7th International Conference
on
Wind Turbine Noise
Rotterdam – 2nd to 5th May 2017

Using long term monitoring for noise assessment of wind farms

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Summary

A relative small wind farm (3 wind turbines) was developed in the center of The Netherlands near a crowded residential area, major highways and waterway. To prevent noise nuisance the local authority applied strict noise limits. These noise limits were based on the background noise (L_{95}) at different wind speeds. However in practice this wind farm had caused a lot of nuisance in the residential area. The local residents had great doubts whether the wind farm would meet its noise limits. Long term monitoring of the noise emission was demanded which had to ensure the local authority and the local residents that the wind farm meets the noise limits.

The local residents demanded that the noise levels were measured at their properties (the location where the nuisance was experienced). From an acoustic point of view such a measurement is less suitable for an assessment due to the disturbing background noise at those locations. The local authority was more interested in accurate measurements with a legally binding assessment. For that reason the noise levels were measured at the nearest dwellings as well at a relative short distance to the wind turbines during a period of a month. Simultaneous the wind speed and wind direction were measured at a height of 10 m. The noise measurements close to the wind turbines were used to calculate the sound power level in accordance with IEC 61400-11. With these sound power levels the noise levels at the dwellings were calculated and assessed. This paper presents the results of the measurements and also gives a consideration whether noise measurements regarding wind turbine noise at locations nearby residential properties can be useful for assessment and to provide these results to local residents.

1. Introduction

A relative small wind farm was developed in the center of The Netherlands. In figure 1 the location of the wind farm is given. The wind farm consists of three wind turbines of the type Vestas V90 with a power of 2 MW each and a hub height of 105 m. The location of the wind farm is located at the border of the municipality. The major noise sources in this area are the motorway A27, the barges on the waterway and the traffic on the major ring roads. Few scattered dwellings are located around the wind turbines. The nearest dwellings are located at a distance of 300 m from a wind turbine. At the east side of the wind farm a residential area is located at a distance of more than 500 m from the nearest wind turbine.

To prevent noise nuisance the local authority applied strict noise limits in the permit. These noise limits were based on the background noise (L_{95}) at different wind speeds.

