

Short-Term Decision Optimisation for Offshore Wind Farm Maintenance

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- The Offshore Wind Farm Manager's challenge
- How does ECN Despatch[™] help the Farm Manager make better decisions?
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Offshore Wind Activities

ECN



ECN IO&M Team Activities





We are building the world's most powerful strategic simulation tools for offshore wind farms





We have some replacements, repairs and routine inspections to complete.





We have resources...

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... and constraints ...

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... and we wish to obtain the "best" choice and ordering of activities for the day.



Input and Output Summary

- List of service orders
- Vessel availability
- Technician availability
- Spares availability
- Weather forecast (winds + waves)
- Service order definition:
 - Vessel, technician and spares requirements
 - Time requirements*
- Turbine and port locations
- Operational weather limits
- Vessel speed and capacity
- * We have obtained this from historical data.
- ** Need turbine power curve to estimate.
- *** Need energy prices and fixed/variable costs.

- Objective for optimisation:
 - Minimum downtime
 - Minimum cost?
 - Maximum utilisation?
 - Maximum energy output**
 - Maximum income***

Time:	7	9	11	13	15	17
Service Order 1						
Service Order 4						
Service Order 5						
Service Order 2						



Main Challenges To Solve

- **1**. Prioritise the Service Orders.
- 2. Create feasible vessel and technician schedules.
- **3**. Run quickly.
- 4. Use resources wisely: do less or more, earlier or later.
- 5. Consider weather forecast and task uncertainties.



The Optimiser

• Exhaustive Search is clearly not a realistic option:

- 5 Service Orders: 120 solutions
- 10 Service Orders: 3,628,800 solutions
- 15 Service Orders: 1,307,674,368,000 possible solutions

• Genetic Algorithm

- 1. Permutation representation for Service Orders: "Travelling Salesman Problem"
 - Mutation rate: 15%
 - Population size: 100
 - Converges for 20 cities in 3000-3500 evaluations
- Intra-day scheduling takes Service Order priority and works out the time-domain solution.





Main Challenges To Solve

- **1.** Prioritise the Service Orders.
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- **3.** Run quickly.
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- 5. Consider weather forecast and task uncertainties.



"Travelling Merchant Problem"

 Instead of just "visiting" each city, why not use limited time available to spend time selling?!





Removing End Effects

• The Evaluator and Scheduler are also used to assign a value to tasks not performed.





The ECN DespatchTM Concept







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Example Prioritisation: Inputs

• 9 open orders:

WTG #	Туре	Man Hours Required	Technicians Used
9	Run	8.5	2
10	Stop	14	2
13	Run	0.5	2
13	Run	1	1
14	Stop	4.5	2
14	Stop	8.25	2
24	Run	19.74	3
34	Run	1	1
44	Run	1.5	2



Example Prioritisation: Inputs

• Weather forecast:



- Transit / transfer limit: 2.5m Hs
- Technicians Available: 12
- Shift times: 06:30 17:30



• Fixed at 12 technicians available, no future valuation.

	Day 1 Completion %	Technicians Used	Man Hours Required	Туре	WTG #
	100	2	8.5	Run	9
	50	1	14	Stop	10
	100	1	0.5	Run	13
69.8MWh los	100	1	1	Run	13
03.010101103	100	2	4.5	Stop	14
	79	2	8.25	Stop	14
	25	1	19.74	Run	24
	100	1	1	Run	34
	100	1	1.5	Run	44



• Fixed at 12 technicians available, including future valuation.

	Day 1 Completion %	Technicians Used	Man Hours Required	Туре	WTG #
	100	2	8.5	Run	9
	50	1	14	Stop	10
	100	1	0.5	Run	13
71.7MWh lost	100	1	1	Run	13
, 17, 11, 10, 10, 10, 10, 10, 10, 10, 10, 10	100	2	4.5	Stop	14
	79	2	8.25	Stop	14
	30	1	19.74	Run	24
	100	1	1	Run	34
	100	1	1.5	Run	44



• Fixed at 12 technicians available, **both days scheduled**.

	Day 1 Completion %	Technicians Used	Man Hours Required	Туре	WTG #
	100	2	8.5	Run	9
	50	1	14	Stop	10
	100	1	0.5	Run	13
71.0MWh lost	100	1	1	Run	13
, 2.0	100	2	4.5	Stop	14
	79	2	8.25	Stop	14
	25	1	19.74	Run	24
	100	1	1	Run	34
	100	1	1.5	Run	44



• Fixed at 7 technicians available, **both days scheduled**.

	Day 1 Completion %	Technicians Used	Man Hours Required	Туре	WTG #
	0	0	8.5	Run	9
	54	1	14	Stop	10
55 1MWh lost	100	1	0.5	Run	13
	75	1	1	Run	13
55121010111050	100	1	4.5	Stop	14
	79	1	8.25	Stop	14
	0	0	19.74	Run	24
	100	1	1	Run	34
	100	1	1.5	Run	44



Interested in Getting Involved?

- ECN is developing a powerful capability for daily offshore wind farm decision making.
- Paper to be submitted mid-2017, including valuation methodology.
- Does your company operate a wind farm?
 - We are looking for new partners to input into the design.
 - Conduct an "offline" study to apply ECN Despatch[™] to historic wind farm operations and build a business case for implementation.
 - Implement into an operational wind farm.

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Thank you for listening!

Further questions? stock@ecn.nl





The Optimiser (2)

• Move to a new representation:

- For each vessel, for each day, a Service Order is assigned a real number.
- Service Orders < 0 are not done.
- Service Orders > 0 are assigned a *proportion* of the available technicians.





Example Prioritisation: Reality

• What they actually did...

WTG #	Туре	Man Hours Required	Technicians Used	Day 1 Completion %	
9	Run	8.5	0	0	
10	Stop	14	0	0	
13	Run	0.5	0	0	
13	Run	1	0	0	45.5MWh lost
14	Stop	4.5	2	100	10101111000
14	Stop	8.25	0	0	
24	Run	19.74	0	0	
34	Run	1	0	0	
44	Run	1.5	0	0	