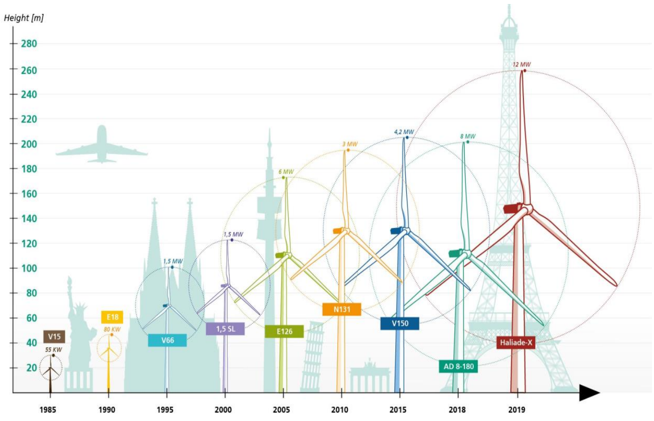
Our challenges



© Siemens Gamesa Renewable Energy

- We need to **predict the functionality** of a hydrogen-producing wind farm!
- **Safety of hydrogen-producing turbines** must be ascertained!
- Hydrogen-producing wind turbines require new **concepts for optimal operation!**

➔ We‘re building a **dedicated simulation tool for large modular systems** to tackle these challenges!

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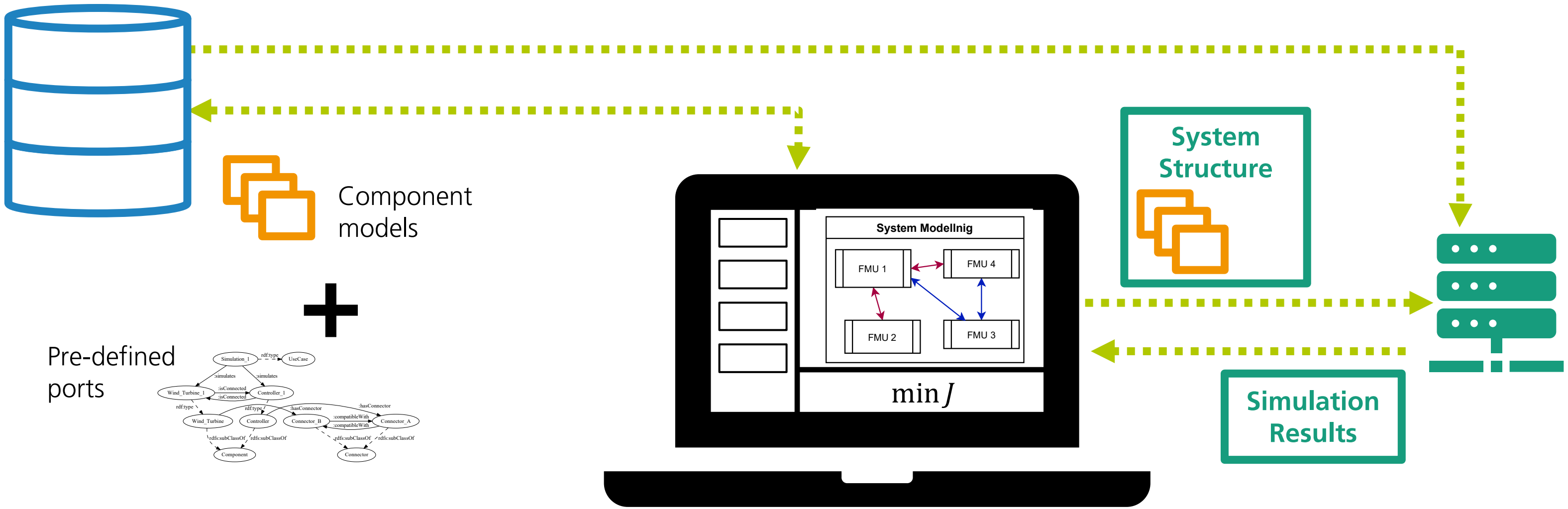
Concept of simulation platform

