The National HVDC Centre

Ørsted's journey & learnings of HVDC Connected Offshore Windfarms

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TRANSMISSION

Ørsted's Journey & Learnings of HVDC Connected Offshore Windfarms

National HVDC Centre Operator's Forum, June 2024

Ørsted

Agenda

- ❑ Introductions
- ❑ UK Project
- Hornsea 3
- ❑ German Projects
- Borkum Riffgrund 1, 2, & 3
- Gode Wind 1, 2, & 3
- ❑ US Project
- Sunrise Wind

Introductions

Kaushik Hore

- Design & Compliance Manager HOW03
- Joined Ørsted: July 2020
- Living in DK since 2019 with wife and 2-year old kid
- 2019 – 2020: Vestas, DK as Lead Engineer
- 2017 – 2019: Hitachi Energy as Senior Technical Consultant
- 2014 – 2017: GE as System Design Engineer in HVDC
- Graduated in 2010 from Indian Institute of Technology, Roorkee, India
- Masters in Power System Engineering.

Akshay Prajapati

- Co-Design & Compliance Manager HOW03
- Joined Ørsted: February 2022
- Live in Leicester, UK with parents, wife and 2 kids (6 & 9)
- 2011 – 2022: National Grid Electricity Transmission, UK
  - Graduate Programme
  - System Design – Power Systems Engineer
  - Long Term Planning – Plan Optimisation
  - NGV Interconnectors – Business Development Manager
- MSc Electrical Power Systems Engineering, University of Manchester, 2018
- MEng Electronics and Communication Engineering, University of Nottingham, 2011

Hornsea 3

UK Market

HOW03 Project Overview

Key Data and Specifications

	Base Case
Nameplate Capacity	2758 MW
Number of Turbines	~200
Turbine Type	SG 14-236 DD
Array Voltage	66 kV
Offshore Substations	2 x 1320 MW HVDC
Export Voltage	320 kV
Length of Cable Route (Offshore / Onshore)	165 + 54 km
Length of array cables	475 km
Grid Connection Point	Norwich Main (NGET)
Grid Connection Capacity (TEC)	3GW - staged
Grid Connection Date	October 2026 (2200MW)
Grid Connection Date	January 2029 (3000MW)

Hornsea 3 – Key ESD Challenges

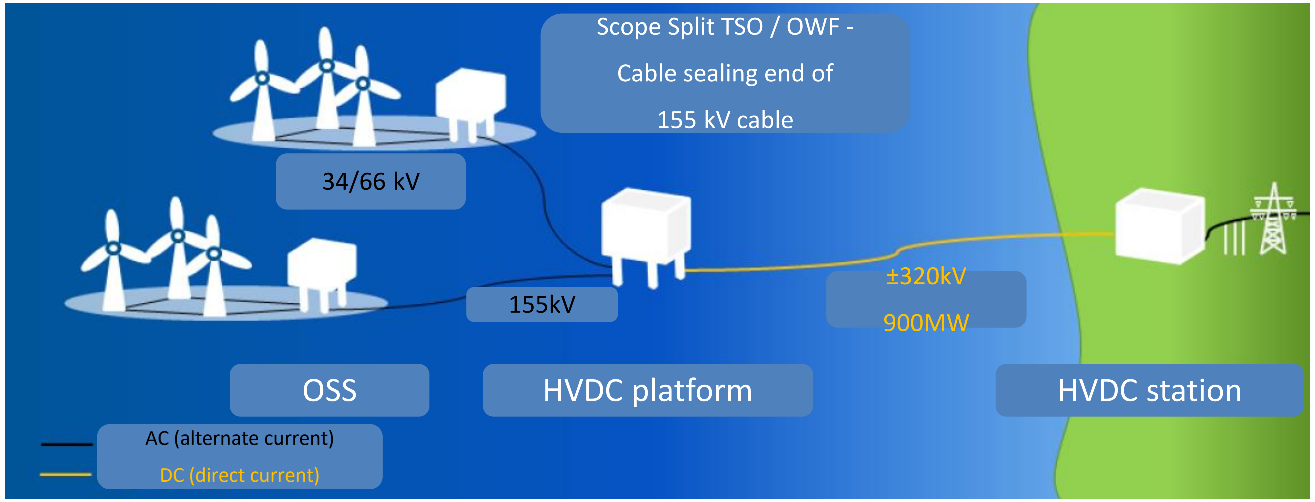
- Ørsted's first large scale HVDC project in UK
  - Grid Connection
    - Staged capacity connection
      → Congested network
      → Significant reinforcement works around POI
  - Grid Code compliance
    - Control Interactions
      → Other power electronic devices and projects in the vicinity
    - Implementation of GC141
    - Network Modelling challenges
- DC Interconnector
  - Ørsted's first experience of implementing of DC interconnection
  - Complex Operational Philosophy

