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An investigation on managing wind farm noise constraints using FeatherEdge® blade technology

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Aercoustics was retained by Biome Renewables to evaluate the potential impacts to receptor noise levels associated with the implementation of their FeatherEdge® (FE) trailing edge serration (TES) technology for wind turbine blades. The FE product uses a novel technique of phase interference[1] with the aim of achieving greater noise reductions than are typically achieved by conventional TES technologies.

Input Data and Analysis Methodology

The analysis in this study was conducted utilising noise reduction data provided by Biome Renewables that was obtained from IEC 61400-11 (ed. 3) noise emission measurements, conducted by others, on a 2-year-old, Tier 1 OEM[2], 3 MW-class wind turbine. The data compares sound levels before and after installing the FE product on the wind turbine blades for the 7m/s (10-m standardized) wind speed. The change in apparent sound power level after FE installation is provided in 1/3rd octave bands in Table 1 below.

Table 1: Difference in IEC 61400-11 sound power after FE TES installation on the 3 MW turbine. Baseline blade condition includes standard OEM TES installed.

$\Delta L_{WA,k}$ – After FE TES installation (dB)[1]													
20	25	31.5	40	50	63	80	100	125	160	200	250	315	400
2.1	3.9	4.4	3.2	4.2	2.9	3.4	3.6	4.3	4.9	5.7	7.9	7.5	6.9
500	630	800	1k	1.25k	1.6k	2k	2.5k	3.15k	4k	5k	6.3k	8k	10k
6.9	7.6	5.4	3.7	2.6	0.4	-0.5	-0.6	-1.1	-1.7	-2.2	-3.3	-4.5	-5.9

[1] Positive numbers indicate a decrease in sound power after FE TES installation over and above the standard OEM TES.

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[1] https://www.biome-renewables.com/featheredge
[2] Original equipment manufacturer

Importantly, the reductions from the FE TES are the most significant at frequencies below 1000 Hz, which can manifest as reductions to receptor noise impacts greater than the reduction in apparent sound power. Further, the baseline test condition (before FE install) included blades that were fitted with standard OEM TES and, therefore, the sound level differences in Table 1 represent the additional noise reductions provided by FE, above what is already provided by the OEM TES. The overall A-weighted sound level after upgrading to the FE TES is 3.4 dB lower than that with the standard OEM TES.

The difference between OEM TES and bare blade apparent sound power – which is not included in this study but mentioned here for the reader's information – is typically in the range of approximately 1-2 dB, based on Aercoustics' experience and manufacturer literature.

This data was input into a noise model to determine how the change in sound levels from FE affect the performance of the wind farm under different scenarios. Noise modelling was conducted using the ISO 9613-2 standard methodology, as implemented by Datakustik's CadnaA modelling software. The noise model uses a ground factor of G=0.5, following the current industry-standard[4] for wind turbine noise. Starting sound power levels for the wind turbines were taken from publicly available noise spectra of wind turbines having similar blade lengths that are installed in Ontario, Canada. Wind farms having a variety of noise reduced operation modes were selected for reasons described later in this report.

This study first presents the change in sound levels predicted at far-field receptors and, from there, evaluates how these noise reductions affect the potential power capacity or turbine arrangement of existing or new wind farms which may otherwise be constrained by receptor noise impacts. Specifically:

1. Could a noise-constrained site accommodate additional turbines to achieve a higher nameplate capacity?
2. How much additional nameplate capacity could be achieved with the same number of turbines?
3. Could a targeted nameplate capacity be achieved with fewer, higher-capacity wind turbines?

[4] ISO 9613-2:2024, ANSI/ACP 111-1:2022

Far-Field Sound Level Impact

Using the input data and modelling techniques described above, the change in receptor sound level after the FE noise reductions were applied to the source are summarized in Table 2 for different turbine-to-receptor setback distances.

Table 2: Reduction in SPL at Varying Distances after the installation FE technology over and above OEM TES technology.

Setback (m)	ΔSPL (dBA)	
	1.5 m Receptor	4.5 m Receptor
500	-4.6	-5.2
800	-5.5	-6.1
1100	-6.3	-6.9
1500	-7.3	-7.8

The data from Table 2 illustrates that the decrease in sound pressure level (SPL) at a distance is greater than the corresponding decrease in apparent sound power level of the wind turbine after FE installation. This is because high frequency noise, the emissions of which are increased by FE, is quickly attenuated over distance through the atmosphere compared to sound at lower frequencies whose emissions are decreased by FE.

Increasing Wind Farm Capacity by Adding Wind Turbines

One of the possible outcomes of the reduction in receptor noise impact provided by FE is the potential to permit a greater number of wind turbines within a given site boundary, as illustrated conceptually below. In this scenario, three turbines with FE produce a lower noise impact than two turbines with OEM serrations at a 1.5 m receptor 500 m away.