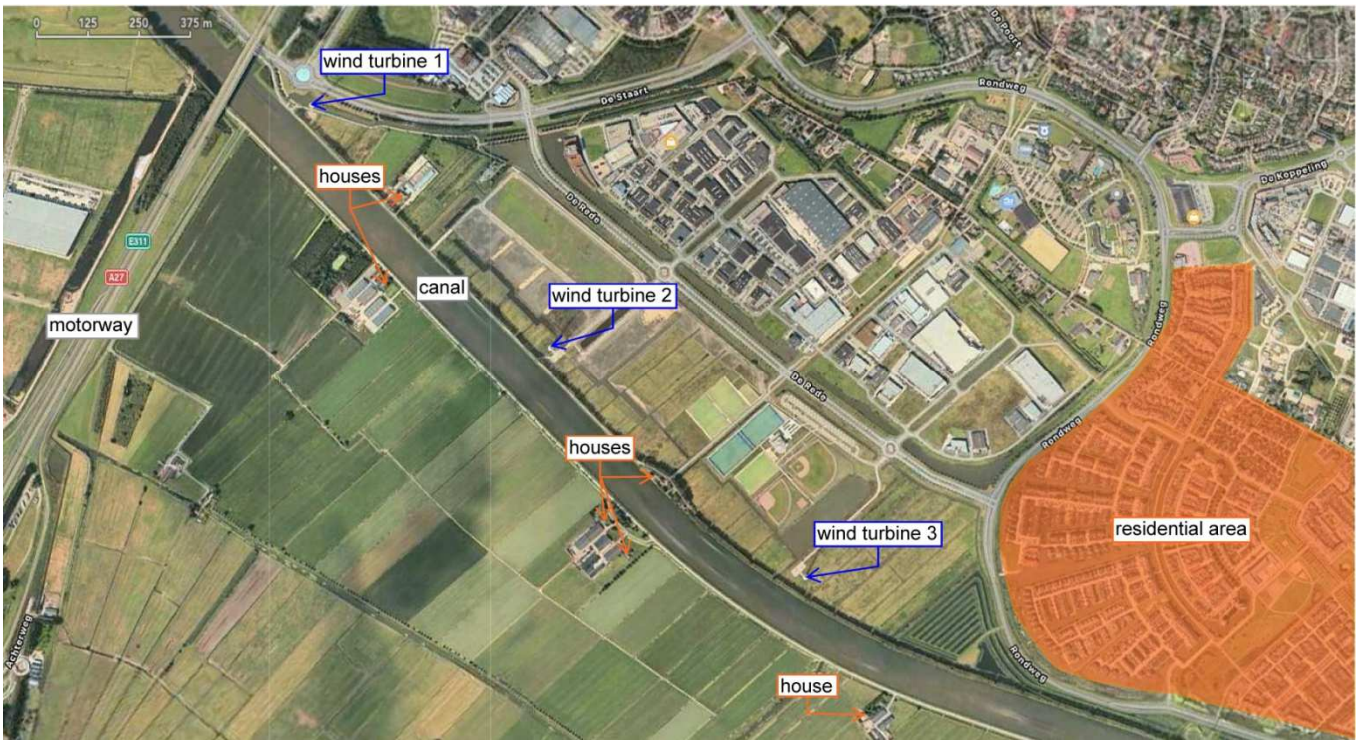

Figure 1: Location of wind farm

2. Reason for noise survey

2.1.Noise limits permit

Prior to the construction of the wind farm there has been much debate about the suitability of the wind farm in this area. The residents feared noise nuisance. Especially in situations when there is low wind speed at ground level (therefore a low background noise level) and a relative high wind speed at hub height (therefore a relevant noise emission from the wind turbine).

On behalf of the permit of the wind farm the authority has extensively investigated the background noise levels in this area. The authority based the noise limits on the background noise (L_{95}) at different wind speeds. The authority wanted to ensure a low noise level due to the wind turbine in all situations. Also in the situation where there is a low wind speed and hence a low background noise level. The noise levels which are included in the permit are given in table 1. The noise limits refer to an equivalent noise level in dB(A) over a 10-minute period and applies at the dwellings. The noise limits are dependent of a measured wind speed at a height of 10 m in the neighborhood of the wind turbines.

	L_{eq} in dB(A)											
Wind speed in m/s	0	1	2	3	4	5	6	7	8	9	10	≥ 11
Day period	34	34	34	34	38/39*	42	43	43	42	42	42	42
Evening period	34	34	34	34	38/39*	42	43	43	42	42	42	42
Night period	34	34	34	34	38	39	40	43	42	42	42	42

* 38/39 dB(A): 38 dB(A) applies when wind direction is between 130 and 210 degrees, 39 dB(A) applies when wind direction is between 210-130 degrees (calculated clockwise; north is 0 degrees)

2.2.Survey questions

After commissioning of the wind farm noise complaints were reported by the local residents. The residents were very doubted whether the wind farm is in compliance with its noise limits of the permit. For the municipality these noise complaints were the reason to investigate it.

In general the compliance checks of wind turbine noise in The Netherlands are done by determining the sound power level of the wind turbine at some occurring wind speeds and comparing these with the manufacturer's specified sound power levels. Such a method of random assessment was insufficient for the municipality as well as the local residents. Long term monitoring of the noise emission of the wind farm was demanded. Only with long term monitoring all different wind speed conditions could be assessed.

The local residents demanded not only long term monitoring of the noise emission but also that the noise levels were measured at their dwellings. The location of their dwellings (facades) was where nuisance was experienced and also the location where the noise limits should be met. From an acoustic point of view such a measurement location is less suitable for an assessment due to the disturbing background noise at these locations. But the local residents had no more confidence in calculation of the noise at their dwellings. So they insisted that the noise levels were measured at their dwellings.

The local authority was more interested in accurate measurements with a legally binding assessment. For that reason it was necessary to measure the noise at a relative short distance from the wind turbines. These measurements were as much as possible carried out in conformity with NEN-EN-IEC 61400-11 by using a measurement board at 150 m (= vertical distance from ground to the rotor center + 0.5 · the diameter of the rotor) of the wind turbine.

As known, background noise measurements should be carried out for more accurate noise measurements on wind turbines. The operator of the wind farm was only willing to stop the wind turbine during some short periods (a few times for 30 minutes). These few short periods were however not enough for an accurate background noise correction for all the measurements during the period of a month. Only the period immediately before and after this background noise measurements are suitable for any background noise correction.

3. Measurements

3.1.Measurement method

In order to satisfy the needs of both the municipality and the local residents both types of measurements (noise measurements at the facades of the dwelling and noise measurements with a measurement board) were carried out simultaneously for a continuous period of one month. In figure 2 a schematic representation of the measurements is shown. For all three wind turbines, the noise is measured at 150 m distance with a measurement board in the field as well as at the facades of the nearest residences.

