ACOUSTIC AND SEISMIC EMISSIONS FROM WIND TURBINES

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Summary

With regards to the interdisciplinary "TremAc" Project funded by the German Federal Ministry for Economic Affairs and Energy, this paper examines acoustic and seismic emissions generated by wind turbines with the aim of identifying a better understanding of their interaction. Measurement campaigns will be carried out in the field around a single wind turbine plant and results in terms of acoustic and seismic signals will be correlated and then evaluated in relation to environmental factors such as wind speed, wind direction and temperature as well as to data related to the wind turbines-specifications (e.g. rotation speed).

1. Introduction

The use of wind parks has been increasingly used as important source of renewable energy [1]. However, their influence on the people's annoyance depends mainly on environmental factors such as noise or landscape impact [2], and their social acceptance has been identified as a necessary aspect for the development of renewable industry [3] [4] [5]. In this context the interdisciplinary "TremAc" project funded by German Federal Ministry for Economic Affairs and Energy aims at investigating vibration and acoustic emissions of onshore wind turbines (WITs) by using measurements and simulations as well as evaluating their impact on people through surveys.

Research suggested that WITs could be evaluated as a source generating vibrations in the ground [6][7] as well as sounds propagating to surrounding areas [8] but those phenomena are not fully understood yet. Although great attention has been paid to evaluate acoustic emissions from WITs [8], systematic observations of WITs-induced seismic emission are very sparse in the literature [6] [9] [10]. However it was observed a correlation between the increasing of seismic noise and the installation of new WITs [11]. Additionally a recent study [6] was able to compare the seismic data with plant-specific measurements, like the rotation speed. On this regard further investigation would be needed to evaluate acoustic-seismic emissions from WITs. In the paper presented here research focuses on the evaluation of sound and seismic emissions generated by wind turbines (WITs). The findings obtained will allow identifying a better understanding of the acoustic-seismic emissions in relation to environmental factors and wind-turbine specifications as well as their mechanism of propagation.

2. Research methodology

Measurements will be carried out for a single wind turbine near a town in Baden Württemberg. This gives the advantages to exclude the influence of additional WITs. The single WIT is located on a flat surface and 1.2 km distant from the nearest resident village. A psycho-survey campaign will be also simultaneously realised among residents living nearby the WIT. Results could be then used to find a correlation between objective acoustic and seismic parameters and subjective annoyance.

Acoustic measurements with particular emphasis to low-frequency sounds will be performed together with seismic measurements for several weeks (day-night time) at different distances in downwind conditions around the WIT. The assessment of background noise will be also evaluated with the WIT switched-off (2 times over 24h). Additionally environmental parameters such as wind-data (speed and direction) and temperature will be contemporary measured through a met mast at 10 m height according to [12]. Preliminary seismic measurements were carried out at wind farms near the town Landau (Germany) as shown in Fig. 1 and results are reported in section 2.2.1.

2.1. Acoustic measurements

2.1.1. Equipment

Acoustic measurements will be conducted by using microphones connected to imc Cronos-flex data acquisition system supporting 4 channels - audio card with 24 bit resolution and max sampling rate of 100 kHz (100kS/sec), which is operated with imc Studio-PRO-5.0 Software. In order to evaluate low frequency sounds, G.R.A.S 47 AC ½" free field microphones with

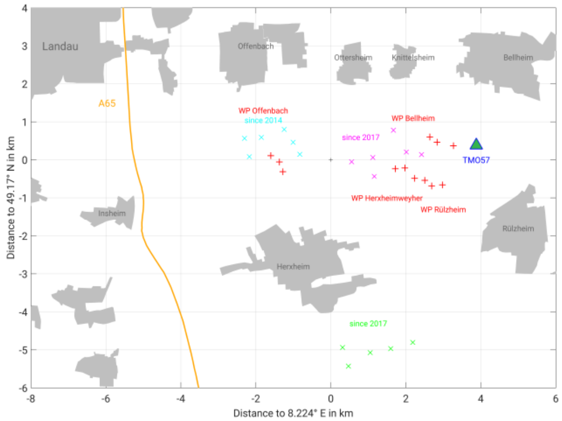


Fig. 1 Map of the study area. Seismic station is indicated as triangle, wind turbines are indicated as crosses.

a frequency response ±3 dB at 0.09 Hz to 20 kHz will be used.The calibration of the analysers and microphones will be checked both prior to and following each set of measurements.

2.1.1. Methods

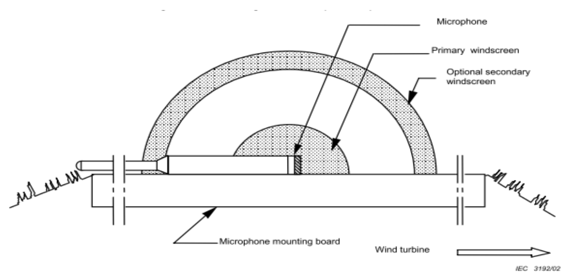
Two different microphones mounting techniques are used for the measurements of acoustic emission. For both two techniques microphones will be located at a horizontal distance R from the wind turbines (Equation 1):

$$R = H + D/2 \qquad (1)$$

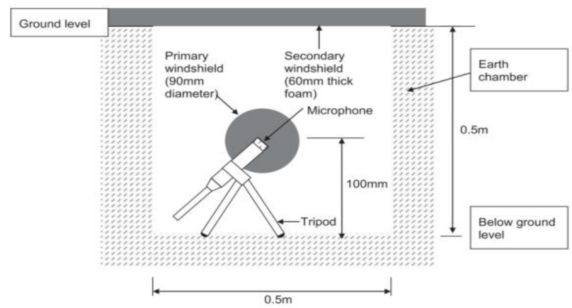
Where H is the vertical distance from the ground to the rotor centre and D is the diameter of rotor [12].

