A comparative analysis of major component repair strategies for floating offshore wind

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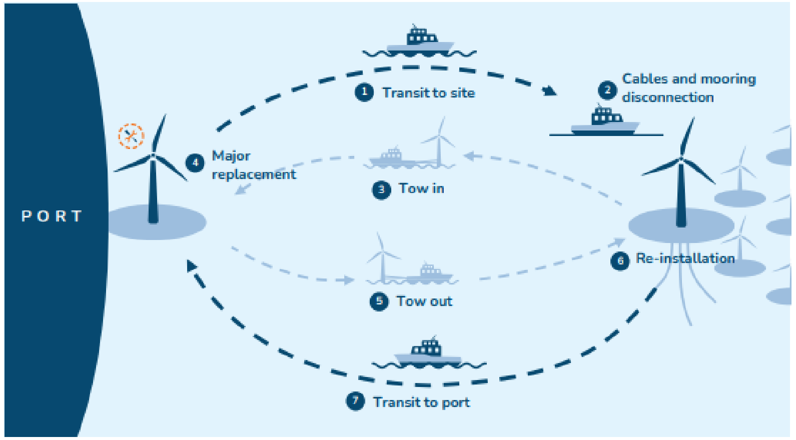
Outline

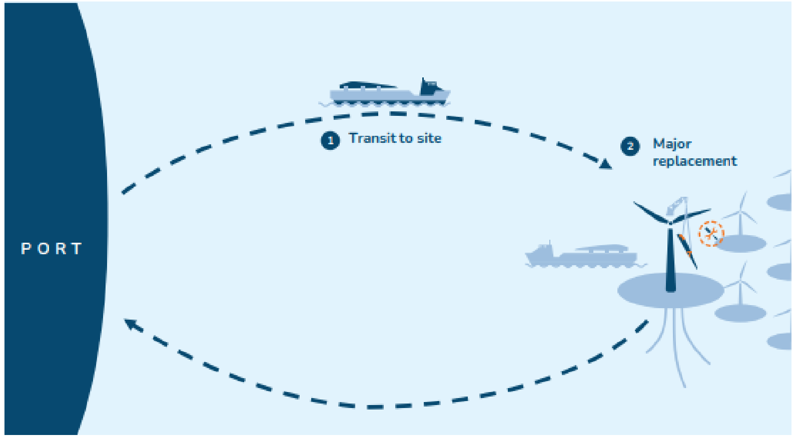
- MCR Strategies overview
- TTP and SHC operation sequences
- MCR interventions to date for FOW
- A Weather stand-by analysis case study
- Conclusions and future work

MCR strategies overview

Tow-to-Port (TTP)



Self-hoisting crane (SHC)



Source: PEAK Wind

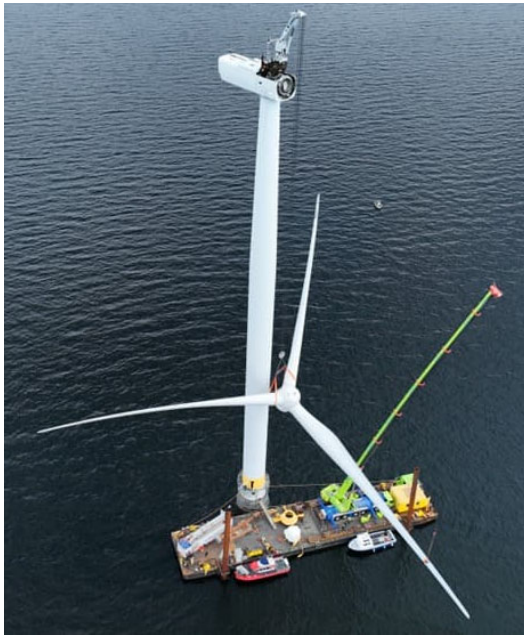
Tow-to-port maintenance

Disconnect moorings & electrical cables → Tow-in to port: Sea transit → Quayside lifting operation → Tow back: Sea transit → Re-connect moorings & electrical cables