Figure 1: Predicted Noise Impact - Two Turbines with OEM Serrations

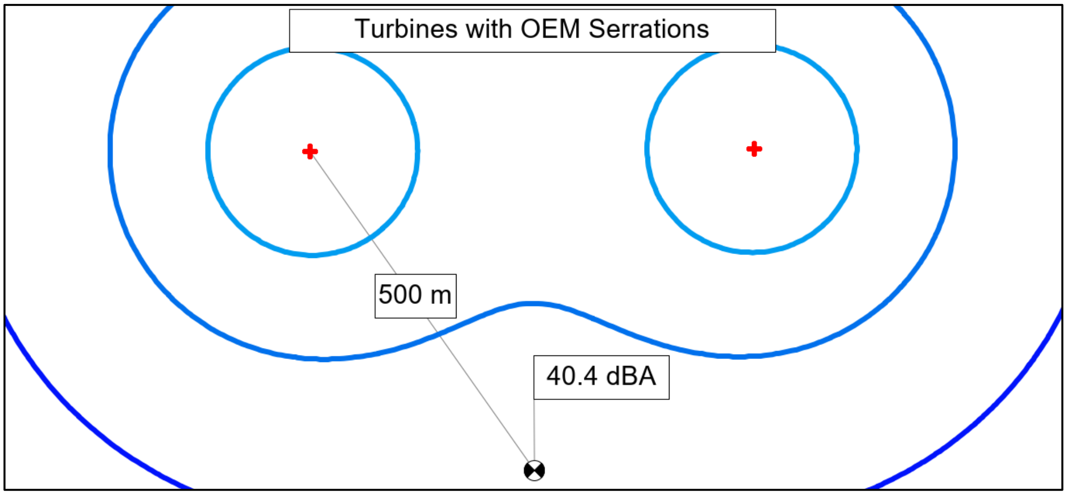
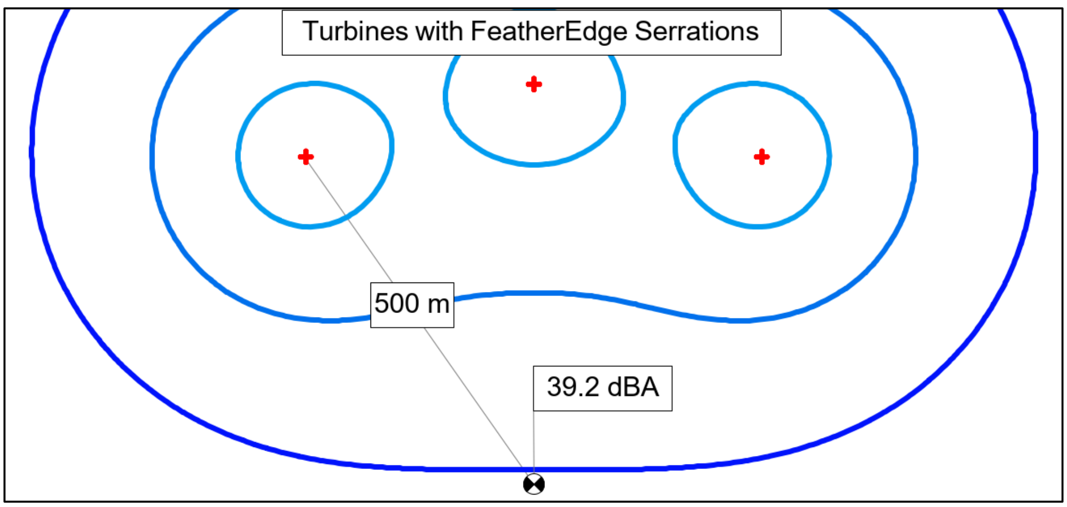


Figure 2: Three Turbines with FeatherEdge Serrations



The number of turbines that may be added will depend on several factors including the facility turbine layout, receptor locations, and turbine model. As such, the scenario above remains an illustrative example. The effect of FE noise reductions on an operating wind farm are provided in the following section.

Increasing Wind Farm Capacity by Increasing Wind Turbine Output

In some situations, facilities are required to de-rate their turbines to comply with noise regulations. This is typically achieved by implementing a Noise Reduced Operation (NRO) mode that provides noise reductions at the cost of reduced power output. In Aercoustics' experience, these trade-offs range between 100-200 kW of maximum output per decibel of noise reduction across multiple manufacturers and MW classes. The potential therefore exists to remove the requirement for these de-rates for turbines at a given site with the installation of FE to reduce the noise output without the corresponding reduction in power output.

