Experiences with methods to assess noise complaints of wind farms

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Summary
Different methods were used to objectify noise complaints in two German wind farms, which were both in accordance with the legal requirements. Psychological surveys collected information about stress effects and annoying situational conditions. Residents reported annoying time periods by filling out complain sheets and or by using sound recorders to provide annoying sound characteristics. By measuring permanently the overall sound field in the vicinity of a wind farm and correlate this data to wind turbine parameters as well as to reported time periods of annoyance turned out to be a promising methodology to get a better understanding under which conditions sound phenomena lead to complaints. In our studies we found that amplitude modulation as well as changing sound levels led to increased annoyance by residents. In both studies only a few residents were willing to support our studies actively, so improvements to our

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1.) Introduction

To keep a good neighborhood between wind farm residents and operators as well as to the regularity bodies it is worth to get a better knowledge about sound patterns, generated from wind turbines (WT), which induce annoyance. In interdisciplinary acceptance studies on two German wind farms (see [1],[2]) − both in accordance with the legal requirements – but with strong noise complaints, we used different assessment methods to objectify complaints and to get a better knowledge about the reasons leading to annoyance. Generally we used following methods:

- Psychological surveys on residents.
- Assessment of annoying time periods
- Physical (permanent) sound measurements

A detailed description of these methods, reasons why we have chosen this approaches and some ideas for future improvements are given in the following. Exemplary results show that sound characteristics like amplitude modulation (AM), which are generally not relevant for legal approvals can lead to annoyance and complaints about WT noise. Also changing situations like the planning or building process of the wind farm or increasing sound levels due to the increase of wind speed lead to annoyance.

2.) Methods

Annoyance of sound is a very subjective feeling and depends on several psychological and acoustical factors. That's why a mixture of psychological as well as physical methods is needed to objectify and to get an understanding of noise complaints of wind turbines. In two studies (see [1],[2]) we used the following methodology:

2.1) Psychological surveys

Residents of the wind farms were interviewed elaborately by psychologists to get information about somatic / psychological stress effects and the most annoying noise characteristics. We used the following indicators; General impact of the wind farm, general impact of WT noise, WT noise annoyance and its temporal change, characteristics of a typical situation with WT noise annoyance,

psychological and somatic symptoms induced by WT noise, cognitive and behavioral coping responses.

2.2) Assessment of annoying time periods

To understand disturbing noise phenomena of wind turbines it is essential to know which specific situations (date/time, operational state of WT, environmental conditions, …) are most annoying and in which stress state residents are during this time periods.

In our recent studies this assessment of annoying time periods was done by using complain sheets and mobile sound recorder devices. The questionnaires were two sided paper sheets, which were handed out to annoyed residents at the end of the interviews described in section 2.1. They were mainly asking for the following information: WT noise annoyance, noise pattern, disturbed activities, emotions and cognitions, and weather conditions.

The sound recorders were used by the residents to record annoying sound patterns together with an electronic time stamp. We used simple linear audio recorders (Olympus LS-100) able to save high quality uncompressed wave files, equipped with a wind shield and mounted on a stand (figure 1) to reduce disturbing noise. During our studies these sound recorders were either available at a well-known contact person within the neighborhood of the wind farm or had been handed out directly to the annoyed residents. This devices cannot be used to obtain information about sound levels during annoying time periods, due to missing calibration options and nescience of the exact measuring place, but the recordings can be used to evaluate sound characteristics.

Figure 1: Used audio recorder system on a stand equipped with a wind shield

For evaluation this dataset was correlated to wind turbine parameters delivered by the operator and sound measurements gained by residents and the permanent sound measuring device described in section 2.3.

In our studies it turned out, that only a few persons were willing to support such assessments, which led to a very weak data basis for further analyses. So residents should be get more motivated to help by reporting annoying time periods. We think this can be done by intensifying our public information procedures and by making it easier to report annoying time periods. That`s why we plan to develop and use easier methods like smart phone applications in the future.

