Presented at CFA/DAGA '04

Underwater noise emissions from offshore wind turbines

Klaus Betke, Manfred Schultz-von Glahn, Rainer Matuschek

ITAP – Institut für technische und angewandte Physik GmbH, 26129 Oldenburg, Germany, Email: info@itap.de

Introduction

At present there are about 30 claims for wind farms in the German North Sea and Baltic areas. At the final stage, some of these farms may consist of several hundred turbines, each one with a rated power of 3 MW or more. While two medium-size offshore farms with about 80 turbines each are already existing in Denmark, the first tubines in German waters will probably be erected in 2005.

Both operation and construction of offshore wind turbines induce underwater noise, which is potentially harmful to marine mammals and fishes.

Operating noise

Vibration of the turbine's gear box and generator is guided downwards and radiated as sound from the tower wall (Figure 1). Sound radiation by surface waves is difficult to compute and to predict, in particular for complicated boundary conditions. Hence, measurements on an already existing offshore wind turbine were made. The setup is shown in Figure 2. Since access to the turbine is only possible at low wind speeds, an automatic recording was made over a one month period. At every full hour, 20 minutes of underwater sound and tower wall vibration were recorded to hard disk. The accelerometer position – approx. 10 m above sea level and perpendicular to the wall – was choosen after preliminary measurements with several sensor positions above and below sea level [1]. Wind and electric power values were taken from the turbine's routine log files.

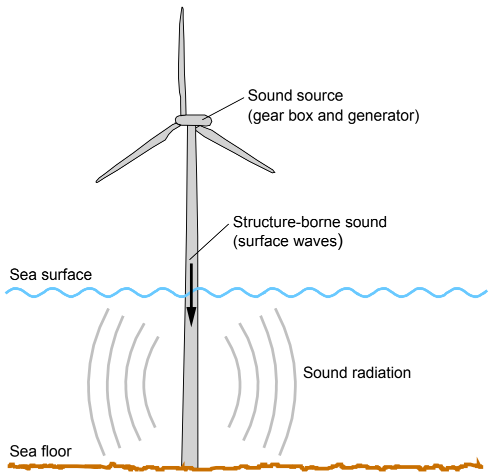

Figure 1: Mechanism of underwater noise generation by an offshore wind turbine

Some acoustic spectra are shown in Figure 3. At low wind speeds, the generator runs at about 1100 rpm, but rises rapidly to the nominal value of 1800 rpm, which is reached at 700 kW. Turbine rated power is 1500 kW. Hence there are mainly two acoustic spectra (caused by two different sets of tooth mesh frequencies), one for low wind speeds, and one for moderate and strong wind.

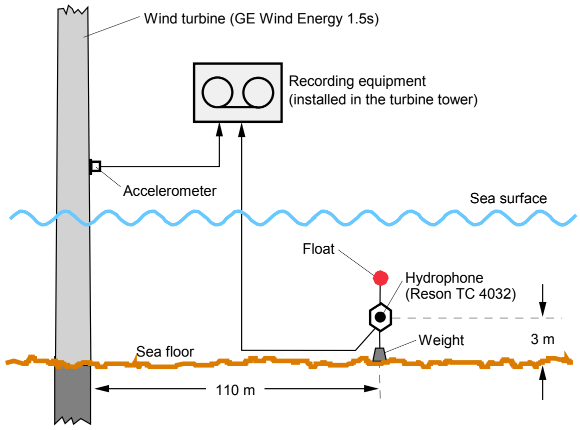

Figure 2: Measurement setup for monitoring underwater noise induced by an offshore wind turbine. Water depth was about 10 m.

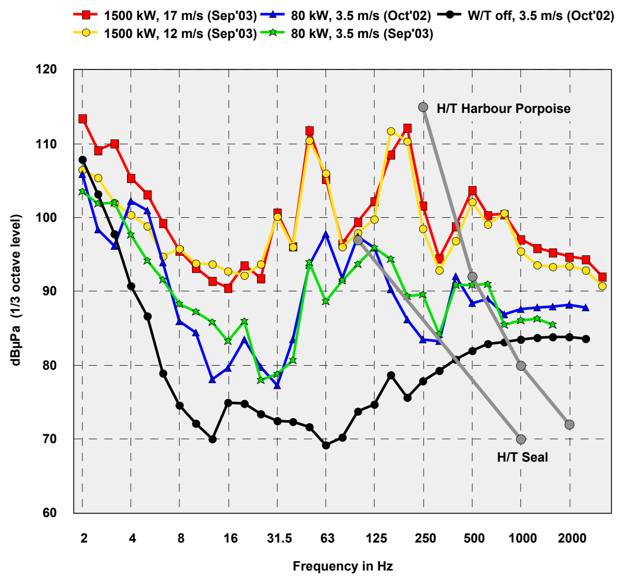

Figure 3: Underwater sound pressure levels (1/3rd octave spectra) recorded at 110 m distance from the turbine for different turbine states. Wind speeds refer to hub height (nacelle anemometer). Low frequency parts of hearing thresholds for two marine mammals are shown for comparison.

