Modelling and Simulation of Offshore Windfarms - Mapping and Analysis of relevant O&M Processes

Philip Joschko, Andi Widok, Bernd Page, Susanne Appel, Saskia Greiner, Henning Albers
Topics of this talk
1. Introduction: Offshore Windfarms
2. SystOp-Project
3. Modelling O+M Processes
4. Simulation of O+M Processes
5. Conclusion and Outlook
Planned Wind Farms in Northern Sea

0.28GW now
10GW until 2020
25GW until 2030
Challenges  
(just examples)

- Weather conditions
- Coordination of involved players
- High planning effort
- High risk level and safety regulations
SystOp Offshore Wind

- Funded by BMU
- May 2011 until April 2014

- University of Applied Sciences Bremen
- BTC AG
- IZP Dresden
- University of Hamburg

- www.systop-wind.de
Object of investigation

- **Operational phase**
- **Processes** of operation and maintenance (O+M)
- **Focus:** Interactions/Interfaces between market players.

- Creating a basis for:
  - Communication about O+M
  - Optimization of O+M
  - Risk analysis of O+M

- Not our scope: Physical or technical models of wind turbines. Planning, building, deconstruction phase.
Expected results

- Documentation of maintenance processes. Guidelines for evaluation and optimization.
- Risk analysis. Identification of critical activities and interfaces.
- Standardised reference processes: German Wind Power Plant Model.
Industrial Partners

- Bugsier Reederei- und Bergungsgesellschaft mbH & Co. KG
- DEWI-OCC Offshore and Certification Centre GmbH
- DOTI GmbH & Co KG
- EWE Energie AG
- EWE Offshore Service & Solution GmbH
- Frisia-Offshore GmbH
- Hochtief Solutions AG
- htm Helicopter Travel Munich GmbH
- Nehlsen GmbH
- Nordwest Assekuranzmakler GmbH & Co. KG
- PHH Personaldienstleistung GmbH
- REETEC GmbH Regenerative Energie- und Elektrotechnik
- RKM Personaldienstleistungen GmbH
- Signalis Germany
- Windparkservice GmbH
- WindMW
- WKU AG
- wpd windmanager GmbH & Co. KG
Business Process Notations

- Flow chart representation of processes

- **Examples**
  - Event-Driven Process Chains
  - Unified Modeling Language
  - Business Process Model and Notation 2.0

- ... differ in ...
  - degree of formalization.
  - number of elements.
Why we chose BPMN 2.0

- **Message Flows**: Mapping the interaction between involved players

- **Attached Events**: Mapping termination conditions
List of modelled processes

- Servicing / Maintenance
- Recognition and Measurement
- Planning
- Processing
- Post-Processing
- Operation

Application planning
- Human resources scheduling
Transport scheduling
- Boarding and pre-departure
- Accomplishment
- Return and key

Communication base!
As a result of this project...
...but also for our sub-projects:
1. Risk Analysis (IZP)
2. Simulation (UHH)
BPMN software of our choice:

- Standardized BPMN 2.0 export
- Solutions, projects and online repository
- Validation and simulation features
- Very ergonomic and fast modeling
- Free professional licenses for academical use

www.iyopro.de
Discrete Event Simulation

Simulation
- Investigating the dynamic runtime behaviour
- State variation is recorded and statistically evaluated
- No experimentation with real system

Stochastics
- Not all influences are modeled deterministically
- Stochastic distributions indicate random fluctuations
Simulating O+M Processes

- Detecting modeling errors
- Key performance indicators
- Comparison of alternative system configurations
- Improve O+M processes
Stochastic Simulation Properties

1. Duration of activities
   - Measured data
   - Estimated data

2. Interarrival time of events
Stochastic Simulation Properties

1. Duration of activities
   - Measured data
   - Estimated data

2. Interarrival time of events
Domain Specific Simulation Tool: DesmoWindparkStudio
<table>
<thead>
<tr>
<th>Wind farm layer</th>
<th>Wind farm editor</th>
<th>Wind turbine components</th>
<th>Stochastic weather generator</th>
<th>Reporting</th>
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<tr>
<td><strong>BPMN simulation layer</strong></td>
<td>Solution explorer</td>
<td>BPMN extension</td>
<td>BPMN graph editor</td>
<td>BPMN import</td>
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<td>Experiment scheduling</td>
<td>Cost editor</td>
<td>Resource editor</td>
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<td>Simulation engine DESMO-J</td>
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<td>Expression parser</td>
<td>Workflow engine / Assistant system</td>
<td>Selection service</td>
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<td>Empinia (Plugin Framework, runtime environment, user interface)</td>
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</tbody>
</table>
DESMO-Windpark-Studio

Was wollen Sie tun?