2.3) Physical sound measurements

Beyond calibrated sound level measurements of wind turbines conducted according to standards like IEC 61400-11 [3] and predicted sound levels according to ISO 9613-3 [4] at resident's houses it is sometimes desirable to have an overview of the whole sound field, which can consist of multiple different sound sources. Loudness for example can have a different effect in silent areas than in very noisy neighborhoods. Also everyone will hear and feel annoyed by a very silent wind turbine after getting awake due to a rare sound occurrence not linked to wind turbines like a passing train or plane. Like shown in [1] there are also rarely occurring sound characteristics, like amplitude modulation (AM), which are not an element of standard sound measurements and regulations. It is also desirable to have calibrated sound recordings during time periods, which are described as very annoying by residents (see section 2.2).

To gain this information we developed a sound measuring station (figure 2) sampling the overall sound field permanently in the vicinity of the studied wind farm or directly at the houses of disturbed residents. This station consists of a omnidirectional weatherproof microphone with a single wind shield, which is mounted 1.2 m above ground, a standard sound level meter (B&K 2236) used as amplifier and a sound recorder (SoundDevices 702 T) able to save uncompressed (24 BIT, 48 kHz) wave files on an attached disk drive. A software was written to evaluate the recorded data and to correlate it to the wind farm parameters like wind speed and direction delivered by the wind farm operator.

We found that the data gained by use of this device was useful to get a better understanding of the emitted sound of the wind farm and the general soundscape around. But at wind speeds above 10 m/s or in rainy conditions the recorded data was strongly disturbed by environmental noise. In future versions a rain sensor should be attached to the measuring station to filter out time periods disturbed by rain. Also it is planned to have a web interface showing actual and historical data allowing a better interaction with residents. It is also desirable to get a better wind shield and to operate simultaneously several measuring stations within one campaign to get a better understanding on directional sound emissions and local effects.

Figure 2: Permanent sound measuring station; left: used enclosure with sound recorder (upper device), sound level meter (greenish device on left side) used as preamplifier, a hard disk drive (silver box on the right side) and some power supply equipment at the bottom; right: used weatherproof microphone unit on a stand

3.) Exemplary results

Some of our main findings gained by the above described methodology are exemplary shown in the following. For more detailed information see [1] and [2]

3.1) Psycholgical outcomes

In both studies we found about 20 residents who were strongly annoyed by WT noise. Strongly annoyed means that they reported not only at least medium annoyance but also symptoms induced by WT noise at least once a week. Most frequently disturbed were sleeping, relaxation, and leisure activities. Typical symptoms were disturbed sleep, fatigue, irritability / anger, negative mood, and reduced concentration. Frequently used coping responses were conversations with relatives / friends, closing windows, and place leaving Factors which are related to WT noise annoyance are negative attitude towards the wind farm, strain during the construction phase of the wind farm, and to be an opponent of the wind farm.

3.2) Amplitude Modulation

In both studies we found, that in many cases it is not the loudness of the broadband WT-noise causing complaints, nor is it tonality or impulsivity at least according to standardized definition of impulsivity. Interviews and sound descriptions in the interviews show that residents complain about sound identified as different from the “natural” background noise, even if the loudness of this special sound is very low and hardly perceptible.This is a WT-specific sound characteristic perceived by humans, and directly correlated to the rotation of the rotor blades. This sound described as swishing in the frequency of the rotor blades is amplitude modulated aerodynamic noise of the WTs (AM).

While sound measurements are usually made under circumstances were no AM occurs, this shows how important it is to get information about the most annoying time periods by the residents and to have a calibrated long term sound measurement to visualize all relevant parameters during this time periods.

By using the numerical tool described in [5] the modulation depth ΔL of all relevant sound recordings can be evaluated. The modulation depth ΔL is defined as the difference between the maximum and minimum sound pressure level and correlates to the annoyance level [5]. A modulation depth of 1 dB is audible. Modulation depths above 2 dB can cause annoyance. Figure 3 illustrates the distribution of modulation depth for the reported annoying time periods during one of our studies, showing that during mostly all reported time periods modulation depth had a level, which could at least cause annoyance.