The first method consists of a microphone placed over a flat circular wood board (1.2 mm thickness; 1 m diameter) and protected by a primary windscreen (90 mm diameter) and secondary windscreen (450 mm diameter) according to the procedure of IEC 61400-11 (Fig.2(a)). On the other hand the second method adopts a below ground technique consisting of a microphone placed in a hole at around 0.5 m distance below the ground level and inside a wood box with dimension 0.5 m × 0.5 m and covered by transparent acoustic material, as shown in Fig. 2(b).

Research showed that the below ground technique can be used to evaluate sound at very low frequency range with a minimal effect of wind on microphones [13] but this cannot be used at high frequency range as the microphone is not placed at sufficiently larger reflecting surface [14]. For that reason the comparison between results obtained from the two methodologies allows understanding the effective contribution of sound emission at low frequency range from the WIT.



(a) Microphone placed on the ground level according to IEC 61400-11 [10].



(b) Microphone placed below ground level according to Turnbull et al. (2011) [11].

Fig 2. (a-b) Different mounting techniques for microphones used for the measurements in terms of acoustic emissions.

In addition, results obtained from the first standard technique (microphone on the ground level) will be also assessed over the whole frequency range (from 0.1 Hz to 20 kHz). Those can be then used to calculate sound propagation according to the procedure of ISO 9613-2 [15]. Research showed that low-frequency sound from WIT is spreading spherically until at certain distance between source-receiver (attenuation of 6 dB/doubling of distance) and then cylindrically (attenuation of 3 dB/doubling of distance) [16]. However the definition of this transition distance between the two different propagations is not clear yet. For that reason the calculated values will be then validated by those measured in the field at immission points in order to define the sound propagation at low frequency level.

2.2. Seismic measurements

2.2.1. Preliminary Measurements

Seismic emissions of WTs and the behaviour of WT-induced signals on seismic stations are not fully understood, especially in comparison with meteorological resp. plant-specific measurements. By using results from preliminary measurements around

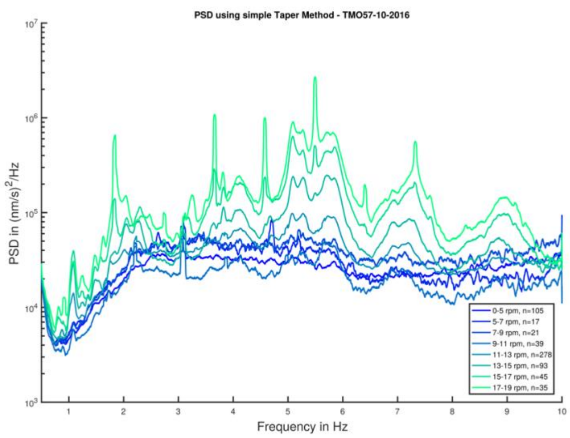


Fig. 3 Seismic measurements: the power spectral density (PSD) over the frequency range from 0.5 to 10 Hz. Data from the station TMO57 (October 2016). In the legend rotation speed bins with the corresponding number of one-hour long segments used for the mean calculation are indicated.

wind farms, seismic noise signals were compared with WT-specific data like the rotation speed. It was observed a clear correlation of the increasing seismic noise level with an increase of the rotation speed of the WT (Fig. 3). Therefore, data from one month-measurement were analysed with data from seismic station located near to a WT (see station TMO57, Fig. 1). More detailed information about data processing can be found in [4].

An increasing seismic noise level with increasing wind speed is not unusual for seismic measurements but this upward trend was observed in several studies as in [9] [17]. However, results showed clear discrete frequency peaks visible between 0.5 Hz and10 Hz (like at 0.9, 1.8, 2.7, 3.7, 4.6 and 5.5 Hz) (Fig. 3) and those were not found in the studies mentioned before [7] [15]. These discrete peaks arise with rotation speeds of more than 11 rpm and increase significantly in their intensity level with the increasing of rotation speed, up to 100 times in the vicinity of the WT.

The frequency peaks can be correlated with the blade-passing frequency (three times of the rotation frequency) of the WT and its multiples and those were also observed in previous research [11].

2.2.1. Seismic Measurements

Results from preliminary seismic measurement showed that the generation of the emitted seismic signals could not just be explained by the blade-passing frequency. For that reason, the interaction between seismic waves and several plant-specific interference effects such as eigenfrequencies of the tower-nacelle system will be evaluated. In addition, it was pointed out a need to differentiate between interference effects of several WTs on seismic waves. This could be fulfilled by studying the seismic emissions from a single WIT. Accordingly results obtained from the measurements presented in this paper will be then used for this goal. Furthermore, several seismic measurement concepts will be used such as profile measurements. The sensors will be deployed along a line with distances up to several kilometers from the WIT and with different azimuths around the WIT. This aims at evaluating the attenuation coefficients for the WIT-induced signals in relation to the geological parameters. Ring measurements will be also performed in the vicinity of the WIT in order to study the characteristics of emitted radiation. Finally, seismic array methods will be then carried out near to the WIT in view of identifying the type of emitted wave.

3. Conclusions

In this paper the research methodology used for combined acoustic and seismic measurements around a single WIT is presented. Results in terms of acoustic and seismic signals will be evaluated in relation to environmental factors as well as plant-specifications data and then together compared. In addition mechanism of acoustic and seismic wave propagation will be studied in order to identify the attenuation effects over distance from the WIT. This allows developing a better understanding of WIT as a source of emission.

4. References

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