PSC of WISCONSIN

Public Service Commission of Wisconsin

MEASUREMENT PROTOCOL FOR NOISE ASSESSMENT OF PROPOSED AND EXISTING WIND ELECTRIC GENERATION PLANTS

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1.0 OBJECTIVES

The primary objectives of this protocol include:

1. To measure and characterize the existing sound and vibration environment within the area of the proposed development.
2. To predict the incremental increase in sound and vibration levels that would occur due to the operation of the proposed development.
3. To assess whether the predicted incremental increase in sound and vibration levels is reasonable.
4. To verify compliance with applicable sound and vibration limitations by taking post-construction sound level measurements.

2.0 PSC WISCONSIN STAFF CONTACT

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Consult with staff prior to conducting any studies under this Protocol.

3.0 INTRODUCTION

The potential noise and vibration impact associated with the operation of wind turbines is often a primary concern for citizens located nearby. This is especially true of wind turbines constructed near residences[1], schools, and hospitals ("sensitive receptors").

Impact assessments are a highly technical undertaking and require expertise to collect reliable and meaningful data for the public's knowledge and potential permitting decisions.

3.1 PURPOSE AND SCOPE

The purpose of this protocol is to establish a consistent and scientifically sound procedure for estimating noise and vibration impacts pursuant to PSC 128.50 (2b). The PSCW expects that the following guidelines are followed for developing a reasonable and defensible estimate of a project, consistent with the statutory requirements of PSC 128.

First, an estimate of the project area's existing soundscape is necessary in order to predict the impact resulting from a proposed project, including other nearby wind projects or other notable sources of community noise. Sound propagation modeling of the facility's expected maximum sound emissions will provide the expected sound levels generated by the facility. Following a successful permit application and construction of the facility, a postconstruction study must be conducted to assess noise compliance with respect to PSC 128.

3.2 PSC 128

Chapter PSC 128 of the Wisconsin State Legislature's Administrative Code regulates wind energy systems. The noise criteria in PSC 128.14 provide noise limits in item 3a:

> *[A]n owner shall operate the wind energy system so that the noise attributable to the wind energy system does not exceed 50 dBA during daytime hours and 45 dBA during nighttime hours.*

Nighttime is defined as 10:00 p.m. to 6:00 a.m. PSC 128 does not define a noise metric or averaging time. However, for the purposes of this protocol, the noise metric is the equivalent continuous sound level (L_{eq}) and the averaging time is 10 minutes, for consistency with ACP/ANSI 111.1 recommendations.

[1] Residences are any structure with an approved septic system for human habitation and include single and multi-family homes, mobile homes, senior living communities, rehabilitation facilities,

4.0 PRECONSTRUCTION NOISE IMPACT ASSESSMENT

The layout of the proposed development and the features of the surrounding environment, including geography, local sound sources, and sensitive receptors must be taken into consideration when designing a noise study. It will be necessary to hire a qualified consultant to conduct the noise study.[2]

The preconstruction noise impact assessment will include both sound propagation modeling and background sound monitoring. A brief Preconstruction Sound Assessment Protocol will be provided to Commission staff prior to deploying preconstruction sound monitoring outlined herein.

4.1 SOUND MODELING

Sound modeling shall be conducted for the project to ensure the wind development meets any and all state and local sound level requirements.[3]

Modeling shall be completed following the requirements of ISO 9613-2 (2024), “Engineering method for the prediction of sound pressure levels outdoors”. Further guidance specifically pertaining to wind turbines is provided in ANSI/ACP 111-1 (2022), “Wind Turbine Sound Modeling” and Annex D of ISO 9613-2 (2024). Based on these standards, the required settings of sound propagation model for wind turbine noise include:

- Ground factor: G = 0.0 over water and large areas of hard ground, G = 0.5 everywhere else
- Modeling uncertainty adjustment = +2 dB
- Receptor/grid height = 4.0 m
- Source height = wind turbine hub height
- Temperature = 10°C, Relative humidity = 70%

Further, wind turbines are modeled as omnidirectional point sources at nacelle height. All dwellings within 1 mile of any facility sound source shall be included in the model. All facility sources within 5 miles (8 km) shall be calculated for each receiver. No foliage attenuation shall be considered.

