Welcome

WIND . ASSURING CONFIDENCE THROUGH COMPETENCE

Analysis, comparison and optimization of the logistical concept for wind turbine commissioning

Dr. Marcel Wiggert
Agenda & Goals

- Topic and challenges
- Introduction WaTSS concept
- Approach
- Case study: Commissioning
- Conclusions
Topic

Title:

Analysis, comparison and optimization of the logistical concept for wind turbine commissioning

Conditions:

- Weather risk of the WTG installation
- Optimization of the number of commissioning teams
- Comparison of 3 different logistical concepts

Decision criteria: lowest cost and risks
Challenge

COAST – Comprehensive Offshore Analysis and Simulation Tool

Installation

COAST¹

Weather Risks

Comparison of logistical concepts
Commissioning team optimization

Resource issue

WTGᵢ Completion

Access for commissioning

¹ COAST – Comprehensive Offshore Analysis and Simulation Tool
IWES Modeling Approaches

VIRTUAL TEST RIGS

- General Tools (e.g. MS-Excel)
- Project Management Software (e.g. MS-Project)
- Engineering Tools (e.g. Matlab)
- Developer Environments (e.g. Java)

COAST
- Transport & installation
- Commissioning
- Regular maintenance
- Large component rep.
- Decommissioning

Offshore TIMES
- Maintenance logistics

1 COAST – Comprehensive Offshore Analysis and Simulation Tool
2 Offshore TIMES – Offshore Transport, Inspection an Maintenance Software

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Information Profile

Local weather conditions, e.g.
- Significant wave heights
- Wind speeds
- Currents
- Temperature
- Visibility

Required cabling processes and sequences
Project overall project time schedule

Location wind farm/ports
Vessel and equipment concept
Guideline requirements
Contractual agreements

WEATHER PARAMETERS
WEATHER TIME SERIES
MEASURED
HINDCAST

PROJECT SCHEDULES

INSTALLATION STRATEGY

WEATHER CONDITIONS
BOUNDARY CONDITIONS
RESTRICTIONS
GUIDELINES

WEATHER RISK PROFILE

PROJECT DURATION

COST AND RISK OPTIMIZATION

SENSITIVITY AND SCENARIO ANALYSIS
ROBUST PROJECT SCHEDULES

CONTINUOUS ANALYSIS PROCESS → EASY WORK FLOW INTEGRATION

24.01.2018
WaTTS – Method
Weather Time Series Scheduling

Consideration of:
- Task sequence
- Contingencies in guidelines
- Different weather restrictions

Calculation of project durations and their probabilities
Virtual Project Test Center
Yearly Simulation

**TIME SCALE**

**DURATION VS. START DATE**

**SIGN. WAVE HEIGHT**

**START DATE:** e.g. 01.01.

24.01.2018
Duration vs. Start Day

![Duration vs. Start Day graph](image_url)
COAST – Software
Simulation Concept

1. Installation dates of the wind turbines per analyzed year
   \textit{Goal: Definition commissioning start dates}

2. Success of the commissioning work for every day
   \textit{Goal: Definition of the turbine accessibility}

3. Post Processing: e.g., MS Excel or MATLAB
   \textit{Goal: Analyzing the scenarios}
   \begin{enumerate}
   
   \item Calculation of the commissioning duration per turbine and year under consideration of weather and resource constraints
   
   \item Calculation of the required vessel days and costs
   
   \item Evaluation and presentation of the results
   
   \end{enumerate}
Case Study: IWES Baltic

Introduction

**Weather parameters:**
- Significant Wave Height ($h_s$)
- Wind Speed ($U$)

<table>
<thead>
<tr>
<th>Boundary conditions</th>
<th>Assumption</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of turbines</td>
<td>60</td>
</tr>
<tr>
<td>Port distance</td>
<td>40km</td>
</tr>
<tr>
<td>Start date</td>
<td>2020-07-01</td>
</tr>
<tr>
<td>Commissioning (1 Team)</td>
<td>160h/turbine (net)</td>
</tr>
<tr>
<td>Team costs</td>
<td>3,000 Euro/day</td>
</tr>
<tr>
<td>Opportunity costs</td>
<td>3,000 Euro/day per turbine</td>
</tr>
<tr>
<td>Duration of installation incl.</td>
<td>100 days (COAST)</td>
</tr>
<tr>
<td>weather risks (P50)</td>
<td></td>
</tr>
</tbody>
</table>
WTG Installation Strategy