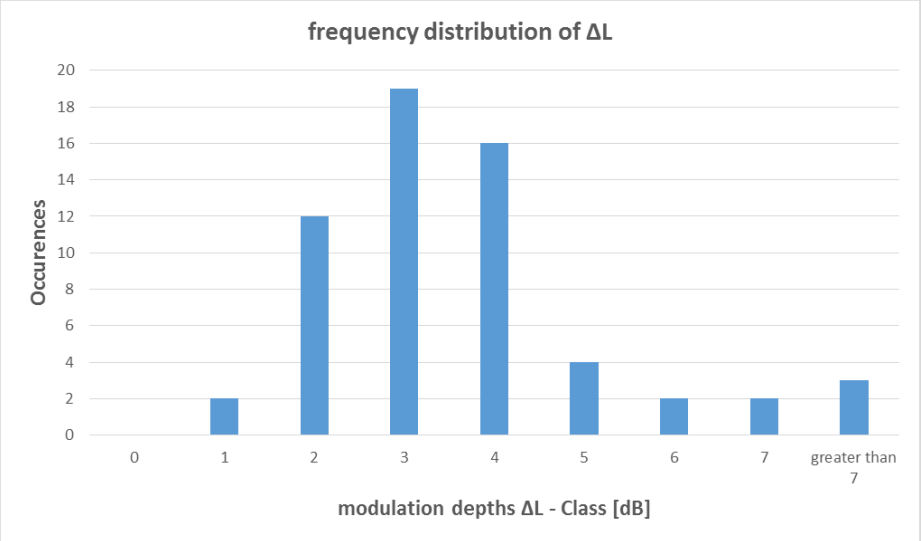

Figure 3: Frequency distribution of amplitude modulation depth ΔL obtained during annoying time periods reported by residents during one of our studies. Modulation depths greater than 7 were due to singing birds.

High modulations can occur in short peaks, which will lead the preceptor to concentrate on WT noise and feel annoyed by that. An exemplary time series of modulation depth ΔL with two short time periods of less than 5 seconds of relevant AM is given in Figure 4.

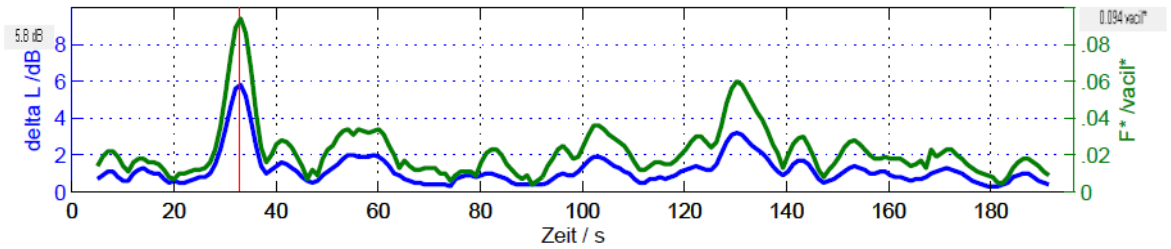

Figure 4: Example of a time series with short AM events

There are different algorithms available like e.g. [6] to evaluate AM, which are leading to different results. All algorithms cannot distinguish between AM caused by a WT or by human voices and birds (values greater than 7 in figure 3). Therefore human listening remains necessary to evaluate AM. The impact of amplitude modulation to preceptors is still unknown and has to be further investigated. In a future study we would like to evaluate how often and how intense AM occurs and how it is correlated to environmental or wind turbine parameters.

3.3) Annoyance due to changing sound levels

By comparing WT parameters and calibrated sound levels gained by the permanent sound measurement stations to the most annoying time periods reported by residents, we found at least two time periods within one study, where the residents were annoyed by increasing sound levels emitted by wind turbines.

Situation 1: Like shown in figure 5 all WT were switched on shortly before the annoyances were reported (black crosses).The sound levels (LAF / lower blue line) increased suddenly while wind speed (9 m/s / upper blue line) and wind direction (204° to 211° / upper red line) were nearly constant. In this situation AM was audible but with modulation depths between 2 and 2.7 dB not very pronounced. This leads to the assumption, that this accumulation of complains is due to the suddenly increasing sound levels

Situation 2: A second time period (see figure 6) with many complaints occurs during a very silent time period shortly after the wind speed has increased from 0 to 15 m/s and the wind turbines were switched on. During this time period the sound levels were slowly increasing and we had a very variable but pronounced AM situation with modulation depths between 1.7 and 5.9 dB during the reported time periods. All the complaints were reported after the overall sound level has increased by more than 5 dB. We think, that this accumulation is also due to changing sound levels and not because of amplitude modulation.
This last example is also showing the effectivity of the sound reduced operation mode as the sound levels are suddenly decreasing when the night time (gray background in figure 6 appears.