[2] Board Certification through the Institute of Noise Control Engineering is recommended. A professional engineering license without experience in noise control engineering is not a suitable qualification to conduct these noise analyses. The qualifications of the preparer should be spelled out in the application and postconstruction sound monitoring reports, if any.
[3] If a project cannot reasonably mitigate to meet any local noise ordinance, then the Application should justify why any noise limit should be waived by the Commission.

The project substation and any related facilities (e.g. battery energy storage) shall be included in the sound model, but those sources would have a minimum 0 dB uncertainty added. Substation transformers, and any other tonal source, should assume a 5 dB tonal penalty [Ref 4] unless it can be shown that the source is not tonal at the worst-case receiver.

Other energy facilities that are operational or have an application submitted prior to a given project within two miles of the closest component of the facility must be included in a separate cumulative impact model run. Consult Staff for guidance if sound emissions data for other wind projects is not available or cannot be adequately estimated.

To assess low frequency and noise-induced vibration impacts of the project, ANSI S12.9 Part 4 – Annex D provides guidance for considering sounds with strong low frequency content. Specifically, modeled octave band sound levels at 16 Hz and 31.5 Hz should be less than 65 dBZ and less than 70 dBZ in the 63 Hz octave band.

4.2 BACKGROUND SOUND LEVEL MONITORING

For background sound monitoring, unattended continuous sound level measurements are encouraged. Any sound monitoring should generally follow the requirements of ANSI S12.18 and ANSI S12.9 Part 3, where applicable. The collection of at least seven days of non-holiday data is recommended.

For sites with existing wind electric generation facilities, the impact of existing facilities should be quantified. This can be accomplished with modeling or monitoring.

Preconstruction Sound Monitoring Protocol

A brief Preconstruction Sound Assessment Protocol will be provided to Commission staff prior to deploying preconstruction sound monitoring.

The Protocol shall include details on:

1) Intended monitoring schedule
2) Modeled sound levels[4]
3) Monitoring locations. Nonparticipating sensitive receptors with highest modeled sound levels are preferred
4) Equipment setup and data collection (sound level meter class, calibration methods, windscreens, logging intervals, criteria for acoustically valid periods, etc.), and
5) Data analysis (data aggregation, anomaly scrubbing methods, etc.).

[4] It is understood that the sound modeling done prior to preconstruction sound monitoring may not be the project layout and is subject to change.

Equipment

Sound level meters shall meet the ANSI/IEC Class 1 performance requirements (i.e., IEC 61672-1 and ASA/ANSI S1.4 Part 1) and log 1/3 octave band equivalent sound pressure levels. The microphone shall be protected by a 7-inch diameter hydrophobic windscreen or equivalent. Qualitative sound recordings of the ambient noise environment should also be collected for the duration of the measurements.

Each sound level meter shall be field-calibrated with a calibrator meeting the requirements of IEC 60942 Class 1 immediately before the monitoring period and after each data download and/or battery change. Any calibration drift above 1 dB shall be noted and addressed with respect to ASA/ANSI S12.18. Each sound level meter and field calibrator shall have been calibrated within two years and one year, respectively, of the completion of monitoring by a National Institute of Standards and Technology traceable facility.

Anemometers must be located adjacent to each monitoring station at microphone height to measure wind speed [Ref 3].

Siting

At a minimum, sound level measurements should be taken at three locations or measurement points. Measurement points shall be selected to provide information on sensitive receptors in the area, particularly areas with private residences and public areas. Siting near sensitive receptors with the highest modeled sound levels from the future facility shall be given priority, if the layout is already known. Preconstruction monitoring locations should be analogous to and applicable for the postconstruction study, to the extent possible. Because each project is unique, more than three measurement points may be necessary, particularly for larger projects.

The measurement points shall be outdoors and acoustically representative of a nearby residence. Specifically, monitoring equipment shall, to the extent practically possible, be placed at a similar distance from prominent soundscape sources such as roadways, heavy vegetation, and stationary equipment. The microphone shall either be façade mounted or in the free-field at least 25 feet from any building, and approximately 1.2 m to 1.5 m above ground level [Ref 3]. Adjustments for façade mounting can be made according to ASA/ANSI S12.9 Part 3.