Standardized library of component models

System and problem definition

Simulation Server (backend)



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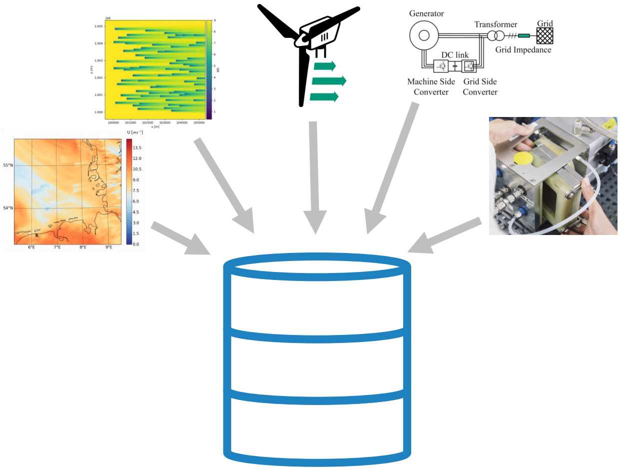
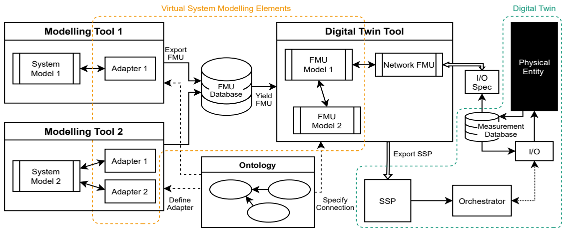
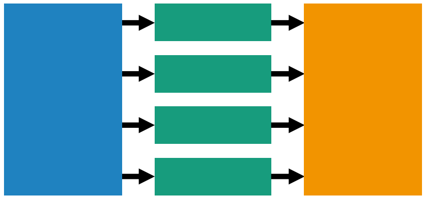
Concept of simulation platform







Provide components models for database

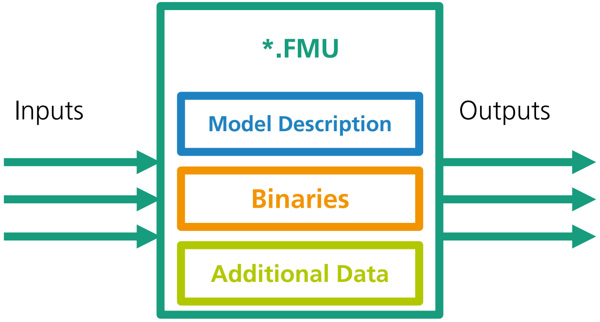
Combination of multiple systems into one simulation model

System simulation and analysis

Provide components models for database

- Component models are implemented in diverse simulation tools
- Standardized means for interconnection is required

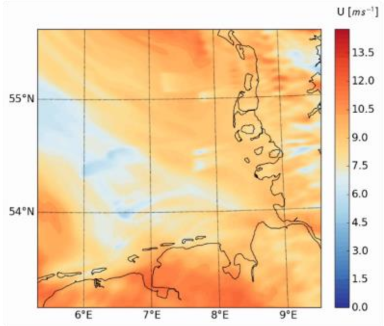
- FMU is a platform-independent exchange format for simulation models
- Almost every modelling tool exports to FMU
- Co-Simulation is used to combine component models



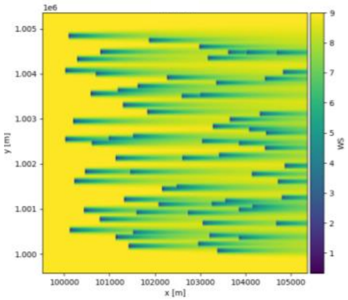
fmi Functional Mock-Up Interface

➔ FMU is suitable to equip our **existing component models with a common interface** for system simulation

