NOISE MITIGATION IN GERMAN OFFSHORE WIND CONSTRUCTION SINCE 2014

PRACTICAL EXPERIENCE AND INFLUENCE OF PILE DRIVING ON HARBOUR PORPOISE

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Bundesverband der Windparkbetreiber Offshore e.V. (BWO) The Association of German Wind Farm Operators
Formerly: AGOW

17 Members
- Companies involved in planning, construction and operation of offshore wind parks
- All wind parks currently operational and under construction in the German North and Baltic sea

What We Do
- Derive political recommendations from members' expertise
- Enable the exchange of information between members
- Promote the development of offshore wind power

Political Demands
- Expand offshore capacity in Germany by 20GW by 2030
- Use all available converter capacity
- Expand the major transmission systems

Working Groups
- WG Engineering
- WG O&M
- WG Politics
- WG Environment
- WG Legal Framework
Presentation overview

• Underwater noise management in Offshore Wind projects
• Current Noise mitigation measures – Deterrence, mitigation, control of efficiency
• Research and development - to understand and reduce environmental impacts
• Summary
Underwater noise during installation

Environmental regulations & impact knowledge:

Country specific approaches range from:

- Impact assessment based on individuals / populations, injury / disturbance, accumulation / direct, frequency weighted/unweighted,
- Generic guidelines <-> each time project specific
- Monitoring & mitigation to be conducted completely from developer/WF owner <-> completely from authority
- Monitoring & mitigation methods differ between countries

- **Weak (but increasing) knowledge base** for impacts on species/individuals/populations is a major challenge
- **Strategic work needed** – all need to come together – **we are ready! (already engaged)**
  - Increase evidence base from OWF monitoring, **remaining uncertainties** about injury & disturbance risk
  - Take **industry experience** on technical / operational and timeline constrains into account
Underwater noise – the concept in Germany

Construction and pile-driving activities in the marine environment can cause disturbance and underwater noise, which may affect marine mammals such as harbor porpoises.

Impact of noise from pile-driving on marine mammals, especially harbor porpoises, has become a crucial aspect in permit process of offshore windfarms in Germany and other EU countries.

Bundesnaturschutzgesetz – Federal law on nature protection

- Forbidden to injure (§ 44 Abs. 1 BNatSchG) → Individual
- Forbidden to significantly disturb (§ 44 Abs. 1 BNatSchG) → Population

To meet these rules for harbor porpoise, following measures were formulated with the „Noise mitigation concept“ (2013) by the Federal Ministry for the Environment (BMU):

- Threshold levels $SEL_{ss} 160\, \text{dB re } 1\mu\text{Pa}^2\text{s}$ and $SPL 190\, \text{re } 1\mu\text{Pa}$ in 750m distance to the piling location
- Max. 10% of German EEZ affected
- Between May – August max. 1% of main-concentration area affected

Since 2015 - new piling regulation in practical implementation – max. 180min piling time (monopiles) including deterrence
Noise mitigation in German OWPs

Noise prognosis
  • Assess potential noise generation during foundation installation

Deterrence
  • Displace animals from areas of high noise levels by e.g. Soft start or deterrence devices

Noise mitigation
  • Mitigation of noise generation – decreased piling energy, alternative foundation installation
  • Attenuation of generated piling noise by Noise mitigation systems (NMS)

Monitoring / Control of efficiency
  • Pre-, during & Post-construction monitoring
    • Document efficiency of noise mitigation by measuring underwater noise
    • Assess effect on harbor porpoise abundance by C-POD measurements
Deterrence

Displace animals from areas of high noise levels e.g. Soft start and ramp up and/or deterrence devices i.e. Pinger, Seal Scarer (ADDs)

Soft Start:
• In most cases required from permitting authorities but moreover from technical point of view, depending on:
  • Installation method (e.g. impulse piling, vibration)
  • Installation spread (e.g. monopiles, jackets)
  • Soil conditions (e.g. punch through)

Deterrence devices:
• Low cost, easy to use, effective
• Type and duration should be carefully chosen (e.g. Fauna guard)

Current industry experience/practice:
• Deterrence mostly from the installation vessel or from „Bubble Curtain Vessel“
• 1-3 pingers 40-50 min. before start of piling or operation of NMS
• 1-2 Seal Scarer 30-40 min. before start of piling or operation of NMS (parallel to pinger)
• Since 2018 “Fauna Guard” device as alternative deterrence system – species frequency specific deterrence and reduced to 30min
Noise mitigation

