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Assessment of the Shadowing Effect Between Windturbines at VOR and Radar frequencies.

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Abstract: Due to the fast-growing of green energy, projects of wind-farms are planned closer and closer to the minimum regulation distances of radio navigation devices (radar, VOR ...). To assess the impact of this windfarms close to radio-navigation devices, modelling tools are in developments [1-4]. Generally, robust modelling methods (MoM) are used to compute the field scattered by the windturbines [1, 2]. However, assumptions must be done to save memory and computation time and different modelling methods are based on physical optics [3, 4] or UTD [2]. Besides, in literature, interactions between windturbines are always neglected. This paper investigates the relevance of the latter.

Indeed, to lower their impact, a simple idea would be to place windturbines behind the one closest to the transmitting antenna to take advantage of the shadowing effect. Therefore, the shadowed windturbine scattering would be reduced. Nevertheless, this effect mainly depends on the distance and the frequency. In this paper, the necessity to account for the shadowing effect between windturbines is established at VOR and radar frequencies to notify wind-energy developer about the shadowing effect of windturbines.

The interactions between the windturbines is shown to be negligible at VOR frequency while at radar frequencies, it is not the case and need to be taking account in simulation tools.

Keywords: VOR, RADAR, windturbines, shadowing, scattering.

References:


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Geometric configuration:

**Windturbine:** ENERCON-E66.
- Mast: metallic cone: height = 64.17 m, Rotor blades diameter = 70 m
  top diameter = 2.18 m, bottom diameter = 4.17 m.

**Distances:**
- Separation distance between windturbines: 2 rotor-blades diameters (140 m) Lowest common separation distances (the most significant shadowing effect).
- VOR station to windturbine mast: 2000m, mast to scattered field: up to 1000m.

Electromagnetic consideration:
- Parabolic equation method (PE) is used to compute the incident field on the windturbine mast [5].
- Physical optics (PO) is used to compute the electromagnetic scattering from the windturbine [4].
- The VOR antenna is at 3m above the ground with a counterweight of 3m diameter.
- The radars are a TRAC2000 at 1.3GHz and a STAR2000 at 2.7GHz. The antennas are at 20m above the ground.
- The polarization is horizontal.

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Simulations and results:

Electrical Scattered field (dBV/m) behind the mast

For the VOR frequency at 114MHz, the scattered field rapidly decreases behind the windturbine mast. It rapidly becomes negligible compared to the incident field.

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Simulations and results: TRAC2000 Radar at 1.3GHz

- For the radar frequency at 1.3GHz at two rotors distance between windturbines, the shadowing effect should be considered between successive windturbines.

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Electrical fields (dBV/m) in a vertical plane at 140 m behind the mast

STAR2000 Radar at 2.7GHz

Ratio (dB) of the incident field without (direct) and with (total) the windturbine mast

For the radar frequency at 2.7GHz, at two rotors distance between windturbines the shadowing effect must be considered between successive windturbines
Conclusion:

It has been investigated the assessment of the shadowing effect behind a windturbine mast for the windturbine alignment at VOR (114 MHz) and radar frequencies (1.3 GHz and 2.7 Ghz).

For further work it will be relevant to add the rotorblades effect.

For the VOR system, no significant shadowing effect is observed.
- Windturbines alignment is not efficient to reduce their impact.
- Windturbine interactions can be neglected in electromagnetic simulation tools.

For radar frequencies, the incident field ratio with and without windturbine shadowing is around 4 dB and 6 dB for 1.3 GHz and 2.7 Ghz, respectively.
- It could be relevant to align windturbines to reduce their impact.
- Windturbine interactions must be accounted in electromagnetic simulation tools.

<table>
<thead>
<tr>
<th>Incident field ratio w/ and w/o windturbine</th>
<th>VOR 114MHz</th>
<th>Radar 1.3GHz</th>
<th>Radar 2.7GHz</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max. Difference</td>
<td>&lt; 2dB</td>
<td>&lt; 5dB</td>
<td>&lt; 7dB</td>
</tr>
<tr>
<td>Typical Difference</td>
<td>1 dB</td>
<td>&gt; 2 dB</td>
<td>&gt; 4dB</td>
</tr>
<tr>
<td>Neglect windturbine interactions?</td>
<td>Yes</td>
<td>May be</td>
<td>No</td>
</tr>
</tbody>
</table>

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