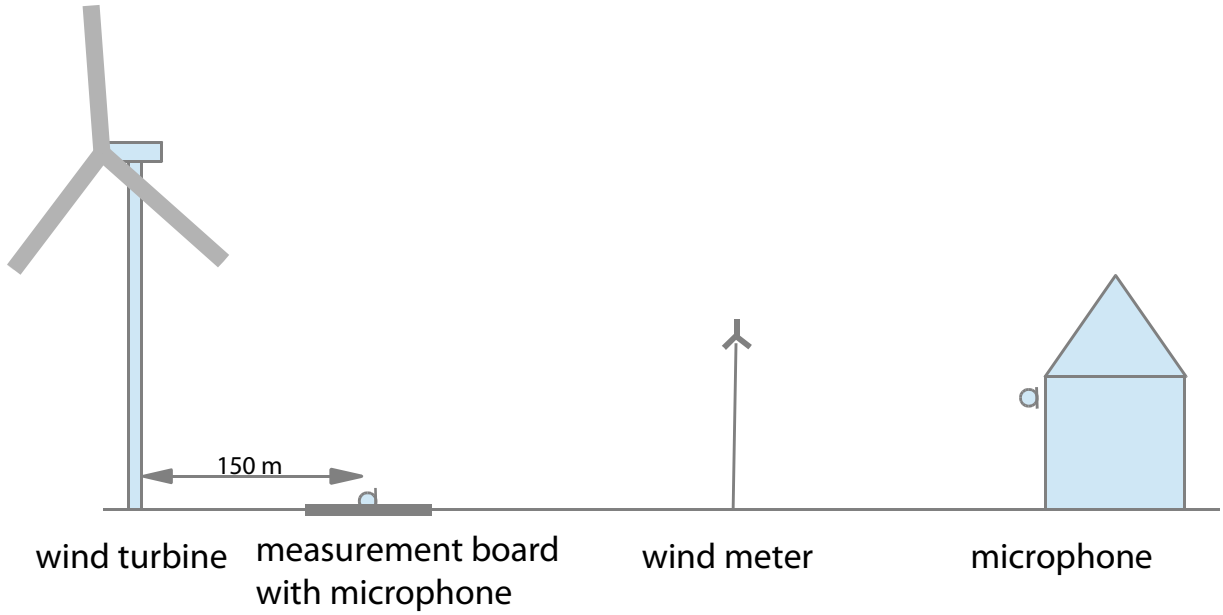

Figure 2: Schematic representation of measurements

The measurement were carried out during a month (February 25th until March 25th). During this period of the year normally it is quite windy in the Netherlands. Beside the noise measurements also weather conditions measurements (wind speed, wind direction, temperature, barometric pressure and rainfall) were carried out. These measurements were carried out at a height of 10 m and averaged every 10-minute period. Also if the wind turbine was in operation during that 10-minute period was registered.

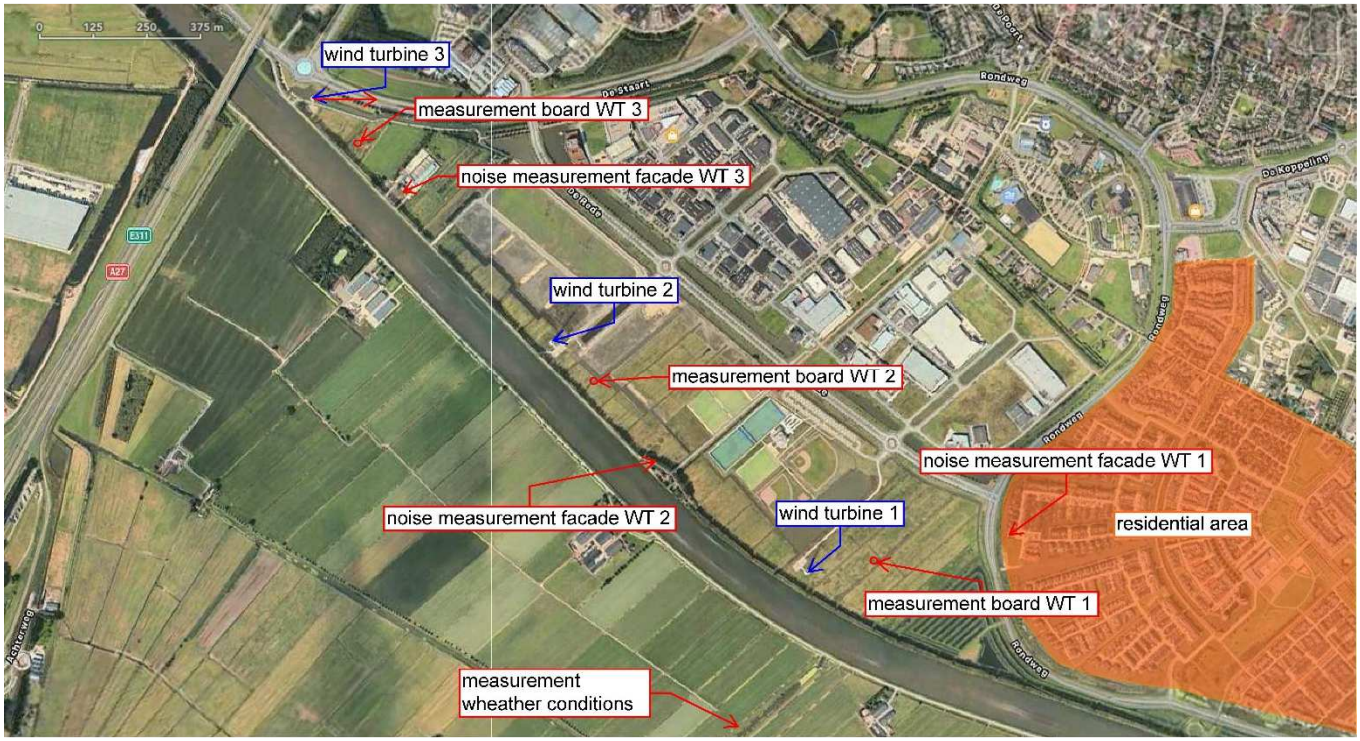

Figure 3:Location of measurement positions

All the measured data has been real time uploaded to an internet database. For the local residents an internet portal was readily available so they could see the measured data and compare it with their own experience at that moment. With this system the confidence of the local residents in the way of assessment has been grown.

