> INTEGRATED PROJECT LOGISTICS AND COSTS CALCULATIONS FOR GRAVIT BASED STRUCTURE

Saraswati, N. (Novita) EERA Deepwind 2019, Trondheim, January 17th 2019





AGENDA

- Introduction & Motivation
- > Installation modelling and simulation
- > Case studies of different GBS (installation) strategies
- > Optimization opportunity
- > Results and recommendation



TOWARDS LARGE-SCALE GENERATION OF WIND ENERGY



ECN > TNO innovation for life

GBS AS LARGE OFFSHORE WIND TURBINE FOUNDATION

- > Alternative for jacket & monopile in deeper water
- > Experience in oil and gas and civil engineering
- Provide designs of GBS for offshore wind large WT
- GBS for wind needs to be transported and installed in rough sea condition
- Better understanding is needed to reduce costs and risk to make offshore wind with GBS economically viable
-) GBS JIP consortium
 - Marin, Deltares, Witteveen + Bos and Vuyk Engineering
 - Deme, Besix, Saipem, Jan de Nul, Statoil, Strukton, Bureau Veritas, ALP Maritime and MonobaseWind

4 | Integrated Project Logistics and Costs Calculation for Gravity Based Structure





Source: Van Oord



OUTLINE OF THE WORK

- > Step by step description on constructions, transports and installations operations for GBS
- Cost of energy analysis
- > Insight into:
 - Cost drivers for LCOE using GBS as foundation (construction, transport, installation)
 - Logistical (time) plan and how to optimize them
 - Resources (material, equipment, technician, harbour) requirements
 - Weather restrictions



ECN PART OF TNO IO&M VISION

Strategic Simulation Tools

for

Optimal Decision Making

Installation



in

Offshore Wind Farms







WHY BUILD COMPUTER MODELS?

Simulations (re-)create, as exactly as possible, time series (from history or for future possibilities), considering causes and effects



Computer simulations are <u>safe</u> and <u>low cost</u>, compared with the real world



ECN INSTALL

Needs of installation modelling tool

- Design and optimize the installation strategy for an offshore wind farm
- > Determine project planning, delays, costs and risks
- > Monitor progress during installation



6 | Integrated Project Logistics and Costs Calculation for Gravity Based Structure

Source: Gemini

Commercial proof / Evaluation

- > Installation methods
- > Support structures & wind turbines
- > Vessels and equipment



Source: Royal IHC

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ECN INSTALL: HOW IT WORKS

			EC	7N Install (GBS testing	scenario]					× o	6 2
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	Construct: Oreate GBF Suppor	Step	1	_	12 hours	2.1.1	18	Duration	12	[hours]	
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Components	Construct: Create GBF Roof	Step	1		12 hours	2.1.3					
Permit Constraints	Wait for available TP Conn. Area	Step	1		0 hours	2.1.4	-	Repeat setting	Use step in ALL iterations		- 0
<u></u>	Load: Move GBF to TP Conn. A	Step	1		1 hours	2.1.5		Learning rate	100	[96]	0
Coerations	 Complete 1 Foundation & put on 	Sequence	1	1/1/2016 12_	1 days	3					
	 Attach TP with GBF and load o 	Group	6			3.1			Calculate learning rate.		
Additional Costs	SendHsg TP connection area a	Step	1		0 hours	3.1.1					
×	Instal: Connect IP to the GB-	Step	1		2 hours	3.1.2		O Out	the second	Contration of the second	
	Wait for available GEP storage	Step	1		0 hours	3.1.3		Keset	Save	Delets	2
Planning ^	Sending CBE on yeared	Step	1		0 hours	31.5					
	Transport Foundation to site	Sequence	4	1/1/2016 12-	10 days	4					
Planning Steps	 Administration 	Group	1			4.1					
	SendMsg GBF storage availabl	Step	3		0 hours	4.1.1	11				
C. Procession	Wait for available GBF storage	Step	3		0 hours	4.1.2					
C	 Prepare for trip 	Group	1			4.2					
Results	Load technicians on board	Step	1		2 hours	4.2.1					
	 Install 3 Foundations 	Group	3			4.3					
	Wait for available prepared se	Step	1		0 hours	4.3.1					
	Travel to next turbine	step	1		78.2 hours	4.3.2	¥				
	Community	5040			n naurs	***					
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- Input/Simulation
 - Deterministic discrete event simulator with historic weather data
 - > Planning using intuitive operations
 - Multiple actors (vessels, equipment, group of technicians) per operation
 - > Weather window and weather restrictions
 - Learning curve
- Result
 - Installation costs, installation planning, resources utilization and installation delays
 - > Excel and graphical