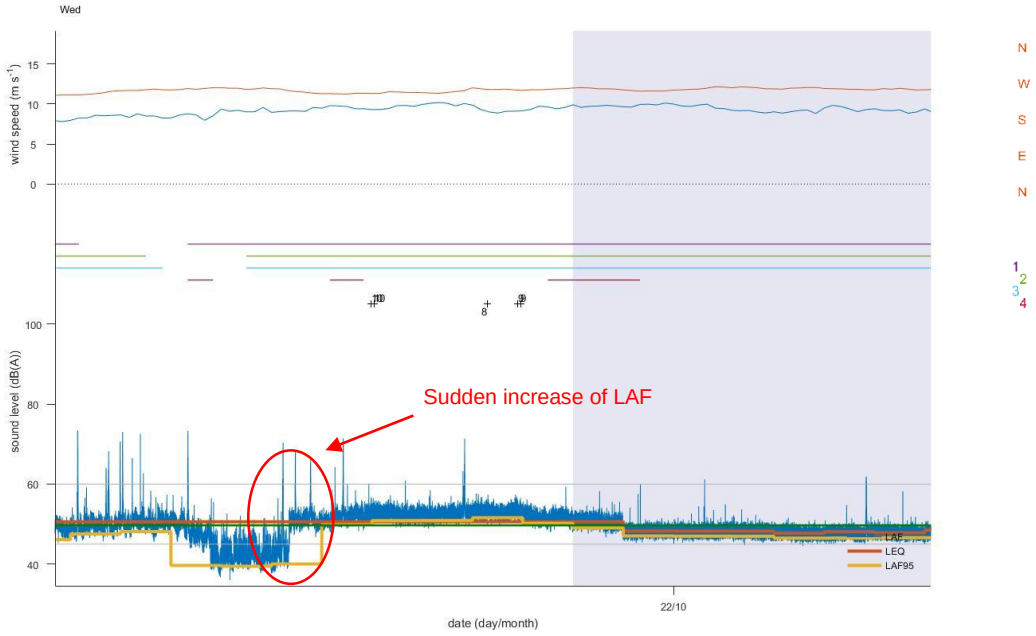

Figure 5: Results from permanent sound measuring station during a time period with an accumulation of complains. The bottom lines are showing the measured sound levels. Black crosses in the middle showing reported times of annoyance. The numerated horizontal lines are indicating the on-state of different wind turbines. And the top lines showing the wind speed (blue) and wind direction (red) as measured by the wind turbines.