Data Analysis

Consistent with ACP/ANSI 111.1, the target sound level metric is the 10-minute equivalent continuous sound level (10-minute $L_{eq,}$ also written as L_{10min}). Sound levels shall be logged at a finer interval than 10 minutes to enable source characterization through spectral analysis and the calculation of statistical sound levels over the course of an hour, i.e. 10th percentile (L_{10}), median (L_{50}), and 90th percentile (L_{90}) sound levels. To this end, 1/3 octave band data should be logged at least once per minute; a one-second measurement interval is preferred.

Data Exclusions

To ensure an acoustically valid dataset, periods during which any of the following conditions occur shall be excluded from analysis [Refs 3, 5]:

- High wind gusts – ground-level wind gust speeds above 5 m/s (11.2 mph).
- Precipitation – snow, rain, and thunderstorm events identified through regional data and inspection of acoustic data.
- Anomalies – The presence of short-term contaminating sound caused by human or other activity that is atypical of the site, directly attributable to the presence of the equipment, or seasonal.
- Temperature or humidity outside the specification of the sound level meter or microphone.

If more than half an aggregated period was not acoustically valid, (due to high winds or precipitation, for example), the entire period should be excluded from the analysis [Ref 3].

Biogenic Sound

Biogenic sounds (particularly insects, birds, and amphibians) are typically tonal and can have a pronounced effect on overall A-weighted sound levels. If biogenic sounds are a dominant aspect of the soundscape during monitoring, their influence on overall sound level should be quantified.

The “ANS” frequency-weighting (ASA/ANSI S12.100) should be applied to spectral sound levels to filter out high-frequency biogenic sound. ANS weighting filters out sound above the 1 kHz octave band. Ideally, ANS weighting should only be used when tonal sounds, indicative of seasonal biogenic sound, are detected.

When the effect of biogenic sound is significant, that is, the overall A-weighted sound level is at least 3 dB greater than the ANS-weighted sound level, then both A-weighted and ANS-weighted sound level results shall be reported.

Documentation to Submit

A preconstruction noise impact assessment study shall include, but is not limited to, the following:

1) Facility Description - Maps and descriptions of sources and monitoring locations, including the distance from each monitor to the nearest facility equipment, the location of existing infrastructure (i.e., roads, transmission lines, gas pipelines, etc.).
2) Sound Monitoring Results
    a. Narrative description of the soundscape, i.e., diurnal fluctuations, common sources of sounds, anthropogenic vs. biogenic sounds, etc.
    b. Summary of overall day and night A-weighted sound level metrics (L_{eq}, L_{10}, L_{50}, and L_{90}).
    c. Overall A-weighted time history sound levels (10-minute L_{eq}, L_{10}, L_{50}, L_{90}) and meteorological data at the monitoring stations
    d. ANS-weighted results for the above, if substantive biogenic sound is found.
3) Sound Modeling Results
    a. Model configuration and inputs.
    b. Sound power level source data for units at full capacity (by 1/1 or 1/3 octave band, if available). If these are marked as confidential by the manufacturer, then these can be sent to Staff under a protective agreement.
    c. Maps of sound level isolines depicting the maximum 10-minute L_{eq} contribution of the Project to the surrounding area in 5 dBA increments, extending out to the 30 dBA contour.
    d. Table of sound level representing the maximum 10-minute L_{eq} at each sensitive receiver within 1 mile of the facility. The table should also include a low frequency assessment octave bands assessment per ANSI S12.9 Part 4 - Appendix D and the cumulative sound level impacts of other nearby wind projects.
4) Discussion - A discussion section of the report should include a narrative assessment of the facility's noise impacts and statement regarding the project's ability to meet the PSCW and any applicable local noise limits. It should also include a detailed description of all noise mitigation used or required to meet the noise limits shall be provided, as applicable, including icing mitigation and minimization.