3.2.Method of assessment

Except for the noise contribution of the ambient noise, the noise levels as measured at the facades of the nearest dwellings can directly be compared with the noise limits after a correction for the reflection of the facade. For direct assessment of the noise measurements at short distance (150 m) the noise limits at the dwellings was first converted to maximum allowable noise levels at measurement boards.

By using an acoustical model the noise transmission (D) was calculated from the wind turbines to the facades of the nearest dwellings. With this noise transmission and the noise limit at the dwelling a maximum allowable sound power level ($L_{W,j,max}$) of the wind turbine per wind speed was be calculated.

$L_{W,j,max} = L_{eq,j,noise\ limit} + D_{wind\ turbine\text{-}house}$

With this maximum allowable sound power level ($L_{W,j,max}$) a maximum noise level at the measurement boards can be calculated using the transmission as defined in IEC 61400-11.

$L_{eq,j,max} = L_{W,j,max} - 5 - 20\log(R) = L_{W,j,max} - 5 - 20\log(183)$

Where

$L_{eq,j,max}$ is maximum allowable noise level at measurement board per wind speed j

R is slant distance from rotor center to measurement board

So for each of the measurement boards and the different wind speeds a maximum allowable noise level at measurement board was calculated.

Figure 4: Wind turbine 2 with measurement board in front (inside barrier fence)

4. Measurement results

4.1.Measurements at the facades

In figure 5 the results of the measurements at the facades are given. In this figure just the results of one day (24 hours) are shown. That day (between February, 28th and March , 1st) can be seen as a representative day of the monitoring period.

The orange line represents the measured wind speed at 10 m height and is related to secondary Y-axis (right side). The grey dotted line represents the noise limit which is associated with the determined wind speed. There is only a value given for the noise limit when the wind turbine is running. In this example the wind turbine starts running at 09:30 am and stops running at 01:40 am next day with a few short stops in between.

The red, blue and green lines represent the measured noise levels at the facades of the dwellings which are nearest to respectively wind turbine 1, wind turbine 2 and wind turbine 3 (see figure 3). The noise levels refers to an equivalent noise level over a 10-minute period and is corrected for the facade reflection.