Borkum Riffgrund & Gode Wind

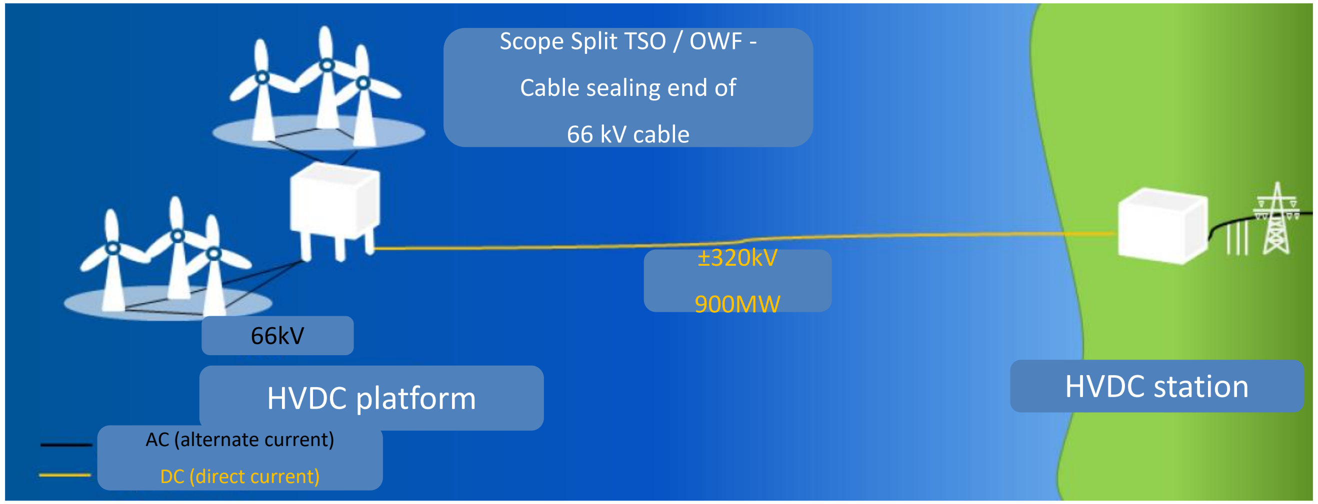
German Market

Grid Connection Concepts in the German North Sea

155kV Connection
w/ OSS
BKR01/BKR02
GOW01/GOW02/GOW03



66kV Direct Connection
w/o OSS
BKR03



BFO: Bundesfachplan Offshore für die deutsche ausschließliche Wirtschaftszone 2016/17