- Eine neue Experiment-Datenbank anlegen
- Neue Projektmappe anlegen
- Mit zuletzt verwendetem Projektmappe fortfahren
- Vorhandene Projektmappe bearbeiten
- Wetterdaten
- Neue Anlagen anlegen
- Neue Komponenten für Windkraftanlagen anlegen
- Neuen Windpark anlegen
Empinia (Plugin Framework, runtime environment, user interface)

Selection service

Simulation engine DESMO-J

Workflow engine / Assistant system

Visual editor

Property editor

Expression parser

Workflow engine / Assistant system

Selection service

Help system

Wind farm layer
- Wind farm editor
- Solution explorer
- Experiment scheduling
- Simulation engine DESMO-J

BPMN simulation layer
- Wind turbine components
- BPMN extension
- Cost editor
- BPMN graph editor
- Resource editor
- Stochastic weather generator
- BPMN import
- Stochastic distribution editor

Technical layer
- Experiment scheduling
- BPMN extension
- Cost editor
- Resource editor

Framework
- Expression parser
- Workflow engine / Assistant system
- Selection service
- Help system

Empinia
(Plugin Framework, runtime environment, user interface)
• Data of the wind farm
  • Geographical information
  • Number of turbines

• Data of the wind turbines
  • Type
  • Power generation
  • Components

• Data of components
  • Failure probability

Alpha Ventus →
- Input: wind speed (m/s)
- Output: generated Energy (MW)

\[
P = \begin{cases} 
0, & \text{if } 0 \leq V < V_{ci} \\
P_r(a + b \cdot V + c \cdot V^2), & \text{if } V_{ci} \leq V < V_r \\
P_r, & \text{if } V_r \leq V < V_{co} \\
0, & \text{if } V_{co} \leq V
\end{cases}
\]

Byon, Perez, Ding 2011: „Simulation of wind farm operations and maintenance using discrete event system specification“
• Definition of components

• Weibull distributions considering the failure

• Costs and other basic information
Failure of components...
- ...result in failure of wind turbines.
- ...different states of whole farm (reduction of energy generation)
- ...start different maintenance processes
Empinia (Plugin Framework, runtime environment, user interface)

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Framework

Empinia
(Plugin Framework, runtime environment, user interface)
Historical Data (~10 years)
• FINO 1 Weather Station
• Located near Alpha Ventus

Saisonal fluctuations
• Wind speed
• Wave height
• Temperature

Important for
• Power generation model
• Access probability
Top: FINO 1 weather station 1 dataset/“dot“ every 10 minutes

Bottom: generated data 1 dataset/“dot“ per hour

Parameter:
• Daily mean Wind speed
• Wind speed hourly standard deviation

Java-based Simulation Library
Ported to C#/.NET
Event-oriented and process-oriented modelling
Easily extendable for domain-specific applications
Apache License (Open-Source)
Download Java sources and binaries: www.desmo-j.de

Simulation infrastructure:
Simulation Clock, Scheduler, Experiment Class, Queues, Statistics and Reports,
...

Stochastical Distributions
Constands, Bernoulli, Beta, Gamma, Normal, Erlang, Binomial, Geo, Hypergeo, Poission, Uniform, Empirical...
Summary SystOp

- Identified stakeholders and relationships
- Modeled O+M processes in BPMN 2.0
- Domain specific analysis tool for calculating KPIs
- Optimized reference process model + Documentation

Communication base for stakeholders, scientists and authorities
Conclusion of interim results

- BPMN 2.0: well-suited to represent processes
- Simulation: well-suited to cover errors and calculate KPIs for those processes
- Need a lot of data, time and patience
  - You‘ll never get all data you need!
- Interdisciplinary team eases the work
Outlook Simulation Tool: Applicable to other domains!

- Concept of extending BPMN 2.0
  - Domain-specific elements
  - Eases understanding

- Unfortunately not scope of specification, not featured by established tools

- Coupling process models to heterogenous, domain-specific models
  - Simulating processes in their environment
SystOp at EnvirolInfo 2013

- Henning Albers, Saskia Greiner, Susanne Appel:
  - Poster: „The process chain offshore wind farm“

- Student Workshop (german language):
  - Tilmann Stehle:
    - „Experimentplanung mit DesmoWindparkStudio“
    - Thursday, 3:20pm

- Cornelia Mengel:
  - „Simulation der Einsatzplanung von Offshore Winparks“
  - Thursday, 3:40pm
Thank you very much!

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