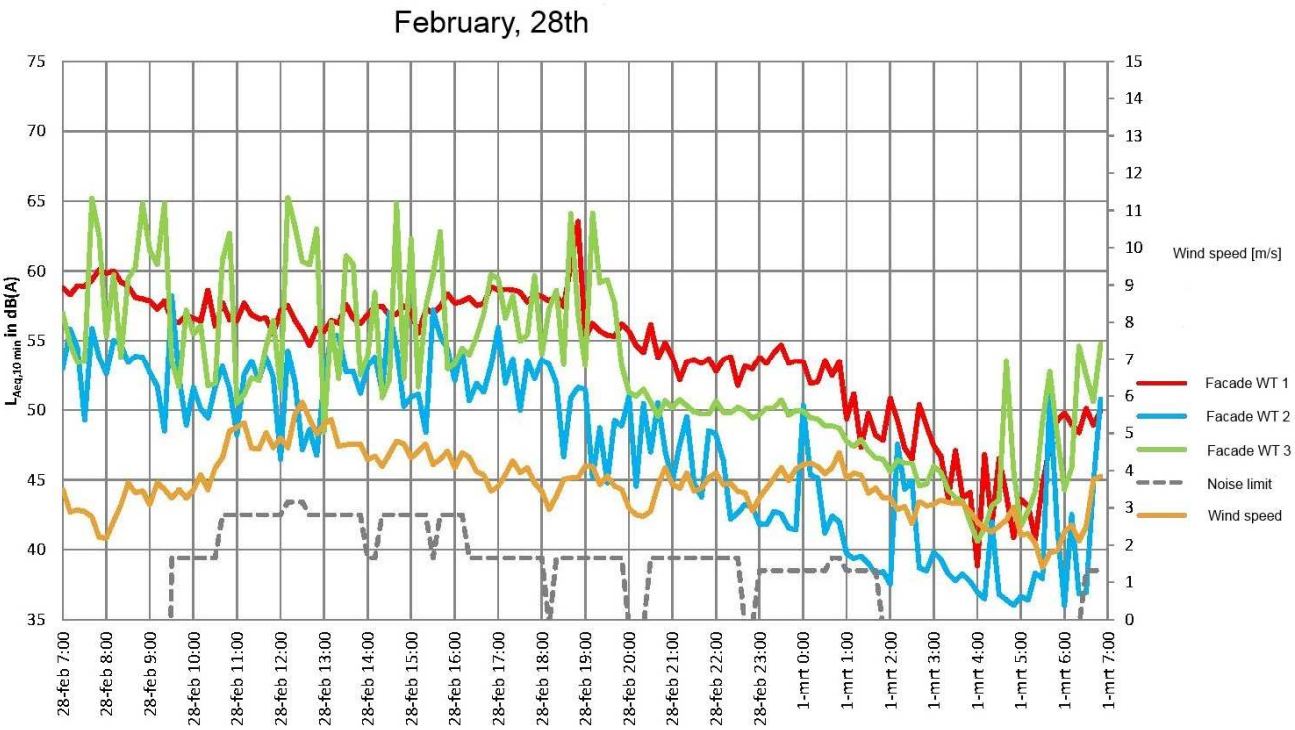

Figure 5: Results of measurements at facades at February, 28th

During the whole day the measured noise levels are significantly higher (up to 20 dB) than the noise limits of the permit. The background noise as traffic of the highway and local roads as well as the shipping on the canal and noise from the dwellings totally dominates the noise of the wind turbine. By listening to the audio files no noise of the wind turbines could be distinguished at any time. This phenomenon occurs throughout the whole month of monitoring. Only in some quiet nights between 01:00 am and 05:00 am a few moments occur that the noise of the wind turbines could be distinguished from the background noise. An example of such a moment is the night period of March, 2nd and 3rd. Figure 6 shows the results of that day.

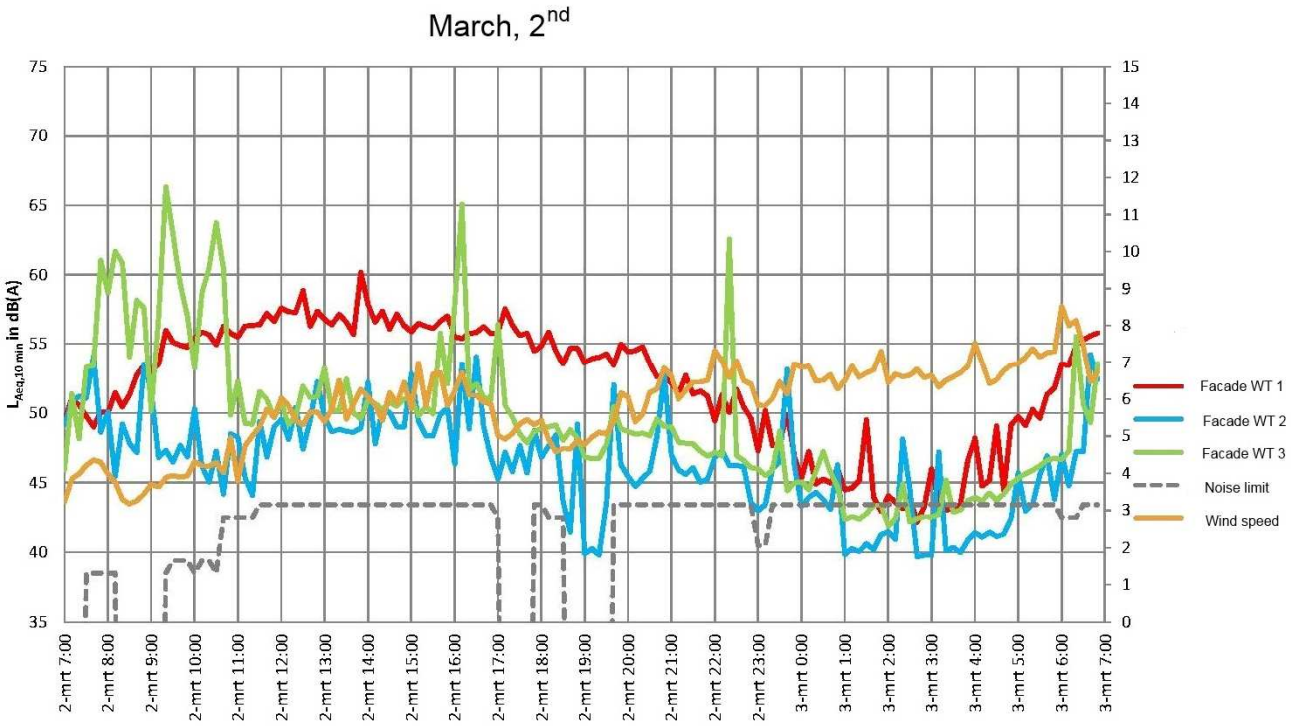

Figure 6: Results of measurements at facades at March, 2nd

Figure 6 shows that during the period between 01:00 am and 05:00 am the measured noise levels at the facade are regularly below the noise limit of the permit. By listening to the audio files of those moments the noise of the wind turbine can be clearly distinguished of the background noise.