Mitigation of noise generation and/or attenuation of generated piling noise depending on:

• Installation method (e.g. impulse piling, vibration, suction bucket)
• Installation spread (e.g. monopiles, jackets; jack-up or anchor vessels)
• Soil conditions (e.g. end depth needs to be reached)
• Weather conditions (weather windows / operational limits)
• Site environmental parameters (e.g. currents, water depth)
Noise mitigation systems

Bubble Curtain system
- Guided & unguided "Little Bubble Curtain" (LBC)
- Small Bubble Curtain (Menck) (SBC)
- Big Bubble Curtain (HTL, Weyres) (BBC)

"Shell-in-shell" system
- Noise Mitigation Screen (IHC) (IHC-NMS)
- Cofferdam & shell-in-shell constructions
- BeKa shell (Weyres Offshore) (BeKa)
- Fire Hose Methode (Menck)

Other systems
- Pile wrapped with foam
- Hydro-Sound Damper
- Resonator system (AdBm)
- HydroNas (W³GM)
- .....
### Noise mitigation - current industry experience/practice

Noise mitigation systems used 2011-2018 for WTG foundations

<table>
<thead>
<tr>
<th>FOU Constr. Year</th>
<th>OWP Project</th>
<th>No of foundations &amp; Ø</th>
<th>Big Bubble curtain variation (BC; Small (S), Double (D), Triple (T), Linear (L))</th>
<th>Sleeve solutions (IHC NMS, Hydrosound damper (HSD))</th>
<th>Water depth</th>
</tr>
</thead>
<tbody>
<tr>
<td>2018</td>
<td>Hohe See</td>
<td>71 MPs, Ø 8m</td>
<td>BBC, DBBC</td>
<td>IHC</td>
<td>40m</td>
</tr>
<tr>
<td>2017</td>
<td>Arkona</td>
<td>60 MPs, Ø up to 7,75m</td>
<td>DBBC</td>
<td>HSD</td>
<td>23-37m</td>
</tr>
<tr>
<td>2017</td>
<td>Merkur</td>
<td>66 MPs, Ø 7,6 m - 7,8m</td>
<td>BBC</td>
<td>IHC</td>
<td>28 - 32m</td>
</tr>
<tr>
<td>2016/17</td>
<td>Wikinger</td>
<td>70 jackets, 4 piles, Ø 2,7m</td>
<td>DBBC, SBC</td>
<td></td>
<td>36 - 42m</td>
</tr>
<tr>
<td>2017</td>
<td>Nordsee One</td>
<td>54 MPs, Ø 6,7m</td>
<td>BBC</td>
<td>IHC</td>
<td>26 - 29m</td>
</tr>
<tr>
<td>2016</td>
<td>Nordergründe</td>
<td>18 MPs, Ø 5,5 m</td>
<td>BBC, DBBC</td>
<td></td>
<td>4-11,5m</td>
</tr>
<tr>
<td>2016</td>
<td>Veja Mate</td>
<td>67 MPs, Ø bottom 8,1m; top 6,5m</td>
<td>DBBC</td>
<td>HSD</td>
<td>average 39,3m</td>
</tr>
<tr>
<td>2015/16</td>
<td>Sandbank</td>
<td>72 MP, Ø 6,4-6,8m</td>
<td>BBC, DBBC</td>
<td>HSD</td>
<td>24,5-33,5m</td>
</tr>
<tr>
<td>2016</td>
<td>Gode Wind 01 +02</td>
<td>97 MPs, Ø 7,5m</td>
<td>BBC</td>
<td>IHC</td>
<td>max. 34m</td>
</tr>
<tr>
<td>2014/15</td>
<td>Amrumbank West</td>
<td>80 MPs, Ø 6m</td>
<td>BBC, DBBC</td>
<td>IHC, HSD</td>
<td>19,5-24m</td>
</tr>
<tr>
<td>2014</td>
<td>Borkum Riffgrd 1</td>
<td>77 MP, Ø 5,9m</td>
<td>BBC</td>
<td>IHC</td>
<td>23-28m</td>
</tr>
<tr>
<td>2014</td>
<td>Butendiek</td>
<td>80 MP, Ø 6 - 6,5m</td>
<td>BBC</td>
<td>IHC</td>
<td>17-22m</td>
</tr>
<tr>
<td>2012/14</td>
<td>Nordsee Ost</td>
<td>49 jackets, 4 piles, Ø 2,4m</td>
<td>BBC, DBBC, linear BBC &amp; DBBC</td>
<td></td>
<td>22-25m</td>
</tr>
<tr>
<td>2013</td>
<td>Dan Tysk</td>
<td>80 MP, Ø 6m</td>
<td>BBC, DBBC, TBBC, linear BBC</td>
<td></td>
<td>21-32m</td>
</tr>
<tr>
<td>2012/14</td>
<td>Global Tech 1</td>
<td>80 tripods, 3 piles, Ø 2,48m</td>
<td>BBC, linear BBC, DBBC, TBBC</td>
<td></td>
<td>38-40m</td>
</tr>
<tr>
<td>2013/14</td>
<td>Baltic 2</td>
<td>80 WTG 39 MP, Ø 5,2-6,5m</td>
<td>DBBC, TBBC</td>
<td></td>
<td>23-35m MP, 35-44m jackets</td>
</tr>
<tr>
<td>2011/12</td>
<td>Meerwind Süd/ Ost</td>
<td>80 MP, Ø 5,5m</td>
<td>DBBC</td>
<td></td>
<td>22-26m</td>
</tr>
</tbody>
</table>