<table>
<thead>
<tr>
<th>Vor</th>
<th>Vorgangsnr.</th>
<th>Dauer</th>
<th>Anfang</th>
<th>Fertigstellen</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>WTG Installation</td>
<td>20 Std.</td>
<td>Sa 01.07.17 08:00</td>
<td>Di 26.09.17 12:00</td>
</tr>
<tr>
<td>2</td>
<td>WTG 1</td>
<td>6 Std.</td>
<td>Sa 01.07.17 08:00</td>
<td>Mo 03.07.17 13:00</td>
</tr>
<tr>
<td>3</td>
<td>Loading in Harbour</td>
<td>32 Std.</td>
<td>Sa 01.07.17 08:00</td>
<td>So 02.07.17 08:00</td>
</tr>
<tr>
<td>4</td>
<td>Crain Works</td>
<td>8 Std.</td>
<td>Sa 01.07.17 08:00</td>
<td>Sa 01.07.17 16:00</td>
</tr>
<tr>
<td>5</td>
<td>Jack down</td>
<td>0 Std.</td>
<td>So 02.07.17 08:00</td>
<td>So 02.07.17 08:00</td>
</tr>
<tr>
<td>6</td>
<td>Transit to Site</td>
<td>4 Std.</td>
<td>So 02.07.17 08:00</td>
<td>So 02.07.17 12:00</td>
</tr>
<tr>
<td>7</td>
<td>Jack Up</td>
<td>5 Std.</td>
<td>So 02.07.17 12:00</td>
<td>So 02.07.17 16:30</td>
</tr>
<tr>
<td>8</td>
<td>WW Tower Installation</td>
<td>7,5 Std.</td>
<td>So 02.07.17 16:30</td>
<td>Mo 03.07.17 16:00</td>
</tr>
<tr>
<td>9</td>
<td>Tower Installation</td>
<td>4 Std.</td>
<td>So 02.07.17 16:30</td>
<td>So 02.07.17 20:30</td>
</tr>
<tr>
<td>10</td>
<td>WW Nacelle</td>
<td>7,5 Std.</td>
<td>So 02.07.17 20:30</td>
<td>Mo 03.07.17 04:00</td>
</tr>
<tr>
<td>11</td>
<td>Nacelle installation</td>
<td>4 Std.</td>
<td>So 02.07.17 20:30</td>
<td>Mo 03.07.17 00:30</td>
</tr>
<tr>
<td>12</td>
<td>WW Blade Installation</td>
<td>11,5 Std.</td>
<td>Mo 03.07.17 08:30</td>
<td>Mo 03.07.17 12:00</td>
</tr>
<tr>
<td>13</td>
<td>Blades 1-3</td>
<td>8 Std.</td>
<td>Mo 03.07.17 08:30</td>
<td>Mo 03.07.17 08:30</td>
</tr>
<tr>
<td>14</td>
<td>Jack Down transit to next site</td>
<td>4,5 Std.</td>
<td>Mo 03.07.17 13:00</td>
<td>Mo 03.07.17 13:00</td>
</tr>
<tr>
<td>15</td>
<td>WTG 2</td>
<td>25 Std.</td>
<td>Mo 03.07.17 13:00</td>
<td>Di 04.07.17 14:00</td>
</tr>
<tr>
<td>16</td>
<td>WTG 3</td>
<td>25 Std.</td>
<td>Di 04.07.17 14:00</td>
<td>Mi 05.07.17 15:00</td>
</tr>
<tr>
<td>17</td>
<td>WTG 4</td>
<td>29 Std.</td>
<td>Mi 05.07.17 15:00</td>
<td>Do 06.07.17 20:00</td>
</tr>
</tbody>
</table>
Scenario Analysis

**ASSUMPTIONS**

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Assumptions</th>
</tr>
</thead>
<tbody>
<tr>
<td>CTV</td>
<td>H&lt;sub&gt;5&lt;/sub&gt; = 1.5m; 3 Teams on board; 12h/7 days; Costs: 4,000 €/d; 8h/day on turbine</td>
</tr>
<tr>
<td>HV</td>
<td>H&lt;sub&gt;5&lt;/sub&gt; = 1.5m; 20 Teams; 24h/7 days; Costs: 20,000 €/d; 10h/day on turbine</td>
</tr>
<tr>
<td>SOV</td>
<td>H&lt;sub&gt;5&lt;/sub&gt; = 2.5m; 20 Teams; 24h/7 days; Costs: 24,000 €/d; 10h/day on turbine</td>
</tr>
</tbody>
</table>

*www.pomaritime.com*  
*https://c-bed.nl*  
*www.siemens.com/windpower*
## Scenario Analysis

### Scenario CTV

- **Assumptions**
  - $H_s = 1.5m$
  - 3 Teams on board; 12h/7 days
  - Costs: 4,000 €/d
  - 8h/day on turbine