- ☑ Currently the only viable solution for major component exchanges of large floating wind turbines
- ☑ Reduced reliance on expensive heavy lifting vessels
- ☒ However, the cost benefits depend heavily on
  - ☒ Distance to shore
  - ☒ Disconnection / reconnection times
  - ☒ AHTS availability and costs
  - ☒ Available port infrastructure
- ☒ In many cases it might prove to be more cost effective to maintain turbines onsite with innovative technologies such as SHCs

Self-hoisting crane maintenance

Install working platform e.g Barge → Install SHC → Onsite lifting operation → Remove SHC → Remove working platform e.g Barge



- ☑ A solution which reduces the reliance on very expensive and complex towing operations
- ☑ Crane matches the relative motions of the turbine, and the maximum height is provided by the turbine itself
- ☒ Existing SHCs have a low lifting capacities and commercialisation will depend on if this capacity can be increased for large machines
- ☒ Very little offshore deployment, to date there have only been two trials on small turbines in sheltered conditions
- ☒ Very limited environmental conditions

MCR interventions to date for floating wind

- **June 2022 → Kincardine [Kin-03]**
  - Towed to Rotterdam, Netherlands (~950km)
  - Duration of 123 days
  - 20+ days of stand-by
  - Average towing speed of1.8 knots
- **May 2023 → Kincardine [Kin-02]**
  - Towed to Rotterdam, Netherlands (~950km)
  - 50-day operation
  - 4 days stand-by
  - Average towing speed of 2.4 knots
- **January 2024 → Hywind Scotland**
  - All 5 turbines requiring major component exchanges
  - Expected to take the duration of the summer
  - Towed to Wergeland, Norway (~450km)

Hywind Scotland turbines require 'heavy maintenance'

Equinor to tow floating Siemens Gamesa units to Norwegian port in four-month operation

12 January 2024 Offshore Wind [Image: Equinor]

RELATED STORIES

Pilot eDNA study concludes at Hywind Scotland
30 MAY 2023

Operations at Equinor's 30MW Hywind Scotland floating offshore wind farm will be interrupted for up to four months this year to undertake "heavy maintenance" to turbines.

The Norwegian developer said operational data has revealed the need for work to the Siemens Gamesa machines, which have been spinning off Aberdeen for the last seven years.

Turbines will be towed to Wergeland port in Norway during the summer where the Wergeland group in Gulen will undertake the work.

Tow-to-port operation sequence

- Operation sequence built from tracking of both Kincardine MCR operations
- Optimal case built for tow-to-shore (reduction of 29)
  - Reduction of disconnection / reconnection time assuming "fast disconnection" connectors
  - Reduction of towing duration assuming local port infrastructure is available
  - Reduction of time at port to match a typical major component exchange

	Kincardine 2023 actual sequence [days]	Kincardine 2023 optimal sequence [days]	Delta
Disconnection	7	4	-3
Tow-in	7	2	-5
At port	14	7	-7
Tow-back	9	2	-7
Reconnection	13	6	-7
Net duration	**50**	**21**	**29**

SHC operation sequence

- Working deck is considered as a multicat for a floating wind deep-water site
  - SHC trials by Liftra in 2023 (Vindpark Vanern, Sweden) mobilized a JU barge
  - Equipment including SHC sea fastened on deck
  - Secure blade and/or drive train components
- Installation and removal of SHCs are the largest contributors to the operation duration
  - In line with Carbon Trust JIP report which assessed 18 SHC concepts

	SHC sequence breakdown for FBW [days]	SHC sequence breakdown for FOW [days]
Mobilize working deck	1	1
Install SHC	2	3
Lifting operation	1	2
Remove SHC	2	3
Demobilize working deck	1	1
Net duration	**7**	**10**

Weather stand-by analysis

- Assess the deployment of these strategies in different local site conditions
  - Kincardine – North Sea
    - Average Hs 1.3m
  - AO6 MED II – Mediterranean
    - Average Hs 1.1m
- ERA5 reanalysis weather data

