

Statistical Analysis of Extent and Occurrence of Wind Turbine Clutter

Implications for Wind Park Assessments in Finland

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FMI criteria for wind park assessment

1. No wind turbines closer than 5 km from (C-band) radar site
2. For wind parks closer than 20 km from radar site, or parks less than 10 km from another park closer than 20 km from radar site:
 - (I) Maximum total power loss behind the wind turbine/park should be less than 10%
 - (II) Maximum size of modelled impact zone should be less than 10 km
 - (III) The angular extent of modelled impact zone should be 30° or less
 - (IV) Distance between two separate modelled impact zones should be more than 10 km

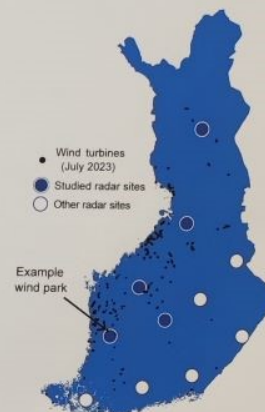
Can the modeling criteria in assessments for e.g. impact zone size be relaxed by relying on statistical analysis of observations from the existing wind parks?

Data sets

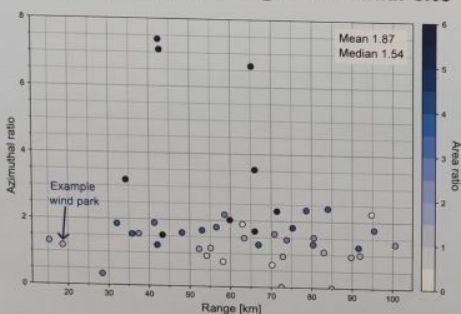
- C-band radar data from Jan - Dec 2022 from fipet, fiuta, fivim, filuo & June - Dec 2022 from fikan
- from 0.3° PPI scans (0.1° for filuo)
- Area / azimuthal ratios & mean reflectivity as maximums of monthly mean values

Measurement bins counted as:

1. turbine clutter: reflectivity 8 dBZ exceeded more than 25% of time
2. tails: reflectivity -6 dBZ exceeded more than 25% of time

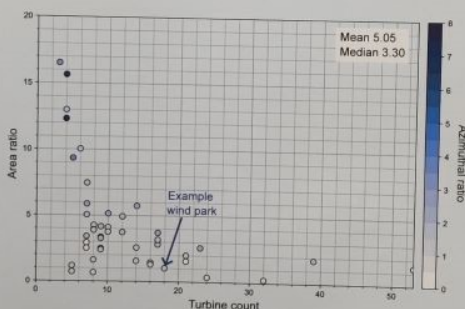


Ratio of cluttered to physical azimuthal width per range from radar site



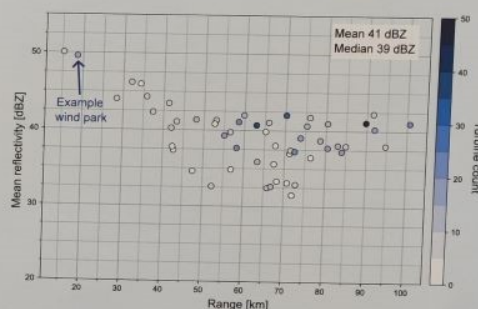
- For most parks, width of the clutter is at most 3.5 times the width of the park in azimuthal direction
- High clutter area compared to physical area does not always lead to a high azimuthal ratio

Ratio of cluttered to physical area per turbine count



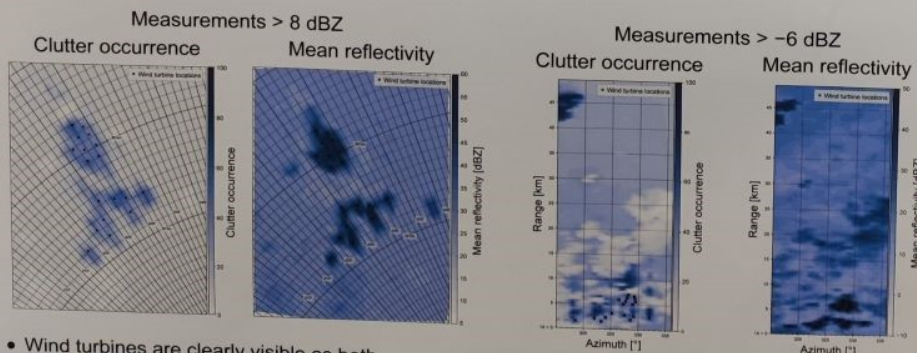
- High turbine count does not lead to high area ratio, and largest area ratios occur in parks with small turbine count

Mean reflectivity per range



- Mean reflectivities > 45 dBZ occur only at ranges less than 50 km
- At further ranges, mean reflectivity is 30...45 dBZ, with parks with more turbines producing higher reflectivities

Example of wind park clutter: Park with 18 turbines located 15 km north-west from fikan radar



- Wind turbines are clearly visible as both increased occurrence probability as well as high mean reflectivity
- Clutter area surrounding the turbines reaches further in range than in azimuthal direction

- Tail areas behind the turbines are visible in the clutter occurrence probability, but exhibit low mean reflectivity

Conclusions

- Azimuthal ratio on average 1.9 & area ratio 5.1
 - In our study, radar beam broadening with range from radar does not appear to impact azimuthal ratio
 - Wind park physical area defined with tower locations, not turbine dimensions, so outliers in area ratio at low turbine count are caused by small physical area, not larger clutter area
 - After 45 km, range from radar does not appear to impact mean reflectivity, but further analysis considering radar visibility & propagation conditions is needed
 - Initial monthly analysis did not reveal a clear impact of refraction to mean reflectivity or clutter occurrence, but the studied parks are mostly located inland, where refraction is less prevalent
 - Tails should be considered when removing clutter for products used to determine rain/no rain, but not necessary e.g. for rainfall accumulation products
- Based on our study, criterias (II) and (IV) can be reformulated to use physical areas of wind parks multiplied by a factor instead of modelled impact sizes