<table>
<thead>
<tr>
<th>Vorgangsnname</th>
<th>Dauer</th>
</tr>
</thead>
<tbody>
<tr>
<td>12/7 CTV Base Case</td>
<td>12 Std.</td>
</tr>
<tr>
<td>1. WTG - Fahrt 1</td>
<td>12 Std.</td>
</tr>
<tr>
<td>Transfer to site</td>
<td>2 Std.</td>
</tr>
<tr>
<td>Comm Works</td>
<td>8 Std.</td>
</tr>
<tr>
<td>Transfer back to harbour</td>
<td>2 Std.</td>
</tr>
</tbody>
</table>

### Scenario HV

- **Assumptions**
  - $H_s = 1.5m$
  - 20 Teams; 24h/7 days
  - Costs: 20,000 €/d
  - 10h/day on turbine

<table>
<thead>
<tr>
<th>Vorgangsnname</th>
<th>Dauer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accommodation Vessel 24/7</td>
<td>24 Std.</td>
</tr>
<tr>
<td>1. WTG - Fahrt 1</td>
<td>24 Std.</td>
</tr>
<tr>
<td>Transfer to site</td>
<td>1 Std.</td>
</tr>
<tr>
<td>Comm Works</td>
<td>10 Std.</td>
</tr>
<tr>
<td>Transfer back to Vessel</td>
<td>1 Std.</td>
</tr>
<tr>
<td>Transfer to site</td>
<td>1 Std.</td>
</tr>
<tr>
<td>Comm Works</td>
<td>10 Std.</td>
</tr>
</tbody>
</table>

### Scenario SOV

- **Assumptions**
  - $H_s = 2.5m$, $U = 10 m/s$
  - 20 Teams; 24h/7 days
  - Costs: 24,000 €/d
  - 10h/day on turbine

<table>
<thead>
<tr>
<th>Vorgangsnname</th>
<th>Dauer</th>
</tr>
</thead>
<tbody>
<tr>
<td>DP2 Vessel</td>
<td>24 Std.</td>
</tr>
<tr>
<td>Fahrt 1</td>
<td>24 Std.</td>
</tr>
<tr>
<td>Transfer to site</td>
<td>1 Std.</td>
</tr>
<tr>
<td>Comm Works</td>
<td>10 Std.</td>
</tr>
<tr>
<td>Transfer back to Vessel</td>
<td>1 Std.</td>
</tr>
<tr>
<td>Transfer to site</td>
<td>1 Std.</td>
</tr>
<tr>
<td>Comm Works</td>
<td>10 Std.</td>
</tr>
</tbody>
</table>
Case Study: IWES Baltic – Results

**Costs (P50)**

**Risk Profile**

![Graph showing costs and project duration](image)

**Number of commissioning teams**

- **SOV**
- **HV**
- **CTV**

**Project duration [days]**

- **Base Case**
- **SOV**
- **HV**
- **CTV**

**COSTS (P50)**

**RISK PROFILE**

![Risk Spectrum](image)

**Costs [Million €]**

- **SOV-10**
- **HV-12**
- **CTV-14**

**Fraunhofer IWES**

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Conclusion

- Post processing extends capabilities of the WaTSS method
- Approach to consider the availability of transport (resources) for the commissioning teams
- Important to consider risks and cost simultaneously
- Case Study: “IWES Baltic”
Acknowledgements
Fraunhofer IWES is funded by the:

Federal Republic of Germany

Federal Ministry for Economic Affairs and Energy

Federal Ministry of Education and Research

European Regional Development Fund (ERDF):

Federal State of Bremen
- Senator of Civil Engineering, Environment and Transportation
- Senator of Economy, Labor and Ports
- Senator of Science, Health and Consumer Protection
- Bremerhavener Gesellschaft für Investitions-Förderung und Stadtentwicklung GmbH

Federal State of Lower Saxony

Free and Hanseatic City of Hamburg

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Thank You For Your Attention

Any questions?

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Background

DETAILED INFORMATION
Detailed Analysis

![Bar chart showing project duration in days for CTV, HV, and SOV]

- **CTV**: Net. time is the largest component, followed by WoW and Ressources.
- **HV**: The components are similar to CTV.
- **SOV**: The components are also similar to CTV and HV.

Legend:
- Grey: Net. time
- Green: Commissioning
- Red: WoW
- Maroon: Ressources
Risk Efficiency

Risk efficiency concept by CHAPMAN/WARD 2003, based on MARKOWITZ portfolio theory

Rule: “that the investor does (or should) consider expected return a desirable thing and variance of return an undesirable thing” (MARKOWITZ 1952, S.77)
Primary and Secondary Weather Risks
Duration vs. Start Day

PROJECT DELAY
4 Months

SECONDARY WEATHER RISK

PRIMARY WEATHER RISK

PROJECT DURATION

START DATE
Weather Impact – Example Accessibility (July – December)

$h_s = 1.5m; \text{ Weather Window } d = 10h; \text{ Data Model: HZG CoastDat v1 (1958–2007)}$