Challenges & Lessons Learnt

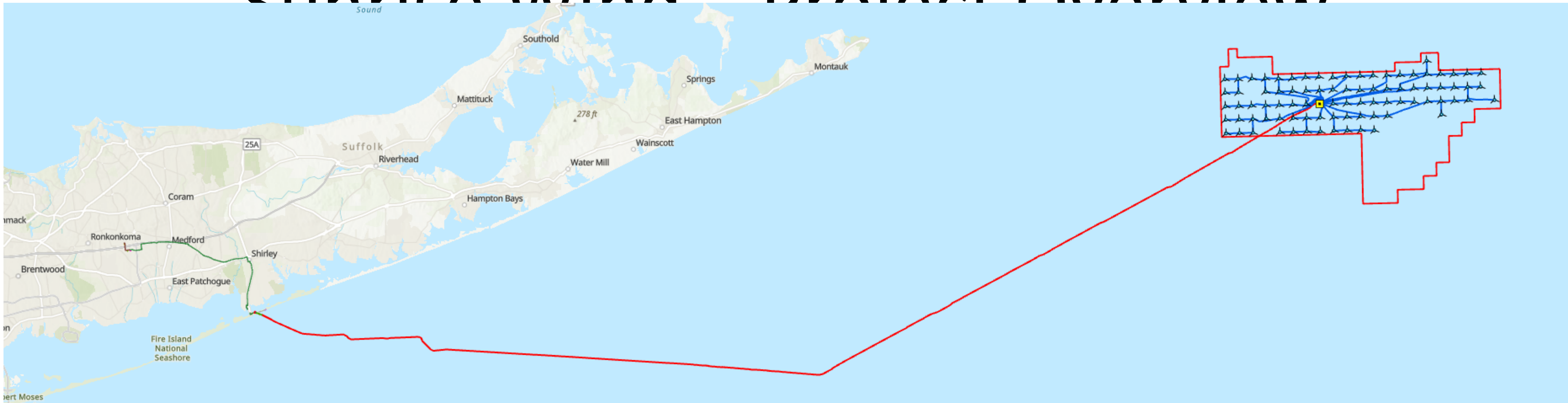
- Technical assessment methodology alignment (WFO / TSO / HVDC)
    - Alignment between various system elements and interfaces
        → Protection & control systems, component ratings, harmonic assessments, etc.
- Risk Assessment: WTG & Transmission System (HVDC)
    - No direct interface with HVDC supplier
        → challenges around scope split, programme alignment
        → SCADA interface
- Interface Clarification
    - Contractual complexities
        → mainly related to the new 66kV direct Connection Concept (WFO / TSO / HVDC)
- Grid Code Compliance (WFO / TSO / HVDC)
    - No. of GEP (connection points) increased
        → complicated compliance process
- Model Data – Availability and Accuracy
    - Exchange of information is challenging