Library of IWES component models

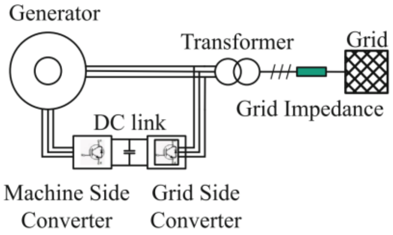


Large-scale wind simulations

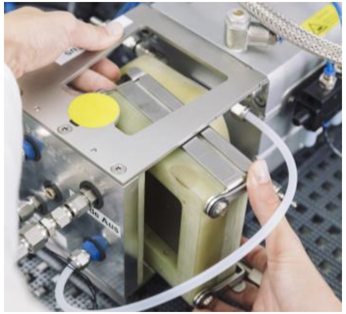


Local wind field in wind farm

Aeroelastic wind turbine



Electrical drive train subsystem



Electrolyzer system

→ IWES component models cover the whole spectrum of wind energy conversion

Combination of multiple systems into one simulation model

1. Definition of simulation case
2. Deduce model structure
3. Assembly of component models into full system model
4. Simulate and evaluate results

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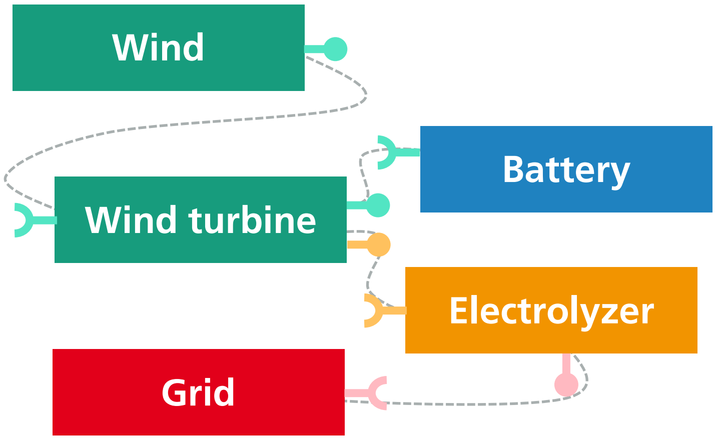
Combination of multiple systems into one simulation model

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

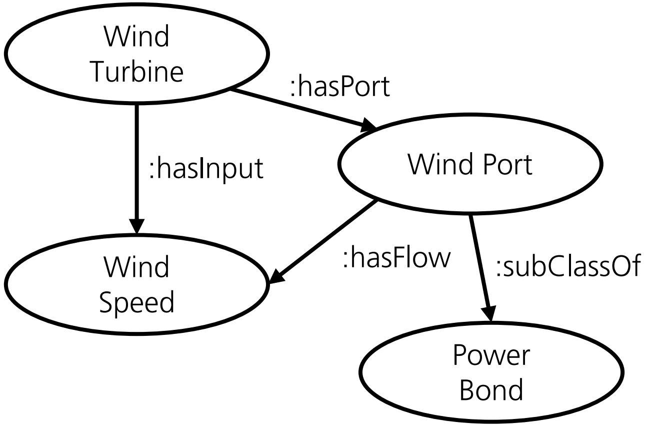


- User represents system structure
- Components are combined like puzzle pieces
  - Mindset in simulation platform: **Think of Energy flow**
- Pre-defined connectors are implemented in each component model
- Details of interconnections are not considered yet

→ Accessible means for modeling a complex system

Combination of multiple systems into one simulation model

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



- Component models and ports are represented in ontology
- Explicit definition of relationships between objects
- Computers can process ontologies