Based on the results of the measurement between 02:00 and 04:00 am you should expect that the wind turbines can meet the noise limits of the permit. The transient increases in the noise level in this period of time are caused by background noise sources which are not related to wind turbines. An accurate measurement with a legally binding assessment of the noise of the wind turbines is not possible by these noise measurements at the facades. Even not when long term monitoring is used.

4.2.Noise levels at measurement boards

In figure 7 some measured noise levels at the measurement board are shown. In this figure only the hours between 09:00 pm and 05:00 am of February 28th and March 1st are given. In other hours of the day too many background noise occurs. These moments are not suitable for a comparison with noise limits.

The orange line represents the measured wind speed at 10 m height and is related to secondary Y-axis (right side). The red, blue and green lines represents the measured noise levels at measurement boards of respectively wind turbine 1, wind turbine 2 and wind turbine 3 (see figure 3). The dotted red, blue and green lines represents the maximum allowable noise levels on the measurement board of respectively wind turbine 1, wind turbine 2 and wind turbine 3 to meet the noise limits of the permit. All noise levels refers to an equivalent noise level over a 10-minute period.

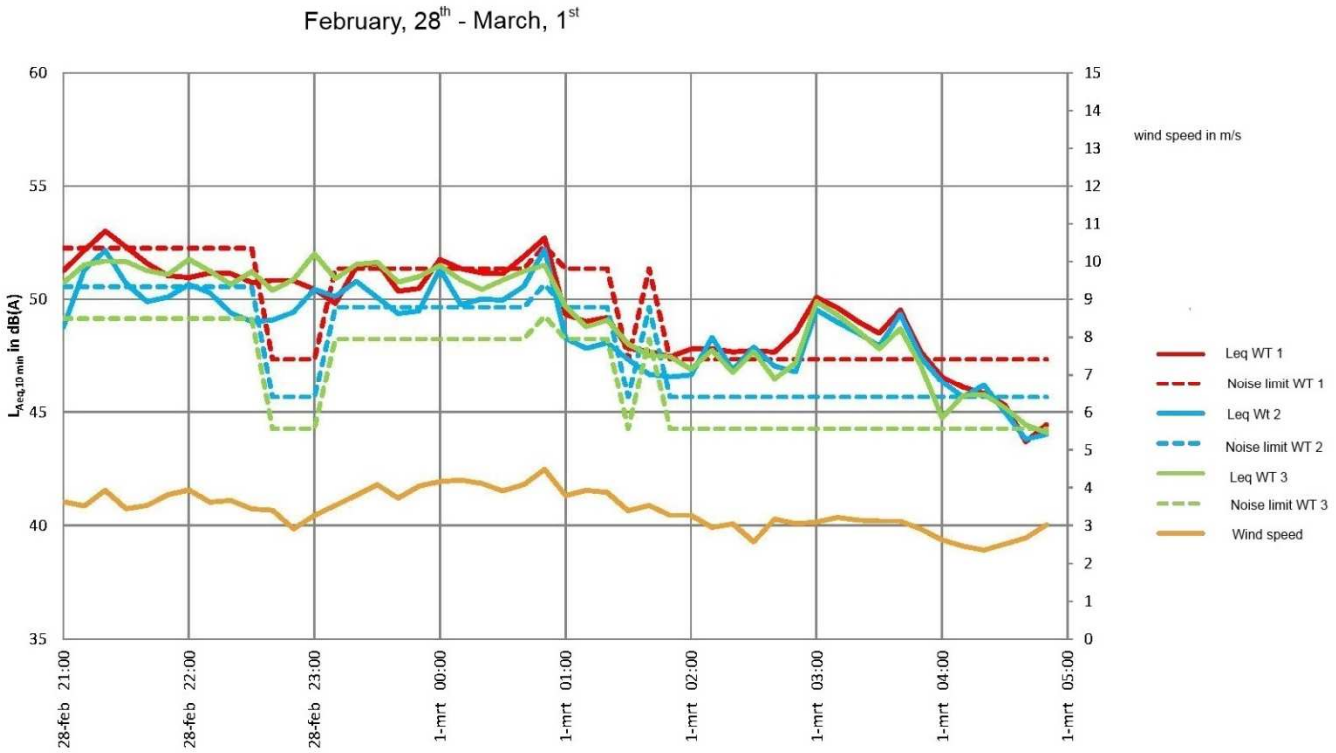

Figure 7: Results of measurements at measurement board in night period February, 28th - March 1st

Figure 7 shows that the noise levels at the measurement boards are often slightly higher than the maximum allowable noise levels. This is mainly caused by all kind of background noise events. By listening to the audio files of this night you can distinguish some wind turbine noise but there is also a lot of disturbing noises. Even as we focus at the relative quiet period of the night.

All the other days during the monitoring period give almost the same results. An accurate measurement with a legally binding assessment of the wind turbine noise seems in general not possible with this kind of measurement, mainly due to dominant disturbing noise.

