Do wind turbines pose roll hazards to light aircraft?
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Introduction
Recent general aviation (GA) airport data (OurAirports; FAA, 2016) and wind turbine data (USGS, 2014) show that:
- There are 48,000+ turbines total in the United States (below)
- 40% are within 10 km of a small airport; 5% are within 5 km

Wind turbines create wakes (below) characterized by wind speed deficit, increased turbulence downwind
Rolling moment = torque about x-axis, caused by turbulence in wind field

Motivation
Concerns for wake-generated roll hazards have yielded conflicting estimates on the extent of wakes’ hazardous influence:
- KU study suggests that wind turbine wakes pose a significant roll hazard to GA aircraft as far as 2.84 miles downwind [1]
- CAA study indicates that the wake poses no roll hazards for aircraft 5 rotor diameters (0.25 miles) downwind [2]

The KU findings have been used in multiple states to limit wind energy development:
- Pratt wind farm project in Kansas was relocated further away from the airport [3]
- Used as a warning to aviators in Virginia [4]

Simulations
Model used: Simulator for Wind Farm Applications (SOWFA)
- Based on OpenFOAM, a library of LES solvers
- Turbine introduced into model: DOE GE 1.5 MW SLE
- Rotor diameter (D) = 77 m
- Hub height = 80 m
- Widely deployed turbine worldwide

Conditions simulated:
- Neutral, 7 m/s
- Stable, 9 m/s

Resolution: 1.25 m

Data Analysis
We represent a typical GA aircraft (Cessna 172) as a line in LES data
- Wingspan ≈ 10 m
- Planform area (S) = 16 m²
- Aspect ratio (β) = 7

At each point determine:
1. Angle of attack
   \( \alpha \approx \tan^{-1} \frac{w}{V} \)
2. Lift coefficient
   \( C_l = 2\pi\alpha + C_{10} \)
3. Lift
   \( L_i = 0.5C_l\rho|V|^2A \)

We define 540 flight tracks in down-wake and cross-wake orientations through the LES data to sample the wind vectors and make the above calculations.

\( C_{roll} \) is calculated for all 540 aircraft transects for 100 s, yielding 17,688,000 roll hazard calculations:
- \( |C_{roll}| < 0.1 \) = “low”
- \( 0.1 < |C_{roll}| < 0.28 \) = “medium”
- \( |C_{roll}| > 0.28 \) = “high”

Conclusions
1. As expected, aircraft within a turbine wake experience higher rolling moments than those outside the wake
2. However, >99.99% of rolling moment instances are classified as “low” roll hazards in both stabilities and flight orientations
3. The largest rolling moments occur most frequently about 5D downwind in both stability conditions

Future work could include: higher wind speeds, multiple turbines, experimental validation with lidar, RPAS

References

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