CASE STUDY

- Location: Borssele area
-) 60 x 10 MW
- > Construction & installation port: Damen Verolme
- > Wind turbine installation port: Port of Esbjerg
- > 3 GBS concept designs compared
- > ECN Install simulation:
 - > Onshore construction and assembly for GBS
 - > Load out, transport, and installation operation (entire wind farm)

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GBS DESIGN FOR 10 MW TURBINES



Parameters	unit	value
Diameter base	[m]	38
Diameter of shaft	[m]	10
Total model height	[m]	50
Min draft	[m]	9.7
tow draft	[m]	8.6
Dry weight	[t]	11200



Parameters	unit	value
Diameter base	[m]	38
Height of base	[m]	12
Height of cone	[m]	13
Diameter of shaft	[m]	10
Total model height	[m]	50
Dry weight	[t]	7240



Source: MonobaseWind

Parameters	unit	value
Diameter base	[m]	45.5
Height of base+foot	[m]	12
Min draft	[m]	9.5
tow draft	[m]	8.6
Dry weight	[t]	12000



COST COMPONENT CONSIDERED



 Other LCOE components (OPEX, power production, other CAPEX costs *components costs and their installation costs)

FLOATING GBS

- Constructed in dry dock (batch 20 GBS)
- > Advantage:
 - > Easy to load out, store
 - Cheap marine logistic (tug boats, ballasting vessels)
- > Challenges:
 - Long construction time (~1 year/batch)
 - > High costs dry dock
 - > Higher risk (delay caused by one GBS)





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25 m

13 m

12 m

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NON-FLOATING (LIFTED) GBS

- Constructed in quay side
- Advantage:
 - No batch time 1
 - Flexible construction site 5
- Challenges:
 - Still long construction time
 - Expensive heavy lift vessel (>7300 tonnes)

25 m

13 m

12 m





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Source: Jan De Nul



ECN - TNO for life

- Constructed in dry dock
- > Advantage:
 - > Faster construction time than other designs
 - Less operation offshore and cheap marine logistic
- > Challenges:
 - > Higher weather restriction (tug boats, turbine)
 - > High man-hours required for construction



Source: MonobaseWind

ECN - TNO for life

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MARINE OPERATION PLANNING

- One load out at a time
- Winter is avoided
- > Case 1 & 3 are commissioned within 2 years



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COSTS





Vessels used for all cases → 23 M€
Wind turbine installation vessel → 21 M€

OPTIMIZATION OF INSTALLATION PLANNING

- Least delay → April September
- > 2 load out at a time
- > Reduction in installation costs:
 - Floating GBS: 6% → 7,5M€
 - Integrated GBS: 5,3% → 4M€
- 600 MW wind farm can be commissioned within 1 year!



GBS Installation Optimization





105,3%

IGBS-2

CAPEX COMPARISON TOWARDS LCOE





CONCLUSIONS

- GBS Construction
 - More GBS per batch has higher risk (drydock). A delay of one of the GBS will impact the whole batch and increase the total construction costs.
- > Offshore Installation
 - GBS offshore operation is long due to the low speed of towing, extended installation operations with limited weather windows → Optimization needed
 - > Transport and installing GBS with heavy lift vessel is fast but the costs are high
 - Lowest installation costs: Integrated GBS Floating GBS Lifted GBS
- > Potential reduction
 - > Higher workability for the longer operations, such as towing, water ballasting and sand ballasting
 - Installation is only done within favourable seasons (April September)



RECOMMENDATIONS

- GBS Construction:
 - Reducing the costs of GBS construction; the direct material costs and then the costs of the construction site (time required).
 - > Evaluate the effect of constructing GBS in smaller batches (5 or 10 maximum)
- Offshore installation:
 - > Explore more effective installation scenarios (e.g. fast ballasting)
 - Investigation of higher workability for towing and installation to reduce delays and eventually installation costs.
- > Investigate the end-of-life options and decommissioning strategy

THANK YOU FOR YOUR ATTENTION

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