During the monitoring period there was one relative quiet night (the night of March, 2nd and 3rd) with moments where the wind turbine noise was dominant compared to the background noise. In figure 8 the results of the measurements of this night of March, 2nd and 3rd are given. In the period from 01:00 am until 05:00 am the background noise seems low enough to state that there was no relevant disturbance by the background noise. But there is no legal proof with unmanned measurements that there is no relevant disturbance by the background noise. This is not a problem in situations that the measured noise levels (wind turbine noise and background noise) is lower the noise limits, like the period between 01:00 am and 05:00 am in figure 8. During the time before 01:00 am there are several moments that the measured noise levels exceed the maximum allowable noise levels at the measurement boards. When listening to the audio files of these moments some background noise can be distinguished. In this period the wind turbines meet the noise limits.

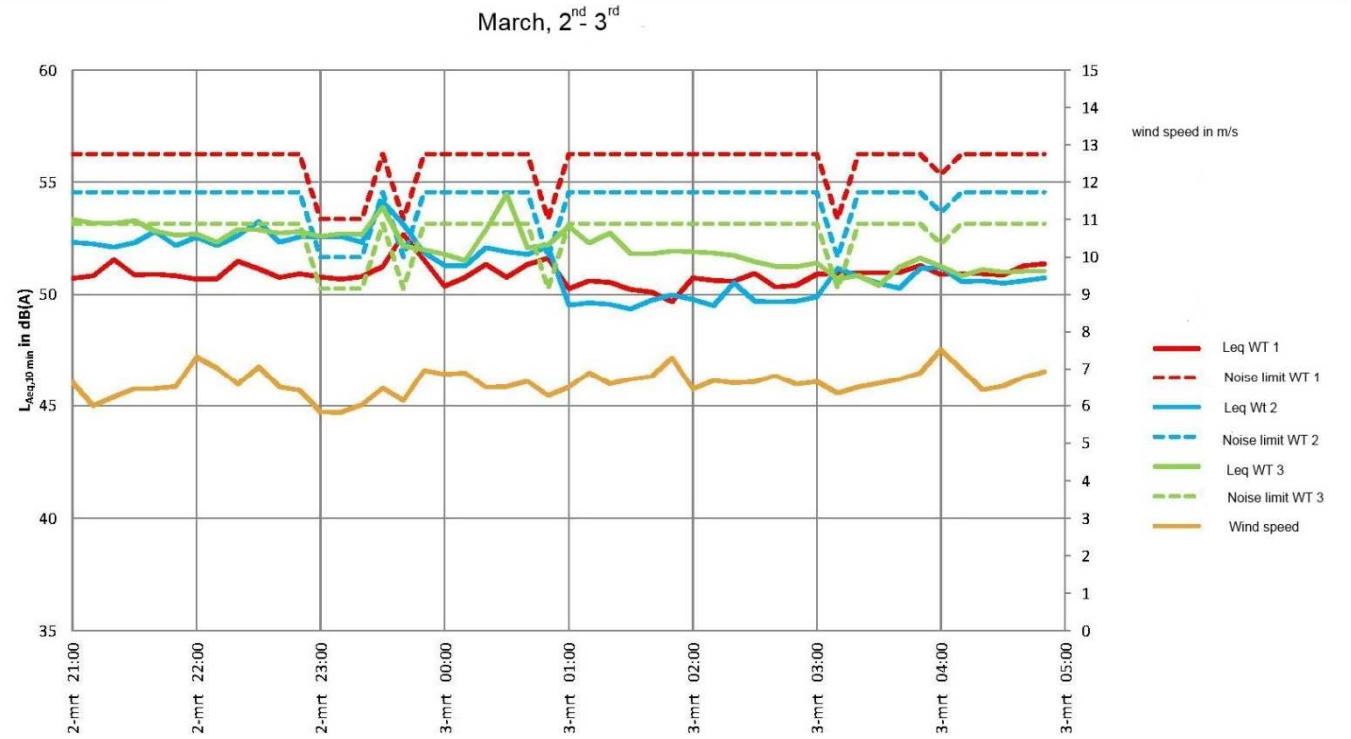

Figure 8: Results of measurements at measurement board in night period March, 2nd-3rd

4.3.Manned measurements

After a few weeks of monitoring it was clear that for legally binding assessment of the wind turbine noise at this wind farm also manned measurements with background noise corrections were necessary. Therefore manned measurements during the night period were carried out wherein the wind turbine was turned off twice for 30 minutes during the measurements.

In figure 9 a part of the measured noise levels at the measurement board 1 as well as the measured wind speed as function of the time is given. The blue line represents the measured noise level (L_{eq}) over 1 minute period, the orange line represents the measured wind speed over 1 and 10 minute period. Any incidental background noise as some geese near the measurement board and a car with the engine running on the other side of the canal are carefully filtered out of the measurement.

Based on these measurements with a background noise correction an accurate noise emission of the wind turbines was established for the wind speeds that occurred during these measurements. These measurements showed that the wind turbines met the noise limits for wind speeds that have occurred.