	Wave height limit [Hs] [m]	Wind speed limit [m/s]
Disconnection	1	10
Tow-in	1.5	16
At port	NA	12
Tow-back	1.5	16
Reconnection	1.5	12

<table>
<tr><th></th><th>Wave height limit [Hs] [m]</th><th>Wind speed limit [m/s]</th></tr>
<tr><td>Mobilize working deck</td><td>1.5</td><td>12</td></tr>
<tr><td>Install SHC</td><td rowspan="3">0.5 & 0.75</td><td rowspan="3">12</td></tr>
<tr><td>Lifting operation</td></tr>
<tr><td>Remove SHC</td></tr>
<tr><td>Demobilize working deck</td><td>1.5</td><td>12</td></tr>
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Case 1: SHC realistic limit

*Apr and Sep not considered as they only serve as upper and lower bounds

Kincardine – North Sea

	SHC [Hs = 0.5m]				TTP			
	Net	P50	P70	P90	Net	P50	P70	P90
Apr	10	66	73	78	21	12	12	22
May		50	57	66		8	11	14
Jun		35	38	56		5	5	6
Jul		26	32	65		5	6	11
Aug		31	51	153		5	5	11
Sep		136	185	246		16	19	33

1. No viable case for SHC deployment in the North sea
2. Best case up to 300% more stand-by than net duration
3. P70 for TTP in the range of 5-11 stand-by days
4. Best case for June at a P90 of 6 stand-by days

AO6 MED II – Mediterranean

	SHC [Hs = 0.5m]				TTP			
	Net	P50	P70	P90	Net	P50	P70	P90
Apr*	10	30	38	44	21	12	4	19
May		20	25	28		6	8	12
Jun		13	16	19		4	6	7
Jul		12	14	23		4	6	8
Aug		8	12	20		3	4	7
Sep*		14	22	33		7	8	11

1. SHCs show significantly more promise in the Med, however stand-by time still double net duration
2. For peak summer (Aug) up to 12 stand-by days for P70
3. TTP sees a reduction of 30-22% in stand-by for P70 with a similar trend for P90

Case 2: SHC optimistic limit

*Apr and Sep not considered as they only serve as upper and lower bounds

Kincardine – North Sea

	SHC [Hs = 0.75m]				TTP			
	Net	P50	P70	P90	Net	P50	P70	P90
Apr	10	25	28	41	21	12	12	22
May		15	20	26		8	11	14
Jun		11	23	24		5	5	6
Jul		6	9	15		5	6	11
Aug		6	12	21		5	5	11
Sep		25	35	62		16	19	33

1. SHCs see a reduction of stand-by days by a factor of ~3
2. P70 for peak summer in the range of 6-9 stand-by days
3. However still significant in comparison to the short net duration of only 10 days
4. TTP still shows greater confidence in terms of managing risk considering P70 – P90 in the range of 25-50% stand-by

AO6 MED II – Mediterranean

	SHC [Hs = 0.75m]				TTP			
	Net	P50	P70	P90	Net	P50	P70	P90
Apr	10	15	18	23	21	12	4	19
May		8	12	16		6	8	12
Jun		6	8	10		4	6	7
Jul		6	7	11		4	6	8
Aug		4	6	8		3	4	7
Sep		6	9	13		7	8	11

1. SHCs feasible and even competitive against TTP across almost all cases up to P70
2. Deployment in Aug obtains P90 less than the net duration which is a first for SHC across both cases
3. **However, it should be noted that SHCs for floating wind deployment are at a TRL of 6 at best!**

Conclusions

- Defined an operational sequence for FOW MCR strategies
  - Based on actual FOW MCR operations for TTP
  - Onshore deployment of SHCs and expert advice

- Performed a weather stand-by analysis
  - The effect of local site conditions on the most optimal MCR strategy
  - The limitations of SHCs primarily due to heavily restricted environmental conditions

Future work:

- Further refine the operational sequences and limits for SHCs

- A breakdown of the operational costs for each of the strategies

- Estimate revenue losses due to downtime

Thank you!

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