To evaluate this scenario, an analysis of the predicted impact of adding FE to wind turbines was carried out on three existing wind farms of varying sizes in Ontario, Canada. These three sites comprised 18, 40, and 87 of the Siemens SWT 3.2-113 wind turbine. These turbines feature a rotor diameter of 113 m and have publicly available noise spectra at various NRO modes in 1 dB increments, ranging from 0 dB of reduction (3200 kW, or “NR-0”) to 5 dB of reduction (2370 kW, or “NR-5”). The analysis considered the change in predicted sound level at receptors after the noise reductions from the FE installation were applied to the turbines. Any noise contributions from third-party wind farms or transformer substations were ignored to isolate the impact of adding FE technology at receptor locations.

For the turbine platform evaluated at these three sites, the analysis showed that the introduction of FE could potentially remove the need for NRO modes altogether, returning the wind turbines to their nominal power output. This translated to a maximum potential increase in rated power to the wind farm of 35%, assuming all turbines were initially operating in NR-5 mode.

To illustrate this, an analysis for a 40 wind turbine farm is presented below in Figure 3. This wind farm has SWT 3.2-113 turbines of various NRO modes, many of which are operating 4 to 5 dB below their nominal capacity. Per Table 2, adding FE technology resulted in a 4 to 5 dB reduction at typical receptor distances, equal to or greater than the reduction offered by the NRO modes at this site. Accordingly, the potential exists to return turbines at the site to their nominal output. The impact on NRO mode after FE installation is presented in Table 3.

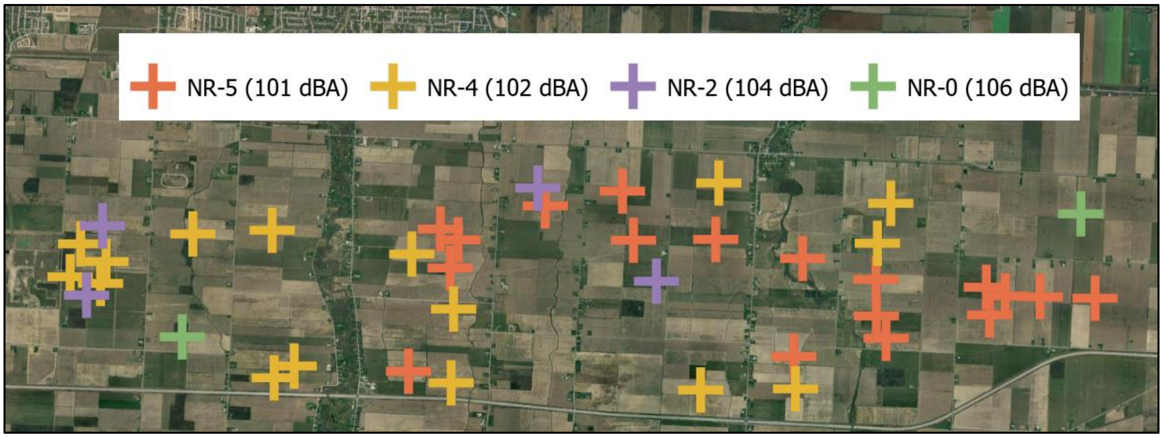


Figure 3: 100 MW Ontario Wind Farm - Permitted Turbine Layout

Table 3: Permitted Turbine Arrangement Before and After FeatherEdge Serrations

Turbine Mode	Power (kW)	Sound Power Level (dBA)	Turbines of Each Specification Before FE	Turbines of Each Specification After FE
Nominal (NR-0)	3200	106	2	40
NR-1	2942	105	0	0
NR-2	2772	104	4	0
NR-4	2473	102	16	0
NR-5	2370	101	18	0
		Nameplate Capacity	100 MW	128 MW
			Change in Nameplate	**28%**
			Change in Noise at Worst Receptor	**+ 0.1 dB**

According to the modelling, the FE technology would allow all 40 turbines to run at nominal nameplate capacity with minimal impacts to noise levels at any receptor, resulting in 28% higher nameplate capacity.

Greenfield Development: Achieving Increased Wind Farm Capacity with Larger Turbine Rotors and MW-Class.

The potential for increased nameplate capacity with the same number of turbines is not limited to facilities with de-rated turbines. Assuming the FE technology yields similar reduction in low-frequency noise emissions for other large-rotor turbine models, upgrading to FE may allow, for example, a nominal 109.5 dBA turbine platform to achieve receptor noise impacts similar to a nominal 106 dBA platform with OEM serrations. This may allow for larger, more powerful turbine platforms to be considered for a given site, as illustrated in the following figures.

