Simulation and Optimization for Offshore Windfarm Installation Logistics

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Overview

- Background
- Offshore wind farm installation
- Simulation tool
- Optimisation tool
- Going forward
Background

- End of 2015: The total wind power installed in Europe reached 142 GW
- End of June 2016: 11.5 GW total installed offshore wind capacity was grid connected in the EU
- The aim of the industry is to bring the cost of offshore wind energy down to €80/MWh by 2025
- Offshore wind is more expensive than onshore, mainly due higher installation and O&M costs.

Based on: WindEurope Statistics, 2016
Project partners

Technip Offshore Wind Ltd
Offshore wind farm

Typically various asset-types and large number of each type of asset to be installed...
Installation vessels
Installation challenges

- Developments are moving further offshore into deeper water
- Larger sites and larger turbines
- Limited industry experience on this scale and complexity
Installation challenges

- London Array (2011/12)
  - 630 MW capacity
  - 20 km to shore
  - Up to 20 m deep
Installation challenges

- London Array (2011/12)
  - 630 MW capacity
  - 20 km to shore
  - Up to 20 m deep
- Round 3 sites:
  - over 1 GW capacity
  - 100s km from shore
  - Over 60 m deep
Our aim – decision support

- **Planning stage**: to enable realistic comparisons between logistical installation decisions

- **Implementation stage**: to identify appropriate reactions to disrupted installation schedules
Our aim – decision support

- **Planning stage**: to enable realistic comparisons between logistical installation decisions
  - Using a *discrete-event simulation* tool
- **Implementation stage**: to identify appropriate reactions to disrupted installation schedules
  - Using a *rolling-horizon robust optimisation* tool
Installation logistics

- Can be split into three main decision areas
  - Port selection for each asset
  - Installation fleet composition
  - Installation vessel scheduling
Simulation tool

- Combines a logical installation model with a weather model
  - The weather model generates potential weather series based on historical data
  - Many potential weather series are generated
  - The installation model is used to measure how the installation would progress under each set of potential weather conditions
  - This is repeated many times to gain an understanding of the uncertainty of the installation progress
Simulation tool

- **Inputs:**
  - definitions of vessel and port use
  - durations, weather and daylight restrictions for every installation operation

- **Outputs:**
  - Costs, durations, progress and delays of an installation scenario

- Can identify the expected impact of logistical decisions on the installation process
Applications

- Distribution of jacket installation process for one installation vessel supported by between 1-8 supply barges:
  - costs,
  - durations
Applications

- Case study
- 1000 simulations
- 3.5 h @ 3.4 GHz dual-core; 8 GB RAM; 64-bit Windows

- Box plots of the duration of each installation vessel, for the selected scenario
Applications

- Investigate impact of weather delays

![Graph showing number of delays (days) for different categories: WT jacket supply barges, WTG installation vessel, WT jacket installation vessel, Inter-array cable vessel, Export cable vessel, All others.](image-url)
Applications

- Investigate impact of weather delays
Applications

- Investigate impact of weather delays
Optimisation tool

- Combines two optimisation techniques
  - rolling-horizon optimisation: takes the current state of the installation as an input and finds the optimal strategy to complete the installation
  - stochastic optimisation: identifies installation scenarios which are robust to uncertainties
- A two-level model: high-level model assigns tasks to intervals; detailed model finds the starting times of tasks within each interval
Optimisation tool

Baseline schedule

Execution of the schedule

Disruption

Need to find a new schedule?

End of installation?

- Early start policy
- Minimum perturbation strategy
- Match-up scheduling strategy
- Minimum cost plan
- Minimum deviation risk plan

Add new constraints on cost/duration/rescheduled tasks

IS DM satisfied?

End
Optimisation tool

- Vessel failure or unavailability
- Progress of operations better/worse than expected
- Delays to supply chain
Going forward

- We are supporting SSE Renewables and Beatrice Offshore Wind Farm Ltd (BOWL) with the application of the tools developed through TIC F103
- The aim of this project is to provide BOWL with justifiable evaluation tools to support financial and contractual decisions
- This is achieved by addressing three key objectives:
  - To maximise the value of the tools by tailoring their functionality in-line with the specific requirements of the Beatrice installation project
  - To verify the operation of the tools as functioning decision support systems through third-party testing of the underlying computer code
  - To validate the suitability of the tools for application to the Beatrice installation through third-party testing of the modelling processes
Installation Model

- more detailed breakdown of operations
- multiple installation vessels per asset category
- single installation vessel used to install different asset categories
- self-supplying vessels or supported by supply barge
- multiple asset categories streams using same load-out port
- additional operations before and after asset installation
- a large number of operational decisions
- distinct operations for the installation of each asset category
Installation Model

- Each installation task has operational restrictions: weather and daylight
- Value of weather limits and expected durations are dependent on the vessel used
Installation Model

- Various types of uncertainty can influence the installation:
  - Uncertain task durations
  - Unplanned vessel breakdowns and the resulting maintenance operations
  - Uncertain weather conditions
More details:


Thank you for your attention