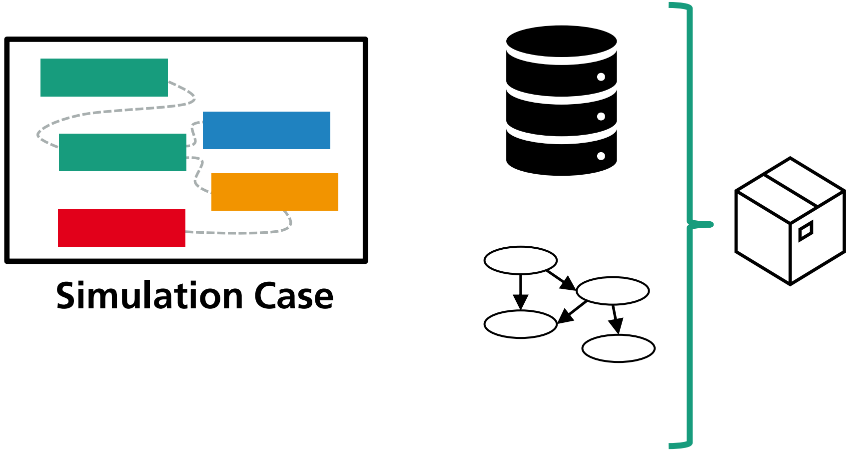
→ Model structure is derived **fully automatically** from user-input system structure

Combination of multiple systems into one simulation model

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

- 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 a simulation is packaged independently



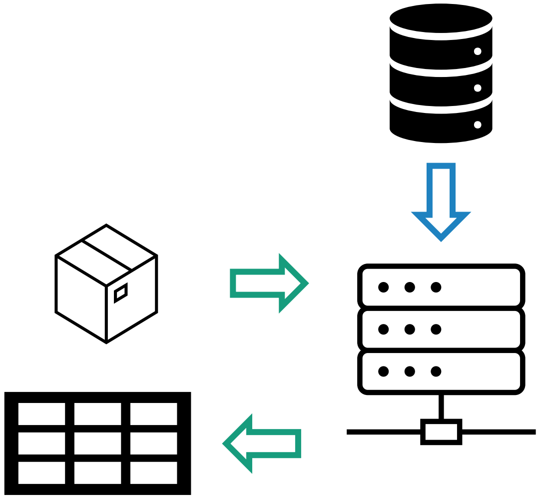
Combination of multiple systems into one simulation model

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

- Simulation server receives full simulation package
- Simulation results are returned *...and then?*

- Multiple simulations can be run in parallel
- Highly scalable

→ Structured solution for many simulations

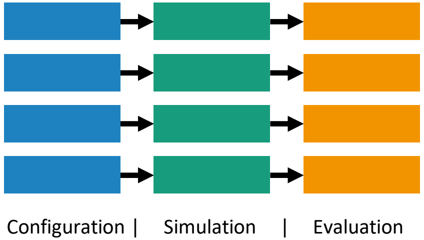


System simulation and analysis

Scenario simulations

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

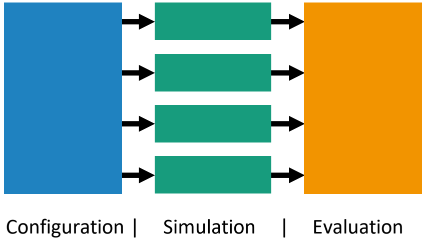
- Deterministic parameter variations
- Manual or specific evaluation of results



Monte Carlo Simulations

„How does an uncertain parameter affect system performance?“

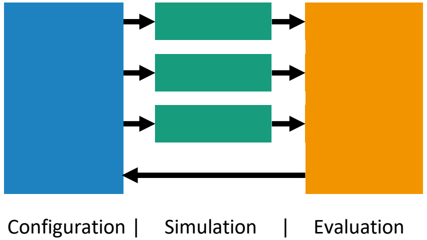
- Stochastic parameter variations
- Automatic post-processing of results