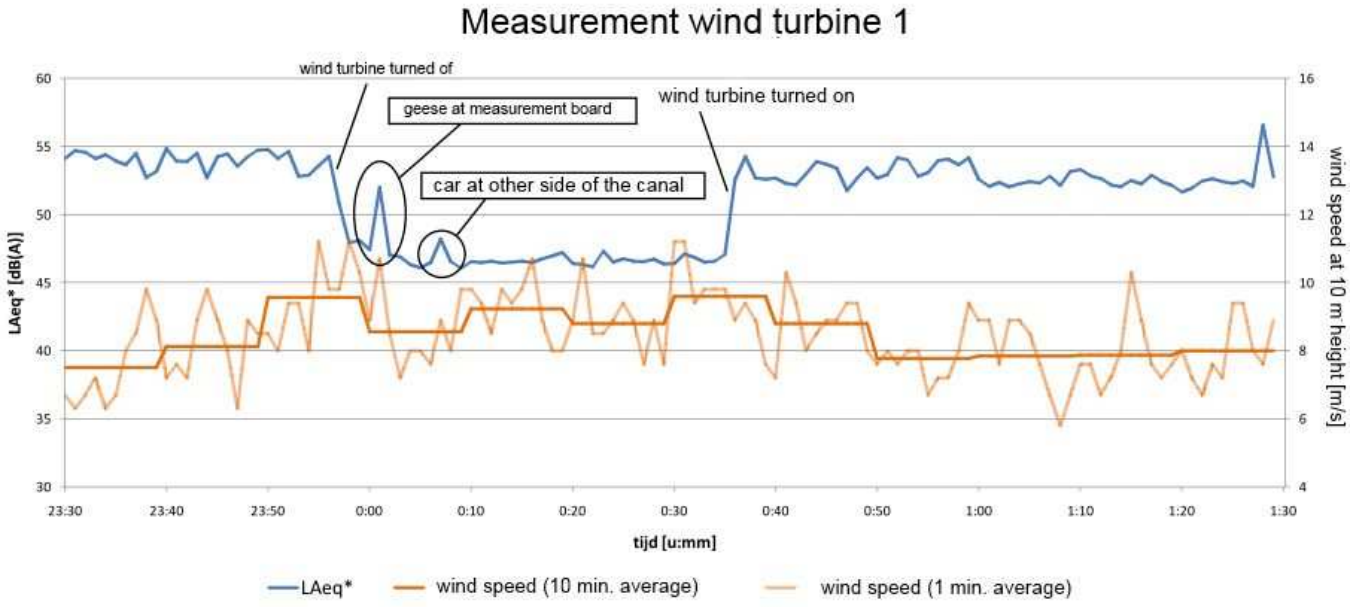

Figure 9: Results of manned noise measurements wind turbine 1

5. The usefulness of long term monitoring

For legally binding assessment of wind turbine noise long term monitoring is limitedly suited. But in many cases where there is distrust between operators of wind farms, local authorities and local residents long term monitoring of wind turbine noise can be very useful, especially when it is combined with an internet portal so anyone has direct access to the measured data. The following aspects are of considerable value for mainly the local residents:

- Transparency. Especially when long term monitoring is used in combination with an internet portal which provides access to the measured data.
- Awareness that many other noise sources in their environment than wind turbine noise determine the acoustic environment in the vicinity of their dwellings
- (Indicative) assessment of wind turbine noise under all kind of circumstances. Although the measurements are indicative the residents have the idea that there has been an assessment under all kind of wind and weather conditions.
- The measured values make the discussions more objective.

The above mentioned aspects may cause that the local residents form a more nuanced representation of the experienced nuisance.

6. Conclusions

Most areas in The Netherlands have significantly high background noise levels. These background noise levels impede an accurate determination of the noise emission of wind turbines. For accurate measurements with a legally binding assessment background noise correction is (almost always) necessary. Background noise corrections are difficult to combine with long term monitoring.

This practice case shows that long term noise monitoring at the dwellings has limited value for legally assessment of the wind turbine noise emission. In this study (monitoring during one month) only one time in a very quiet night an indication of the noise emission of the wind farm is obtained with the noise measurements at the facades of the dwellings.

By using measurement boards at a relative short distance of the wind turbines, the disturbance of ambient noise (background noise) can be reduced. But the results of these measurements even in the relative quiet night periods remain indicative.

For legally binding assessment of the wind turbine noise emission, manned measurements with careful adjustment for background noise are necessary. A major disadvantage of these kind of measurements is that in practice not all wind and weather conditions can be investigated. Only the wind and weather conditions that occur during that manned measurements are considered.

Despite the limitations of long term noise monitoring (without background noise correction) these measurements can be very useful for the local residents to get a more nuanced point of view about the experienced nuisances.

References

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IEC 61400-11: 2002 (May 2003) *Wind turbine generator systems Part 11: Acoustic noise measurement techniques*

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