Postconstruction Sound Monitoring Protocol

A Postconstruction Sound Monitoring Protocol shall be developed by the applicant to adequately assess compliance with the PSCW and any applicable local noise limits. The sound monitoring should be planned following the guidance in Section 6. The Protocol shall include details on:

1) Intended monitoring schedule.
2) Monitoring locations (final monitoring locations may be adjusted due to facility siting changes after the project is permitted and to accommodate noise complaints).
3) Equipment setup (sound level meter class, calibration methods, windscreens, etc.)
4) Data collection (including logging intervals, meteorological and operational criteria for valid periods, minimum number of valid periods, background measurements, etc.)
5) Data analysis (including background correction methods, data scrubbing methods, tonality assessments, etc.), and
6) Noise complaint response and resolution pursuant to PSC 128 Subchapter IV (PSC 128.40 to 128.42).

5.0 POSTCONSTRUCTION NOISE STUDY

Within twelve months of the date when the project is fully operational, sound level measurements adhering to the postconstruction Protocol submitted with the permit application or as defined in a permit, to demonstrate compliance with any noise limits imposed by the Commission.

5.1 DESCRIPTION

The recommended methodology described in this guidance effectively applies the filtering method in IEC TS 61400-11-2. It includes scheduled nighttime wind turbine shutdowns to allow for the subtraction of background sound levels or any other method outlined in the standard. The recommended application of the technical standard in Wisconsin provides practical simplifications to alleviate specialized equipment and high-fidelity SCADA data.

5.2 METHODOLOGY

Maximum wind turbine sound shall be assessed at night. During nighttime hours, background sound (particularly anthropogenic and avian activity) is typically lowest and meteorological conditions for robust propagation of sound are most common. If the project has different operational settings during the day and night, for example different noise-reduced operational modes, then evaluation of daytime project sound must also be undertaken.

Monitoring locations should be at least 25 feet from any vertical reflecting surfaces to minimize reflections, as shown in Figure 1. Positions where the measurement point is downwind of the prevailing wind direction is preferred, but not required.

If applying the shutdown method, all wind turbines within 1.5 miles of a monitor location shall be shut down at least two times per night for 20 minutes at a time, except under weather conditions that would not result in valid periods. Sets of 10-minute periods of wind turbine operation before and after each shutdown shall be evaluated within about an hour of a background shutdown period.

The purpose of the shutdowns is to compare periods with the project operating to similar periods without the project operating to determine the sound levels attributable to the project. The temporal filtering method assumes that wind speeds do not substantively change in the 20 minutes the project is shut down. This can be confirmed qualitatively by comparing the turbine power production prior to the shutdown to the power production afterward. Alternatively, ground wind speeds measured at each monitor can be evaluated. If they are sufficiently similar, the background period can be assumed to be representative of the background conditions up to an hour before and after the shutdown period.

From logged data for each monitor, each 10-minute period is aggregated to determine the following:

- Overall A-weighted L_{eq}
- Unweighted 1/3 octave band L_{eq} for the assessment of tonality
- Unweighted 1/1 octave band L_{eq} at 16 Hz[5], 32.5 Hz, and 63 Hz for the assessment of noise-induced vibration.
- Maximum wind gust near the ground
- Average wind speed near the ground
- Wind direction
- Hub-height wind speed of the nearest turbine or turbines
- Wind turbine power production of the nearest turbine or turbines, and
- Project operational state (e.g., ON or OFF)

[5] Measurements at 16 Hz are required only in response to vibration complaints. In such cases, an wind screen designed for infrasound measurements should be considered and/or limits to ground wind speed to reduce pseudonoise.