Additionally Small Bubble Curtain (SBC) at Alpha Ventus (2009) and Bard Offshore 1 (3 locations 2010/2011)

OSS foundations up to Ø 2,5m piles used BBC or DBBC in all projects from 2016 on
Noise mitigation - current industry experience/practice

Additional measures & requirements to mitigate noise **generation** and /or **attenuation** of generated piling noise for WTG foundation installation since 2015:

- Adjustment of piling method - high frequency & low energy piling
- Online hydrosound monitoring with hammer energy reduction if needed
- Restriction of piling time to e.g. 140 minutes per pile
- Restriction of piling energy to e.g. 1.000 kJ
- BBC re-use limited to e.g. 40 piles (otherwise prove functionality)
- BBC hose length limited to e.g. 800 m
- DBBC deployment time limited to e.g. max 5 days
- Number of BBC compressors limited to e.g. 22 max.
Status Noise mitigation systems

NMS reliability and constraints:
Efficiency monitoring

Underwater noise measurements by hydrophones & harbour porpoise abundance by C-POD measurements

Hydro-sound measurement:
- Mobile and stationary hydrophones with data storage
- Online hydro-sound monitoring

Harbour porpoise (CPOD) measurement:
- Mobile and stationary C-PODs with data storage
- Online POD monitoring

Current industry experience/practice:
- 1-2 mobile PODs at 750m, 1-2 mobile PODs at 1500m,
- 4-5 single POD stations,
- 1-2 PODs further field (e.g. at POD station and/or nature conservation areas nearby)
- Online POD monitoring occasionally
- 1-2 hydrophones at 750m, 1-2 hydrophones at 1500m and increased effort at reference locations (4-6 positions)
- 1-2 hydrophones further field (e.g. at POD station and/or nature conservation areas nearby)
- Online hydro-sound monitoring in most projects
Costs of noise mitigation measures status 2018

• Costs of Noise mitigation systems still range between 6 – 25 Mio EUR,
• Costs for efficiency monitoring ranges between 200,000€ - 1 Mio EUR
• Several additional vessels / vessel- operations:
  • For noise mitigation/ efficiency monitoring
  • Increased offshore trips / extra barges due to deck space limitation caused by NMS
    • Increased costs in case of delays, extra time - cost per day for installation spread range between 250,000 – 350,000 EUR, plus lost revenue, plus additional costs caused by knock on effects
  • Increased HSE risks
  • Increased requirements of intensive risk assessment and increased marine coordination needs
  • Increased environmental impact due to extra disturbance by vessels and fuel use by vessels and compressors
Summary noise mitigation development – 2011-2014 vs 2014-2018

- **Costs 2011-2014**: 25 Mio €
- **Costs 2014-2018**: 36 Mio €

**Noise Mitigation System (NMS) 2011-2014 (up to Ø 6,5m)**
- Big Bubble Curtain (BBC)
- Combinations of BBC/DBBC etc
- NMS sleeves
- Combination of NMS sleeves + BBC

**Noise Mitigation System (NMS) 2014-2018 (up to Ø 8m)**
- + piling energy reduction
- + piling time restriction
- + NMS regulations