The sound levels found here will certainly not cause damage to the hearing organ of marine animals, but might affect their behaviour in the vicinity of a turbine. However, somewhat higher tower vibration levels than for this turbine type have been measured onshore on several 2 to 2.5 MW turbines. If set up offshore, these turbine models are likely to produce higher underwater noise levels than those of Figure 3. On the other hand, the larger the turbine, the lower the tooth mesh frequencies, radiation efficiency of surface wave declines towards low frequencies, while hearing thresholds increase. At present, it is not clear if the underwater noise from offshore wind turbine will influence the behaviour of marine animals.

Construction noise

Most offshore wind turbines are built as "monopiles" with up to 6 m diameter. The tripod – a three-legged construction "nailed" to the sea floor with piles of 1.5 to 2 m – is discussed as well, but has not been applied to large wind turbines so far. In both cases, the piles are brought into the ground by means of a pile driver. Pile driving produces extremely powerful impulsive underwater noise.

Figure 4 shows the time of a single impulse recorded at 400 m distance from a pile driver. The spectrum has a broad maximum in the range 100 – 300 Hz (Figure 5). Impulse rate during these works was about 40/minute.

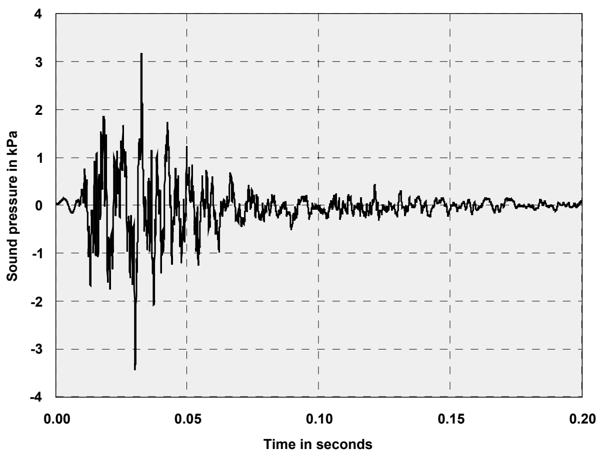

Figure 4: Time function of a pile driving impulse recorded at 400 m distance from the from the FINO 1 construction site [2]. Pile diameter was 1.5 m.

Figure 5: Spectrum of pile driving noise recorded at 400 m distance; average of 300 impulses. Note: SEL (single-event sound exposure level) is the L_{eq} normalized to an event duration of 1 second.

Impulse amplitudes of several 1000 Pa are likely to cause temporary threshold shift (TTS) in some species. But in order to estimate the biological data more precisely, a model for the level decrease with distance is necessary, in which a simple analytic formula is preferred.

North and Baltic Seas are acoustically shallow waters with neither spherical wave nor cylindrical wave propagation; level versus distance usually lies in between. Experimental data from pile driving works in the Baltic indicate a level decrease of roughly 4.5 dB per distance doubling (or 15 dB per decade; Figure 6). This is in agreement with the more detailed approximation formula given in [1].

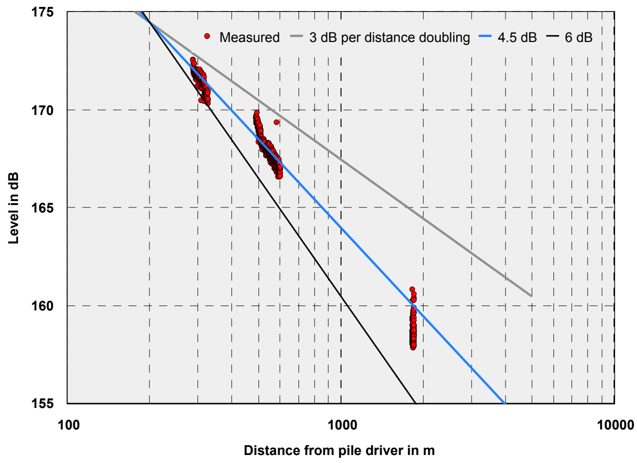

Figure 6: Measured sound levels versus distance for pile driving. The source level (measured close to the pile driver) did not vary by more than 2 dB during the whole operation.

Acknowlwdgments

This work was funded by the German Ministry of Environment (BMU) within the project *Standardverfahren zur Ermittlung und Bewertung der Belastung der Meeresumwelt durch die Schallimmission von Offshore-Windenergieanlagen.* We would also like to thank GE Wind Energy for their excellent support of the measurements at Utgrunden wind farm, Sweden.

References

[1] K. Betke et al.: Messung der Unterwasser-Schallabstrahlung einer Offshore-Windenergieanlage. In: Fortschritte der Akustik – DAGA'03, 322-323. Deutsche Gesellschaft für Akustik e.V. (DEGA), Oldenburg 2003

[2] FINO – Research platforms in the North and Baltic Seas `http://www.fino-offshore.com/`