Flicker emission of wind farms during continuous operation

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Flicker emission of a wind farm during continuous operation has three main sources: wind turbulence, tower shadow and generator or power converter oscillations at frequencies. Flicker emission of a wind farm during continuous operation can be derived from the output of a single wind turbine since fast fluctuations are low correlated among turbines.

A stochastic model of the power spectral density (PSD) of power output is parameterized (Fig. 2 and Fig. 3).

A statistical model of the flickermeter in the frequency domain has been derived (Fig. 1), based on the small signal model of the wind farm network (Fig. 4).

The model has been tested with data from several wind farms. In wind farms with squirrel cage induction generators, 80% of the flicker was due to spatial variations in the wind field that produces a torque modulation depending on rotor angle at blade crossing frequency (around 1 Hz). The remaining 20% flicker contribution was due to mechanical oscillations in the 5.5 - 7 Hz range (see Fig. 5).

The main source of flicker are the turbulence in the 4-14 Hz frequency range, which can be seen in Fig. 6 as a smooth tendency (the graph scales are not normalized).

In wind farms with doubly fed induction generators, the fluctuations due to rotor angle are muffled, accounting for only 5% of total flicker. The rest of the flicker is due to turbulence, as in the variable resistance induction generator case.

In wind farms with variable resistance rotor, the opti-slip control dampers effectively fluctuations due to rotor angle (its flicker contribution is negligible) and the main source of flicker are the turbulence in the 4-14 Hz frequency range, which can be seen in Fig. 6 as a smooth tendency (the graph scales are not normalized).

The flicker level can be estimated as:

\[ P_f = \frac{\cos(\psi) \sin(\phi) \tan(\theta)}{S_{b,f} f_0} \sqrt{S_1 (C_0 f_i b_0 + 10.14 f_2 + 0.1332 \cosh[0.04462(2-5.383)(r-12.548)])} \]

where the parametric coefficient is:

\[ C_0(S_0, b_0, S_2, r) \approx \frac{1}{36} S_0 b_0^{1.55} + 10.14 f_2 + 0.1332 \cosh[0.04462(2-5.383)(r-12.548)] \]

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