Presented at the

IEA Annex 23 Meeting

Roskilde, Denmark

February 25, 2009

Wind Turbine Wake Research at AWS Truewind, LLC

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AWS Truewind, LLC

AWS Truewind: Who We Are

- One of North America's leading consultancies
  - About 100 professional staff
  - European branch: Meteosim-Truewind (Barcelona)
- Supports entire wind project life cycle from site identification and resource assessment to plant performance evaluation and real-time forecasting
- Known especially for wind resource mapping, energy production estimation, and forecasting
  - MesoMap: Over 50 countries mapped at 200 m resolution using a blended mesoscale/microscale modeling approach
  - eWind: Forecasting for 14,000 MW of wind (>50% of US wind capacity)
  - Computational infrastucture: ~1000 core cluster dedicated to mapping and modeling applications, 250 additional cores for forecasting
  - openWind: First open-source wind farm design and optimization software package

The Wake Crisis

- The wind industry is losing confidence in existing wake models
  - Growing evidence of underestimation of wake losses in moderate-size wind farms (e.g., Horns Rev)
  - Suspicion that wake models contribute to ~10% overestimation of energy production
  - Growing awareness that science does not support applying existing wake models to large arrays (more than ~5 rows deep)
- Clients are demanding answers
  - AWST is currently assessing 3 wind projects of >1000 MW capacity
  - 3x to 4x difference between “standard” wake loss and that estimated based on rudimentary first principles (roughness technique)
  - If the worst scenario is correct, it is disastrous for large array economics: the wind industry must change course

What do we tell our clients?

Limitations of Current Approaches

- Standard engineering models (e.g., Park, eddy viscosity) assume one-way PBL-wake interaction (Frandsen et al) – this will never work for large arrays
- More advanced engineering/hybrid will be much better, but likely to require much site- or plant-specific "tuning"
- "Roughness" approaches are very useful for order-of-magnitude estimates in large arrays but can never be fully realistic
- RANS CFD models are good at the turbine level but treat the atmosphere in a simplified fashion: idealized boundary layer profiles, steady-state inflow conditions, limited ability to handle stability
- Mesoscale numerical weather prediction models simulate the atmosphere well but typically are too coarse to resolve individual turbines
- LES models resolve individual turbines well but entail far too much computation to handle more than a few turbines/cases

Where is the greatest opportunity for progress in ~6 months?

AWS Truewind

AWS Truewind's Wake Program

- **Monitor POWWOW, UPwind, IEA, other scientific forums**
- **Develop a plant data base (3 projects to date, ongoing)**
  - **Will be used to evaluate wake and wind resource models**
  - **SCADA data being analyzed to separate wake, topographic, and other effects**
  - **For wake studies, best to have simple terrain**
- **Assess "standard" wake models (eddy-viscosity, Park)**
  - **Review published research (Horns Rev, etc.)**
  - **Evaluate models against plant data base**
- **Implement near-term "fix" based on roughness method (1-2 months)**
  - **So far validated only offshore (GH "offshore model")**
  - **Should be applicable onshore – why not?!**
  - **Not a satisfactory long-term solution: *wrong physics***

continued

Wake Program (continued)

- **Develop and test a new wake model (2-5 months)**
  - **"Dynamic CFD" or "mesoscale" approach**
  - **Based on ARPS (Advanced Regional Prediction System), an open-source model developed at Oklahoma U. for storm prediction (www.caps.ou.edu/ARPS/arpsdoc.html)**
  - **Individual turbines represented as momentum/energy sinks and turbulence sources at the grid cell level (e.g., Adams & Keith)**
  - **Employ high resolution (~100 m horizontal, ~ 30 m vertical) to partially resolve turbine rotor, fully resolve spaces between turbines**
  - **Dynamic 24-hour simulations for a representative sample of days (e.g., 72)**
  - **Expected total simulation time: about 10 days on 288 cores**
  - **Start with simple, idealized arrays, verify against available data and models**
  - **Build confidence and move to larger arrays in complex terrain**

“Mesoscale” Wake Modeling: Advantages and Disadvantages

- Advantages
  - Simulates wake-wake and two-way PBL-wake interactions
  - Addresses topographic and wake effects in an integrated fashion
  - Accommodates different wind climates in a natural way
  - Avoids idealized representations of the boundary layer
  - Allows dynamic features of wind flow to be simulated
  - Captures a range of stability conditions
- Disadvantages
  - Computer time and cost
  - Cannot be used directly for array optimization – a different approach is required for that
  - Challenging to fully resolve rotor wakes (LES required)
- ***Our bet is that, for large arrays, this method will be worth the time and cost. The details of individual turbine wakes can be handled by other methods.***

openWind

- Open-source wind farm design and optimization program
- Provides a common platform on which different wake models may be implemented and tested
- Currently has the Modified Park and Ainslie Eddy-Viscosity model
- Will likely be used to implement roughness method in near term
- Visit http://www.awsopenwind.org/
- Try it – it's fun!