WFO -> Wind Farm Owner
TSO -> Transmission System Operator

Sunrise Wind

US Market

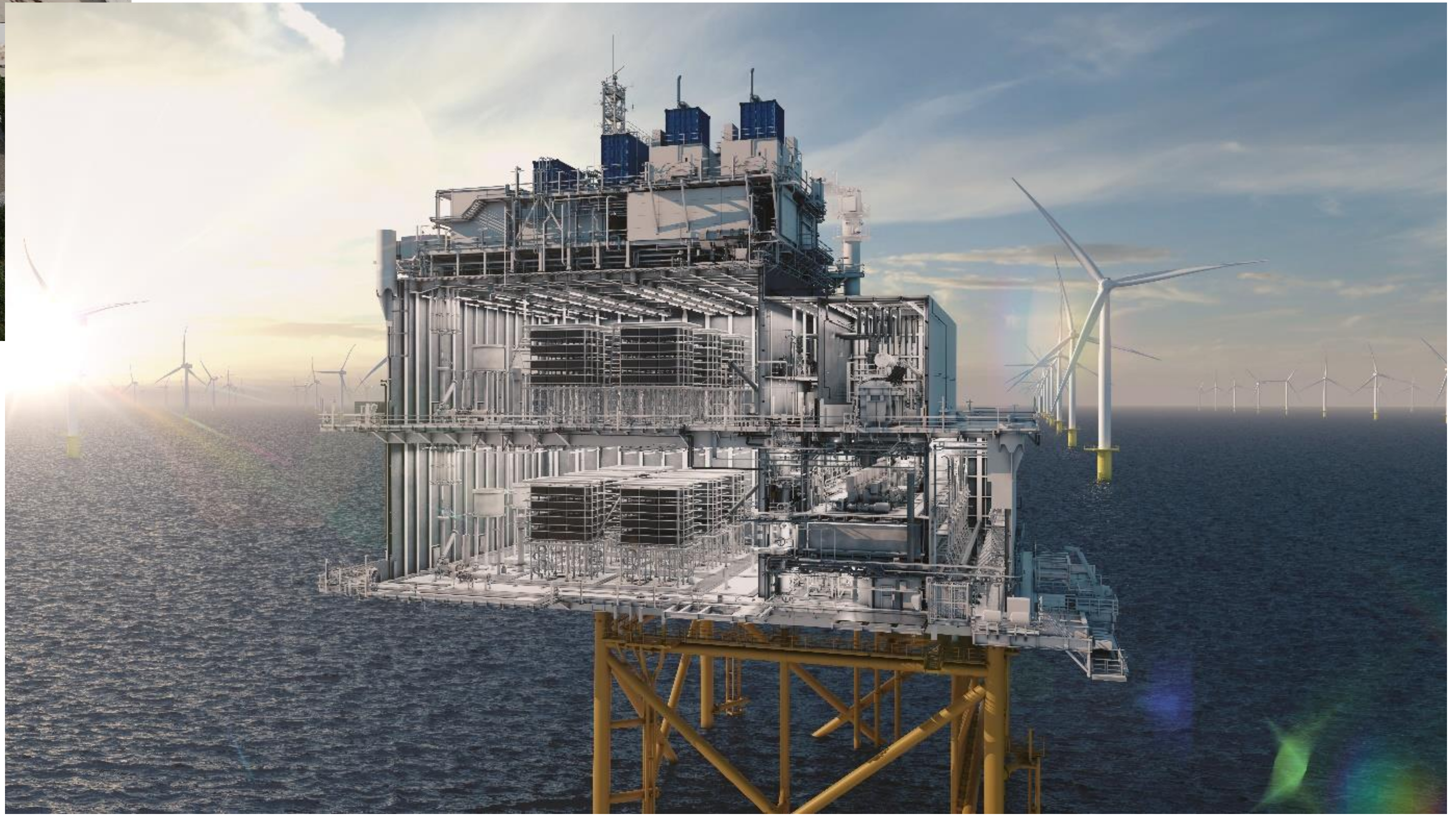
Sunrise Wind – Project Overview



Project location	BOEM Lease Area 500 – US	**Array system voltage**	66kV
Project installed capacity at WTG	924MW + 5% power boost	**Array cables**	XLPE (Prysmian)
WTG	SGRE DD200 11MW + 5% PB	**Number of array strings**	12
Capacity at onshore POI	924MW	**Transmission technology**	HVDC Plus (Siemens Energy)
Interconnecting system operator	NYISO	**HVDC transmission voltage**	±320kV
Interconnecting trans. owner	LIPA	**HVDC configuration**	Symmetric monopole
Interconnecting trans. operator	PSEG-LI	**HVDC cable**	XLPE (Nexans)
Onshore POI	Holbrook substation 138kV	**HVDC cable length**	≈130km offshore + ≈30km onshore

Source: L. Zeni et al. "Sunrise Wind: USA's first HVDC connected offshore wind farm". Accepted for publication at Cigré session 2024, Paris. Paper ID 11589.

Sunrise Wind – Overview



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Sunrise Wind – Requirements and solutions

- Onshore harmonics
  - High frequency resonances between 138kV HVAC cables and grid impedance may lead to large IT product
    → Small harmonic filter installed at onshore converter station
- Offshore harmonics
  - Natural resonance of array cable capacitance and WTG and HVDC transformers can lead to high distortions around h10
    → Application of IEEE 519 standard
    → Remove conservatism from modelling
    → Backup: impedance shaping of WTGs
- Onshore dynamic and transient performance
  - HVDC offers robustness in terms of
    - Stability in low short circuit ratio
    - Smooth energization via pre-insertion resistor
    - Decoupling of reactive power control onshore/offshore
- Onshore frequency / active power control
  → WTG plant controller directly senses onshore frequency to ensure proper active power / frequency control at POI
- Connection at relatively low voltage (POI voltage is 138kV)
  → Use of two 138kV circuits with two conductors per phase
  → Generation runback scheme (quickly reduce power to max 50%) for 138kV cable trip

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