**Compliance with noise emission value 2011-2014**
- 0%

**Compliance with noise emission value 2014-2018**
- 86.25%

**Scope of efficiency monitoring 2011-2014**
- basis measurement (BM)
- BM + additional measurement (AM)
- BM + AM and/or online measurement (OnM) harbour porpoise (hp)
- BM + AM and/or OnM hp and OM hydrosound (hs)

**Scope of efficiency monitoring 2014-2018**

**NMS noise mitigation 2018**:
- <30m water depth with one system 10dB (up to 15dB) with two systems: 15dB
- >30m water – decreasing mitigation efficiency and still a challenge

* NMS noise mitigation 2018:
  - <30m water depth with one system 10dB (up to 15dB) with two systems: 15dB
  - >30m water – decreasing mitigation efficiency and still a challenge
Summary noise mitigation experience

The results and developments described show the strong commitment of the industry. Noise mitigation however still provides a challenge and technical / logistical constrains need to be taken into account:

- **Installation spread** is fixed 1 year before construction - no possibility to change setup anymore. **Installation sequence** is fixed once manufacturing (~1 year before construction) and construction has started.

- **Set of foundations on installation vessel** is adjusted to ship bearing capacity. Noise mitigation systems can decrease deck space and lead to increased installation time due to higher numbers of installation cycles.

- **High flexibility** for developers in terms of means adopted to meet specific regulations important due to project specific needs

- **Meeting thresholds** is still a challenge and a NMS **adjustment phase** is in most cases needed

- **Any Offshore work needs to be planned in detail (method statements) and approved upon with involved parties e.g. authorities, insurance, certifier** - **possibilities for short-time changes limited**

- **HSE is a high priority for all companies!** Introduction of any mitigation tool will lead to an increased HSE risk.

- **Increased R&D effort** since 2012 with DEPONS, Blue piling, GESCHA I&II …
R&D - GESCHA I+II
- Studying impacts on porpoises in the German bight

About the project
The project evaluates recent data from all OWFs installed between 2010-2016 in the German Bight concerning impacts of underwater noise during foundation installation on harbour porpoises.

Gescha II (ongoing): Assessment of 9 additional OWPs built between 2013 and 2016

Value for Wind industry
• Better evidence/facts to inform key decisions: Need for deterrents (“seal scarers”), revision of current noise reduction requirements, relevance of piling duration and cumulative effects from parallel construction sites.

Publications:
• Brandt et al. 2018, in press MEPS. Disturbance of harbour porpoises during construction of the first seven offshore wind farms in Germany

Duration: GESCHA II 2018-2019
Partners: 21 funding and scientific partners, commissioned by „AG Umweltschutz“ of the Bundesverband der Windparkbetreiber Offshore e.V. (BWO), representing all wind farm developers with projects within the German North Sea
R&D - UW noise frequency based impact & mitigation

Animal reactions to sound are complex – frequency dependent noise reactions and mitigation measures should be taken into account to optimize mitigation

- Response thresholds critically depend on noise frequency, i.e. frequency weighting need to be considered when assessing impacts
- Threshold values based on inverted audiogram frequency weighting functions have lately been revised by NOAA (2016)
- The efficiency of mitigation systems is highly dependent on the type of weighting function applied (Tougaard & Dähne 2017)
- Frequency weighting makes a difference, especially for high frequency marine mammals (e.g.) harbour porpoise, as most NMS such as BBC most effectively attenuate the higher frequencies of piling noise
- So far frequency weighing is only taken into account in the US and UK
Underwater noise mitigation

Basic consideration:

- Offshore wind energy helps to **achieve government climate change targets**
- Mitigation measures should be based on a **clear evidence based rationale**, that can and will be reviewed and updated as new evidence is building up e.g. Noise mitigation frequency still mostly neglected
- **Strategic work** towards environmental impact assessment and mitigation regulations should include all stakeholders including industry experience of challenges during offshore installation and operation
- **Cost / benefit** of mitigation measures and renewable energy production should be assessed in an **ecosystem/ holistic approach** i.e. assessing also resource use, disturbance, emissions and increased renewable energy production
- **Early transparency** in regulation is crucial for proper project planning (especially in tender systems!)
- **R&D** to better understand environmental impacts and for new low-impact technologies e.g. alternative installation techniques, is **crucial!**
We aim to assess our actions & impacts from a full ecosystem perspective

By considering the trade-off between local environmental impacts and climate benefits gained from reducing greenhouse gas emissions by replacing fossil energy.

Better evidence → Less precaution → Better decisions

Thank you for your attention!