Wind Turbine Separation Distances Matter

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Summary

Siting wind turbines too close together has a number of predictable consequences resulting from the turbulent nature of the air exiting turbines and entering adjacent turbines. The consequences include:

- increased wear on the turbine components, ultimately increasing early failure rates;
- increased audible noise;
- increased infrasound and low frequency noise.

These predictable and long known consequences of placing turbines too close are frequently ignored by both wind turbine manufacturers and developers; particularly if they are operating in a country with systemic regulatory failure of the wind industry, such as Australia.

Evidence is that the manufacturer-recommended separation distances of 7 to 8 rotor diameters for turbines in line with the prevailing wind and 5 rotor diameters for turbines abreast, still allows turbulent air exiting one turbine to retain significant turbulence when entering the next; so the manufacturers' recommended spacings can be considered as an unfortunate compromise and inadequate to contain noise.

The most efficient turbine spacing, i.e., that which allows the turbines to economically extract the most energy from the wind, has been shown to be some 15 rotor diameters. Most efficient extraction of useful energy will approximately coincide with the least production of waste energy, namely sound and vibration.

The Waubra Foundation currently considers that for a block of turbines that is likely to be subject to changing wind directions, noise will be minimised if the turbine spacing in all directions approaches the most efficient spacing of about 15 rotor diameters.

The way renewable energy subsidies work in Australia almost certainly rewards spacing below the most economically (without subsidies) efficient. Clearly this is beneficial to both developers and manufacturers, but damaging to residents.

Financial modelling, with and without subsidies, and acoustic measurements of wind projects with significantly different turbine separation distances, would be useful.

Noise guidelines in Australia and in other jurisdictions fail to address turbine spacing, but should include some minimum specification levels.

Specifically the closer the spacing the greater noise and vibration effects on project neighbours. These include repetitive sleep disturbance; physiological stress; symptoms and sensations called "annoyance"; greater impairment of their quality of life; plus destruction of amenity; reduction in property values, and occasionally bushfires and "component liberation" (windspeak for disintegration) resulting from catastrophic turbine failure.

Increased Turbine Wear

Wind turbines are not designed to run continuously on turbulent air. Doing so results in additional load on, and vibration of, bearings, brakes and rotating parts and ultimately breakages, fires and, catastrophic failure. The useful life of a turbine is thereby shortened as a result of turbines being too close.

There are public safety consequences from the increased risk of catastrophic failure, which can include nacelle fires scattering burning material, disintegration of rotating parts and blades, flying debris and bushfires. There have been three such wind turbine fires in Australia, at Cathedral Rocks (Acciona), Lake Bonney, (Infigen) and Starfish Hill at Cape Jervis (Transfield/Ratch), all in South Australia.

At Starfish Hill, Cape Jervis, the turbine air brakes failed, resulting in the turbine spinning out of control for days. This eventually resulted in wind turbine "component liberation" with 20kg metal brake components flying off the spinning turbine, subsequently found within metres of one of the surrounding homes, some 400 metres away from the turbine base.

For a comprehensive list of turbine failures see: www.caithnesswindfarms.co.uk Whilst all these failures are, by definition, mechanical and premature, it is quite possible that excessive turbulent air inflow played a part.

Consequences of Increased Wind Turbine Acoustic Emissions

Turbines subject to turbulent inflow produce less power and more waste energy in the form of airborne pressure waves (sound) and ground-borne pressure waves (vibration or seismic vibrations). The increased sound energy will be expressed as an elevation of the sound level (effectively loudness in the audible sound range) across all the frequencies composing the signature sound output from wind turbines.

Consequences for the neighbours are, as one would expect, worsened symptoms such as **sleep disturbance**, an **impaired quality of life** and an increase in **"annoyance,"** symptoms well identified in the field work of the Waubra Foundation and others, and identified in the limited research literature and confirmed by the recent Australian National Health and Medical Research Council ("NHMRC") 2014 Draft Information Paper "Evidence on Wind Farms and Human Health", 2014) (Pages 11 and 14)

Vigorous and repetitive denial and dissembling by the industry about the cause of the symptoms demonstrated by wind turbine neighbours has managed, quite surprisingly, to maintain doubt in certain, (not particularly scientific), quarters about causality.