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?“

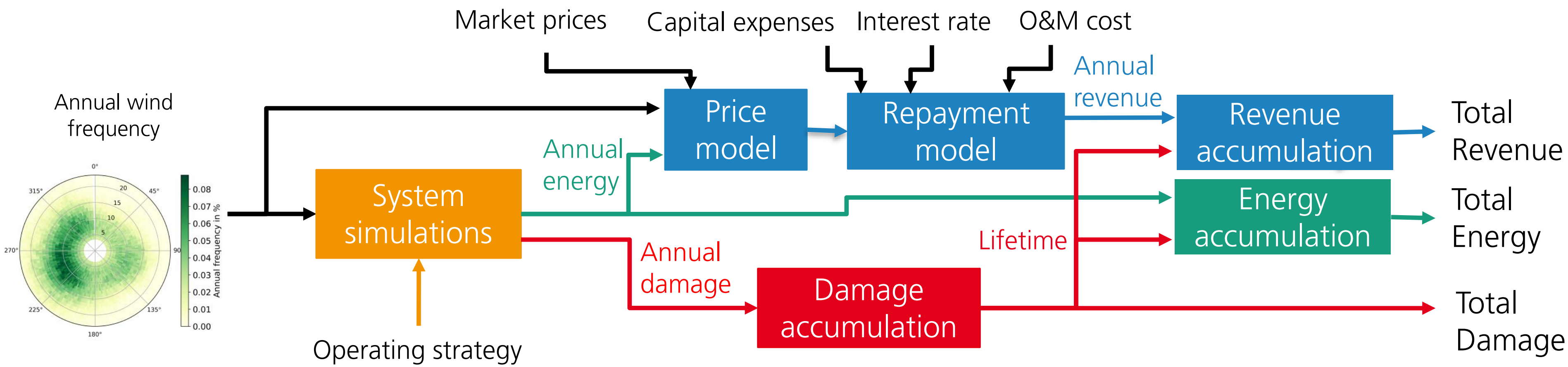
Economic feasibility

„Is this a business case?“

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

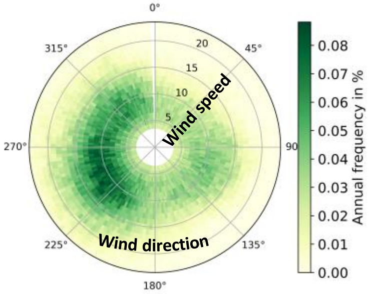
H2Mare use case: Operational optimization

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

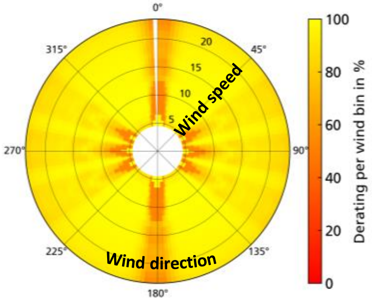


- Challenge: Aging of electrolyzer components must be taken into account
- Result: Planned operation of all turbines for entire lifetime

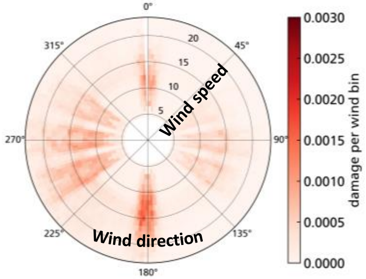
H2Mare use case: Operational optimization



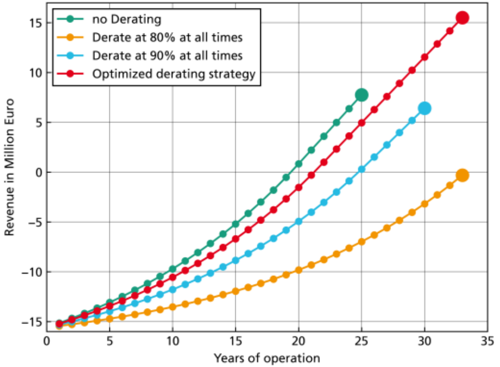
From wind distribution



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

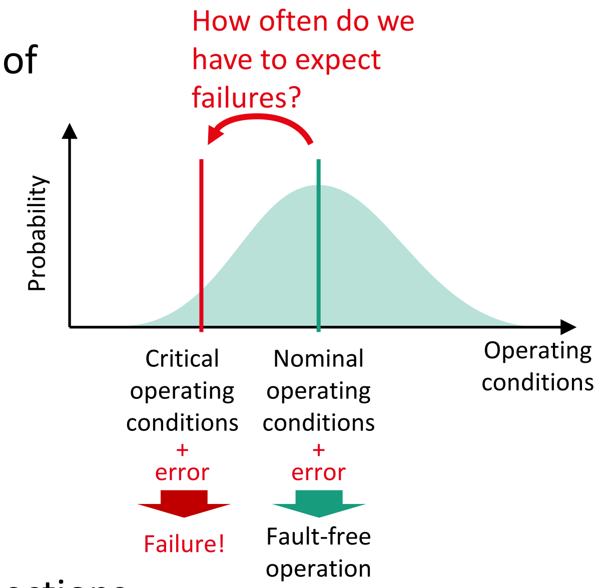
➔ Clever planning of operation can yield **large increase in lifetime and revenue**