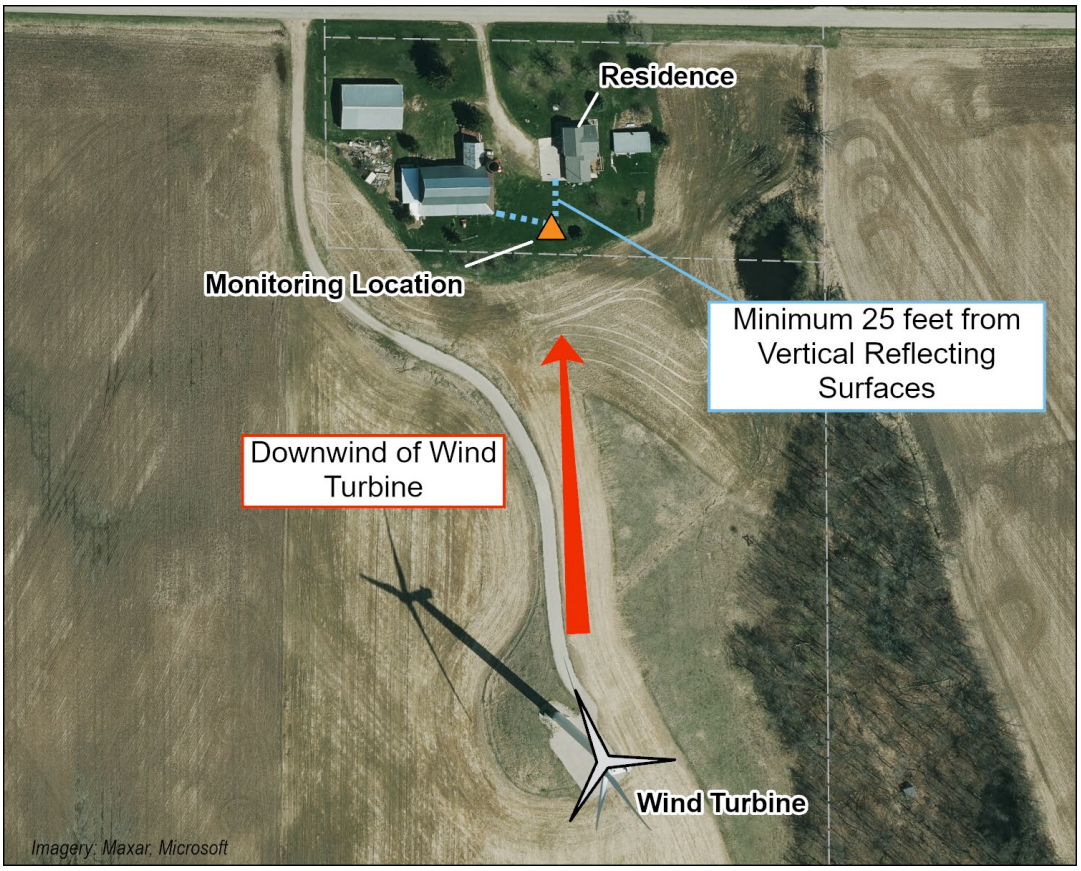

FIGURE 1: RECOMMENDED SITING OF SOUND MONITORS

5.3 TARGET EVALUATION PERIODS

To qualify as a potential measurement of the maximum project sound, each 10-minute period shall meet the target evaluation criteria:

- Data is acoustically valid (i.e. at least half not excluded for wind gusts, precipitation, or anomalies),
- Wind turbines within 1.5 miles are operating at or within 1 dB of their maximum sound power output, expressed as an arithmetic average of those wind turbines,
- Average wind speed at microphone level is below 4 m/s and one minute wind gusts are below 5 m/s, and

Ensuring that sound level data is free from anomalous and transient data during the target evaluation periods is critical to ensuring the accuracy of the study. Anomalous data shall be excluded from background and turbine operation periods.

To calculate the sound from the project, the background L_{10min} shall be logarithmically subtracted, on a 1/3 octave band basis, from the L_{10min} during operation, as described at the beginning of this section (ANSI S12.9 Part 3 Section 7).

At least six periods meeting the target evaluation criteria maximum valid L_{10min} periods must be collected. The highest facility L_{10min} shall be used for comparison to the noise limit(s).

5.4 DOCUMENTATION TO SUBMIT

A sound monitoring report shall be submitted within 60 calendar days of end of the field data collection. If additional time is required, a request must be made to Staff with the reason why an extension is required.

Sound monitoring reports must include a facility site map identifying relevant project components and nearby features of interest, including the nearest dwellings and monitor locations.