Definitive research omitted by the NHMRC Systematic Literature Review, which enabled the reviewers to collectively but erroneously assert there was no evidence of direct causation of symptoms from wind turbine noise, is detailed in the Waubra Foundation's critique of the NHMRC draft statement at:
(http://waubrafoundation.org.au/resources/waubra-foundation-open-letter-nhmrc-re-systematic-literature-review/

The omitted research headed by Dr Neil Kelley was funded by the US Department of Energy, and involved two branches of NASA and some fifteen different research institutions. **Direct causation of the "annoyance" symptoms and sensations by impulsive wind turbine generated infrasound and low frequency noise, which then resonated inside some homes, was identified by Dr Neil Kelley's teams' acoustic field research, and subsequently confirmed with laboratory research.** The 1987 laboratory research was presented at the Windpower Conference in 1987, attended by US and international wind companies.

This Kelley research resulted in a dramatic change in wind turbine design, from downwind bladed to upwind bladed turbines, to try and reduce the generation of these health-damaging frequencies. However in 1989, NASA researchers Shepherd and Hubbard showed that contrary to their expectations, significant levels of ILFN could also be generated by upwind-bladed wind turbines, ***when the inflowing air was turbulent.***
http://waubrafoundation.org.au/resources/shepherd-k-

hubbard-h-noise-radiation-characteristics-westinghouse-wwg-0600-wind-turbine-generator/

This is precisely what happens when turbines are sited too close together.

The omission of the Kelley/Hubbard research by the NHMRC is a demonstration of the limits of literature studies. The research has been well known but "forgotten" by the wind industry for nearly thirty years. However it was sent to the NHMRC on being "rediscovered" in July 2013.

What Is the Optimum Turbine Separation Distance for Cost Efficient Power Generation?

Scientists from the USA (Meneveau, Johns Hopkins Fluid Mechanics and turbulence expert) and Belgium (Meyers, Katholieke Universiteit Leuven) recommended in 2011 ***that 15 rotor diameters was the optimal turbine separation distance in order to maximise cost efficient power generation***. Their new research took into account interaction of arrays of wind turbines with the atmospheric wind flow.
http://www.theengineer.co.uk/video/wind-turbines-need-to-be-farther-apart-suggests-study/1007037.article

What Turbine Separation Distances Are Supported by the Scientific Evidence?

Researchers from Adelaide University have recently established that turbine blade tip vortices have only just started to be broken down at 7 rotor diameters, (at a wind speed of 10 metres/second) providing independent scientific empirical support for adopting a minimum of 7 rotor diameters as a separation distance.
https://www.adelaide.edu.au/imer/news/newsletter/2013/using-wakes.html

What Turbine Separation Distances Have Been Generally Accepted?

Accepted turbine separation distances in the industry have generally been 5 – 8 rotor diameters. For example, the NSW government Wind Farm Planning Handbook from 2002, developed in conjunction with the wind industry stated (p53):

"A wind-farm layout must take into account that turbines have substantial 'wakes', which interfere with each other depending on wind direction and spacing. The general rule of thumb for spacing (the '5r-8r rule' is five times rotor diameter abreast and eight times rotor diameter downwind.. On very directional sites the 'abreast spacing' can be decreased by around 15 per cent, but the down-wind spacing is not as variable. Layout geometry can be primarily driven by the need to follow narrow ridgelines or to align arrays across the prevailing wind. On more complex terrain, individual sites need to be carefully evaluated to make best use of the wind resource, so the spacing may be quite variable."

The Waubra Foundation does not consider the generally accepted industrial practice as optimal. At this stage the Foundation is of the opinion that blocks of turbines in a location where winds are variable in direction should be a minimum of 8 rotor diameters apart in all directions. To further control turbulence of entering wind it would be advisable to approach the economic spacing of 15 rotor diameters indicated by Meneveau which indicates the turbine is operating at its most efficient and will thereby be producing the least noise.

Why Are Turbine Separation Recommendations Ignored?

Turbine manufacturers are clearly keen to maximise their sales, and developers are equally keen to maximise the subsidies they are paid – in Australia called Renewable Energy Certificates. There is a clear financial incentive on both to site the maximum possible number of wind turbines in a given area. Noise predictions used for planning approvals do not generally feature adjustments for turbine placements closer than manufacturers' recommendations.

This document has been prepared in good faith from information available at the time of writing. The author does not warrant that the information is complete or that the conclusions are necessarily correct. What the author does represent however is that the science he has had access to has been interpreted and summarised with care, and without bias, to the best of his ability.