H2Mare use case: Functional safety

- Goal: Ensure safety requirements are met
- Approach: Simulation of error in system and evaluation of system behavior

- Errors can be mitigated if taken into account
- Errors combined with critical conditions might lead to systematic failures
- To reliably detect systematic errors, deviations from the ideal operating conditions have to be taken into account
- To achieve this, SimDetect uses a Monte-Carlo approach

- Challenge: Complex system with non-intuitive interconnections
- Result: Failure probability is determined



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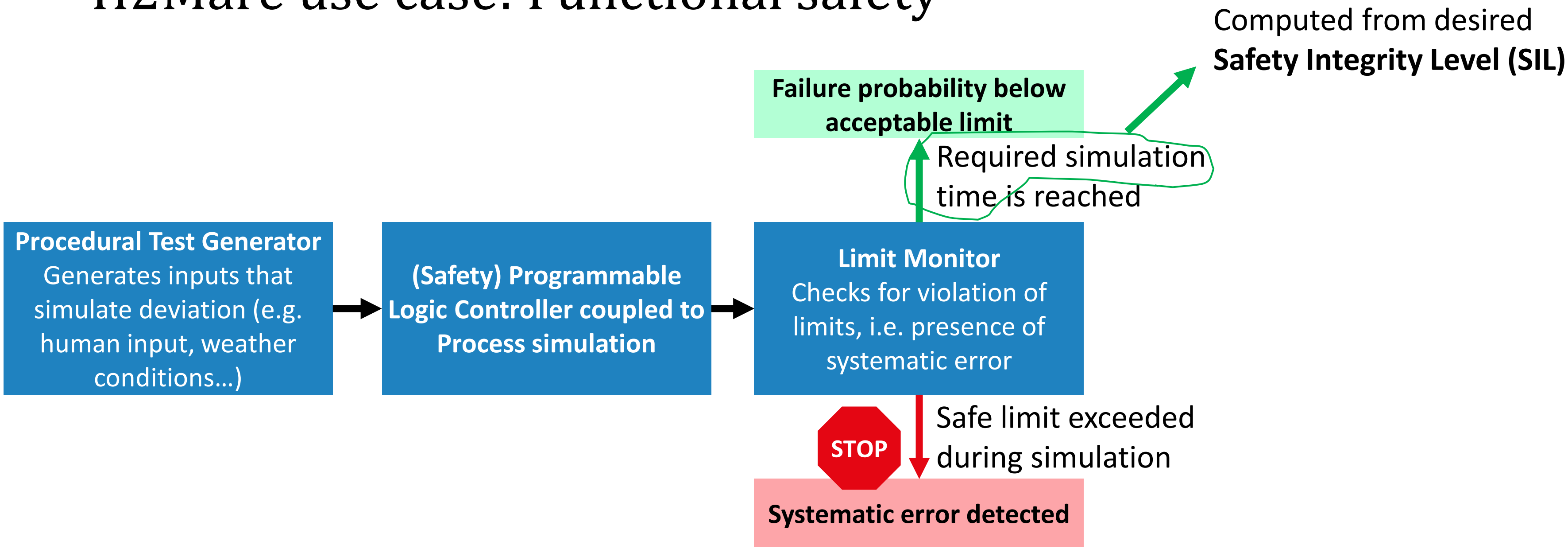
H2Mare use case: Functional safety