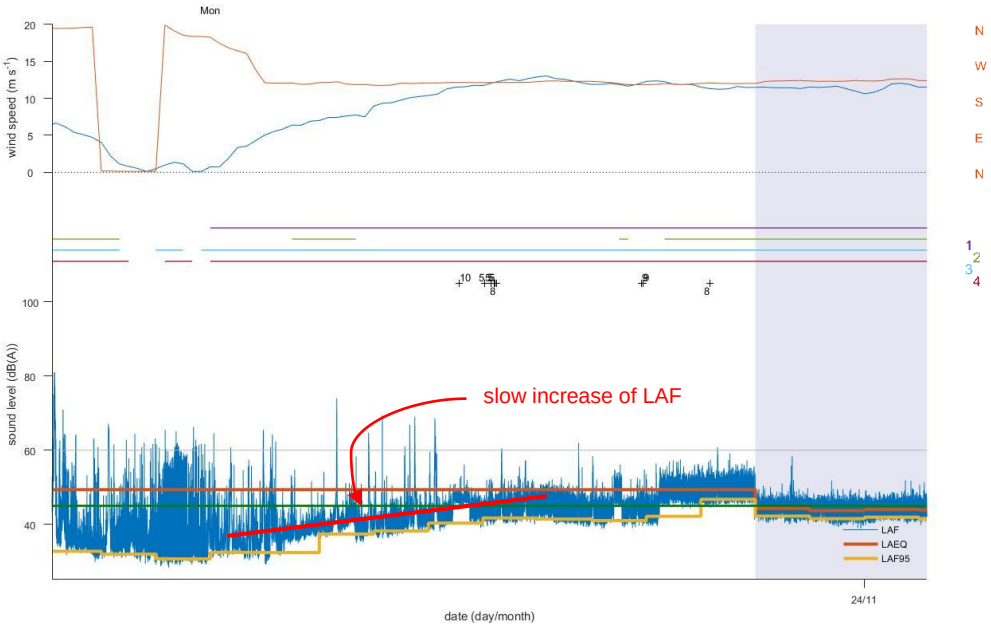

Figure 6: Results from permanent sound measuring station during a time period with an accumulation of complains. The bottom lines are showing the measured sound levels. Black crosses in the middle showing reported times of annoyance. The numerated horizontal lines are indicating the on-state of different wind turbines. And the top lines showing the wind speed (blue) and wind direction (red) as measured by the wind turbines.

4.) Conclusions

Different methods were used to objectify noise complaints in two German wind farms, which were both in accordance with the legal requirements but which had strong noise complaints.
Assessment methods used to objectify complaints and to get a better knowledge about the reasons leading to annoyance, were:

- Psychological surveys on residents.
- Assessment of annoying time periods
- Physical (permanent) sound measurements

Psychological surveys collected information about stress effects and annoying situational conditions. In both studies we found about 20 residents who were strongly annoyed by WT noise. Strongly annoyed means that they reported not only at least medium annoyance but also symptoms induced by WT noise at least once a week.
Assessment of annoying time periods is crucial to understand which parameters lead to annoyance. This assessment requires the support of the residents. We tried to motivate residents to fill out complaint sheets and to use sound recorders to report their complaints. However in both studies only very few residents cooperated. This leads to a very weak data basis for further analyses. We plan to develop and use easier methods like smart phone applications in the future to make it easier to report complaints.
A permanent sound measurement in combination with wind turbine parameters (like wind speed, …) is a good tool to objectify the feelings of the residents and to get a better understanding of the emitted sound of the wind farm and the general soundscape around. The combination of more permanent measurement stations could be a further promising methodology to get a better understanding of the factors that lead to complaints. Providing live sound level data measured with the permanent sound measuring device via webserver could be a good method for a better integration of residents to the studies.
Exemplary results show that sound characteristics like amplitude modulation (AM), which are generally not relevant for legal approvals can lead to annoyance and complaints about WT noise. We found also, that changing situations like the planning or building process of the wind farm or increasing sound levels due to the increase of wind speed lead to annoyance.
Further studies on other wind farms should be conducted to get a better understanding of annoying sound patterns. Topics like amplitude modulation require further research to understand the effect of this noise patterns on residents.

References

[1] G. Hübner, J. Pohl (2010). Akzeptanz und Umweltverträglichkeit der Hinderniskennzeichnung von Windenergieanlagen. Abschlussbericht zum BMU-Forschungsvorhaben (FKZ: 03MAP134). Halle (Saale): Institut für Psychologie der Martin-Luther-Universität Halle-Wittenberg.

[2] F. Wilts, J.Pohl, T. Neumann, Untersuchung der Schalleinwirkungen auf die Anwohner des Windparks Anzetel-Wehlens, Abschlussbericht, August 2016

[3] IEC 61400-11 (2012), Wind turbines - Part 11: Acoustic noise measurement techniques, International standard

[4] ISO 9613-2 (1996) Acoustics -- Attenuation of sound during propagation outdoors -- Part 2: General method of calculation

[5] S. Vogl, Erfassung und Bewertung von Amplitudenmodulation in Windenergieanlagengeräuschen, Bachelorarbeit am DEWI, 12.02.2013

[6] G. Lundmark , Measurement of Swish Noise, a New method. Fourth International Meeting on Wind Turbine Noise, Rome, Italy, April 2011.