Figure 4: 3.2 MW Turbine with OEM Serrations

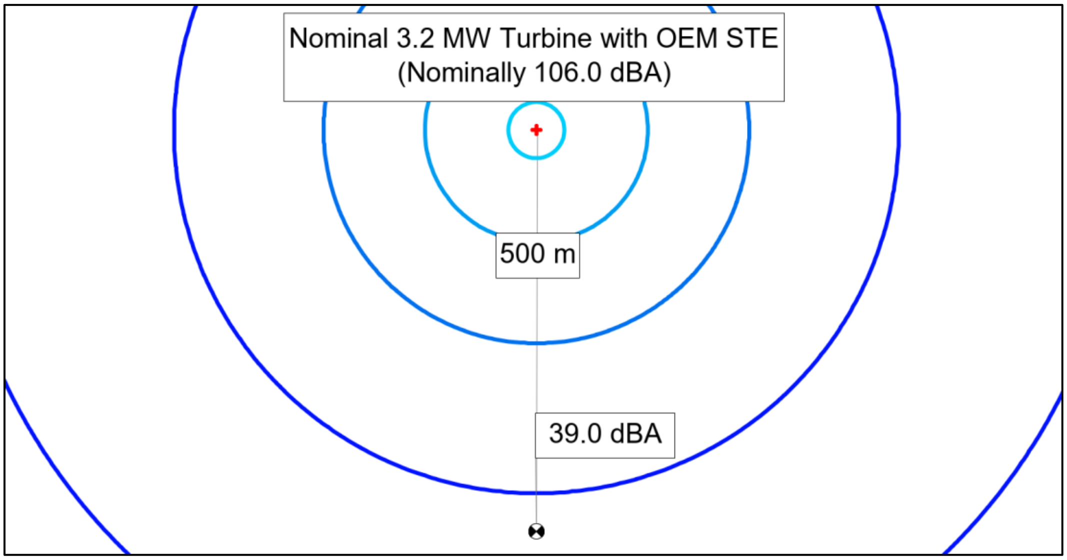
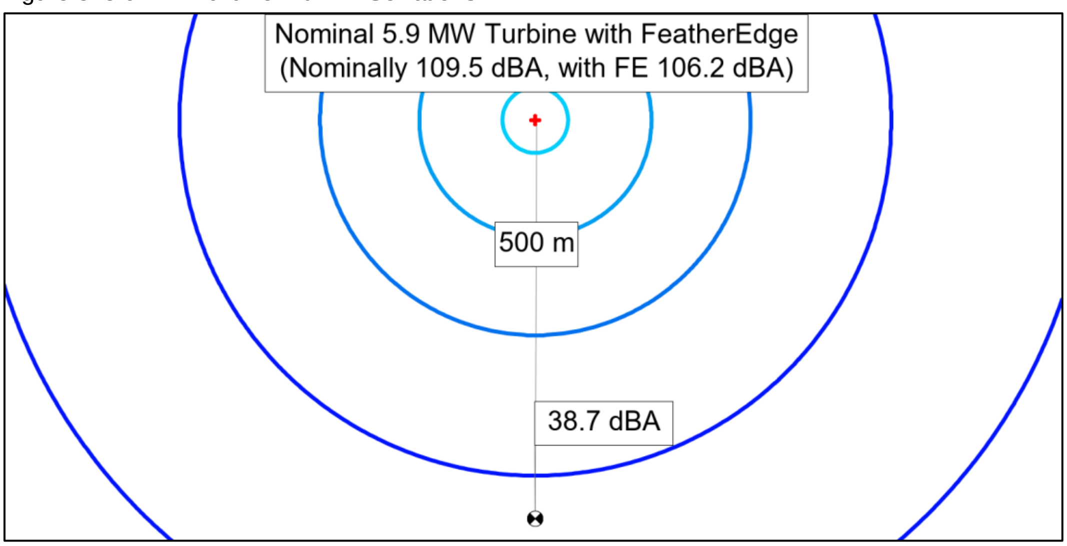


Figure 5: 5.9 MW Turbine with FE Serrations



Conclusion

The impact of the noise reduction provided by FE technology was analysed in this study. Assessing first the difference in far-field noise impact provided by FE, and then extrapolating these effects to three different scenarios, the potential gains enabled by the noise-reduction performance of the FE technology are shown to be significant. While assumptions are made in this study that apply the measured noise reduction performance from one turbine platform (Tier 1 OEM, 3 MW-class) to another (Siemens SWT-3.2-113), and even to larger MW-class turbines, the analysis here still provides a strong illustration of the potential benefits of the FE technology when applied to manage noise constraints in a variety of different scenarios.