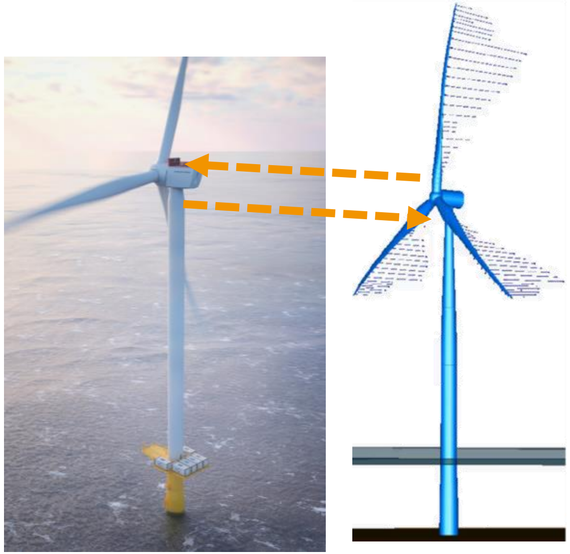
- Requires detailed model of the entire system

➔ Probability of failure due to systematic error can be determined

This is work by Fabian Frank @ Fh ICT

H2Mare use case: Simulation as basis for a digital twin

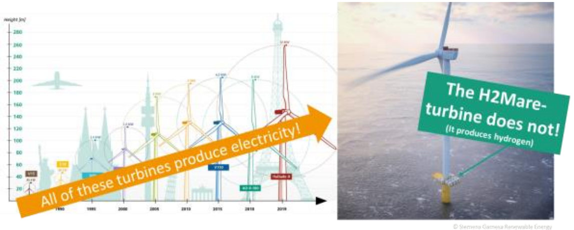
- Digital twins…
  - require bidirectional communication
  - model follows measurement data
  - insights from the model are fed back into the system
  - cover entire operational lifetime
- Use-cases are e.g.
  - Fatigue tracking: *„How much usable lifetime is left?“*
  - Event simulation for fault diagnosis: *„What went wrong?“*
  - Pre-evaluation of critical operations: *„Can we do this?“*

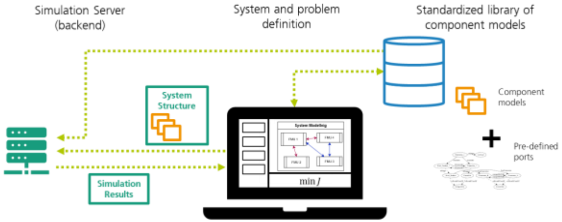


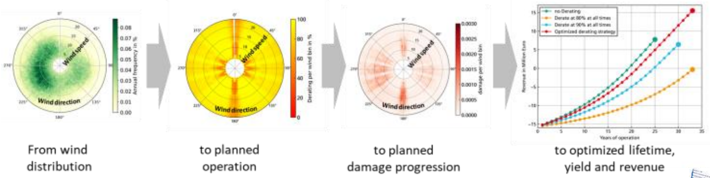
→ Simulation platform can be used for setup of Digital Twin

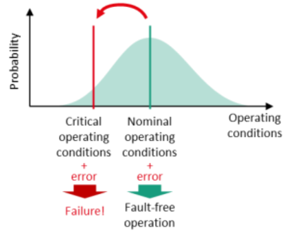
To sum up…

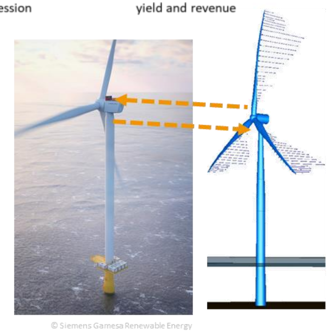
- Hydrogen-producing H2Mare turbine poses unique challenges
- Sophisticated system optimization required
- Development of simulation platform for systems simulation, optimization and analysis
- Use case: Operational optimization
- Use case: Functional safety
- Use case: Digital twin











➔ Dedicated simulation tool allows detailed **model-based system optimization**

➔ Only with full system analysis and optimization, **technology equity** can be reached

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Thank you for your attention

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