A postconstruction noise study shall include, but is not limited to, the following:

1) Facility Description - Maps and descriptions of relevant project components and nearby features of interest, including the nearest sensitive receptors and monitor locations. The distance from each monitor to the nearest wind turbine equipment shall be noted.
2) Overall Results Narrative
    a. Narrative description of the soundscape, i.e., diurnal fluctuations, common sources of sounds, anthropogenic vs. biogenic sounds, relative presence of wind turbine noise in the soundscape, etc.
    b. Summary of overall day and night A-weighted sound level metrics (L_{eq}, L_{10}, L_{50}, and L_{90}).
    c. Overall A-weighted hourly sound level time histories for L_{10min}. The 10-minute L_{90}, L_{50}, and L_{10} sound level metrics can also be included.
    d. ANS-weighted results for the above, if substantive biogenic sound is found.
    e. Ground-level wind speed and rainfall.
    f. Facility operational data (power output, wind speed)
3) Results for Evaluation Periods - For each 10-minute evaluation period, provide (in the report or in electronic format):
    a. power output for closest turbine(s)
    b. hub height wind speed and wind direction for each wind turbine within 1.5 miles of the measurement location[6]

[6] Any offset to true north should be noted.

c. Average wind speed and maximum wind gust from the monitor anemometer

d. Temperature and relative humidity (onsite or from the nearest National Weather Service station)

e. Unweighted 1/3 octave band and overall A-weighted sound levels

f. Determination of whether the period is acoustically valid and qualifies as a target evaluation period

g. For target evaluation periods, provide a tonality evaluation, and the background-corrected facility 1/3 octave bands and overall A-weighted sound level.

h. The presence of icing as indicated through icing alarms or visual observation.

If results of the postconstruction study indicate that the facility sound levels exceed the noise limit, mitigation measures shall be detailed in the report along with a schedule of implementation. Upon implementation of mitigation measures, the sound measurements shall be repeated under similar conditions as the exceedance(s), with the updated results filed to the docket.

5.5 DATA REQUESTS

Upon the request of PSCW Staff, all sound monitoring data and results shall be submitted in electronic format. If necessary, confidential data may be submitted with a confidential protective order.

6.0 REFERENCED STANDARDS

This protocol is based on current national and international standards, including,

1. ACP/ANSI 111-1 (2022). Wind Turbine Sound Modeling
2. ASA/ANSI S1.4/Part 1 (2014) IEC 61672-1 (2013). Electroacoustics – Sound Level Meters – Part 1: Specifications
3. ASA/ANSI S12.9-2013 Part 3 (2023). Quantities and Procedures for Description and Measurement of Environmental Sound — Part 3: Short-term Measurements with an Observer Present
4. ASA/ANSI S12.9-2021 Part 4 (2021). Quantities and procedures for description and measurement of environmental sound — Part 4: Noise assessment and prediction of long-term community response.
5. ASA/ANSI S12.18 (1994). Outdoor Measurement of Sound Pressure Level.
6. ASA/ANSI S12.100-2014 (2014). Methods to Define and Measure the Residual Sound in Protected Natural and Quiet Residential Areas .
7. IEC 60942 Ed. 4 (2017). Electroacoustics – Sound Calibrators.
8. IEC 61400-11 (2012). Wind turbines – Part 11: Acoustic noise measurement techniques.
9. IEC TS 61400-11-2 (2024). Wind energy generation systems – Part 11-2: Acoustic noise measurement techniques – Measurement of wind turbine sound characteristics in receptor position.
10. IEC TS 61400-14 (2005). Wind turbines – Part 14: Declaration of apparent sound power level and tonality values.
11. ISO 9613-2 (2024). Acoustics — Attenuation of sound during propagation outdoors — Part 2: Engineering method for the prediction of sound pressure levels outdoors.

If individual standards have been updated since the date of this publication, please consult with staff before using.

7.0 REVISION HISTORY

Revisions of May 26, 2010:

- Adapted the November 17, 2008, version of the PSC Noise Protocol to apply specifically to wind energy developments.

Revisions of July 22, 2014:

- Section II, updated staff contact information.
- Sections IV.B.1 and V.2, clarified that turbines ON measurements be taken with the turbines operating in normal mode, and not in any noise reduction modes.
- Section IV.C.2, added requirement to provide sound level contour maps using ground absorption coefficients of both 0.0 and 0.5.

Revisions of October 2024.

- All sections were updated to reflect current industry standards of practice.