Producing multiple forecast scenarios of wind power generation using multiple grid points from a single ECMWF forecast

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Project background

- PhD at CEEM was funded by the Australian Government to develop wind forecasting techniques for Australian conditions
- Completed PhD in 2009
- Current project is funded by Australian Energy Market Operator (AEMO) to further develop the PhD wind forecasting techniques into a prototype extreme events wind forecasting model. If successful, this could be incorporated as an enhancement to AEMO’s Australian Wind Energy Forecasting System (AWEFS)

Wind Power Penetration

- Many of the power systems in these countries are interconnected to other countries
- The Australian power system is not even connected east to west!
- Take South Australia on its own… (data source www.aemo.com.au for 2008-9 financial year)

Wind Energy in Australia

- National Electricity Market (NEM) ➔
- Wind Farms currently installed in the grid ➔
- 1600 MW of wind in Australia (July 2009)
- More than half in SA (868 MW)

Legend:
- Wind farm size
  - 0-1 MW
  - 1-10 MW
  - 10-50 MW
  - > 50 MW
Value of wind forecasting

- Wind power generation has been shown in a previous study to have an effect on spot prices in SA*
- Wind forecasts (0-24 hours lead time) can allow better spot price forecasts, and in turn allow:
  - Generators to optimise their bidding strategies
  - Demand-side response groups to better capitalise on price spikes
- Power system operators can use wind power forecasts to plan for potential large disturbances
- Slow-start generators can better plan their unit commitment


Wind power forecasting methods of use

- Wind power forecasting can be used in two ways:
  - Best guess generation used automatically for commercial optimisation (eg. in electricity markets)
  - Multiple scenarios provided for visual interpretation to characterise forecast uncertainty and assist decision-making in critical situations (eg. Managing power system security and large rapid changes in aggregated wind power)

Outcomes from the PhD thesis (1)

- Large, rapid changes in wind power in Australia are largely caused by horizontally propagating synoptic weather phenomena:
  - Eg. Cold fronts and low pressure systems
Outcomes from the PhD thesis (2)

- Large, rapid changes in wind power in Australia are largely caused by horizontally propagating synoptic weather phenomena:
  - Eg. Cold fronts and low pressure systems
- By their nature, statistical forecasting methods based on past observations will struggle to provide useful information on large rapid changes
- Numerical Weather Prediction (NWP) systems are the best tool available to forecast significant changes in the weather

NWP systems

- Represent the atmosphere on a coarse horizontal grid (25 km for global ECMWF system) and cannot directly model local, fine-scale detail topographic effects on the wind
- Good at forecasting broad synoptic weather phenomena (such as cold fronts and low pressure systems) and how they affect near-surface winds out to around 48 hours ahead
- Uncertain in the timing, or more generally the precise position of such synoptic weather phenomena

→ “Misplacement error”
Outcomes from PhD thesis

- Identified that conventional single grid point extraction and corresponding time-series forecast may be missing useful information in NWP system
  - Misplacement errors during large rapid changes in wind can cause large differences in single grid point forecast
- Developed technique to display multiple grid point information from NWP systems to characterise wind power forecast uncertainty due to misplacement errors
  - Problem: the wind at each grid point is influenced by the local topography

PhD outcomes: Terrain standardisation method

- Develops relationships between grid points based on historical data to standardise effects of topography

Transforming wind speed forecasts to wind power

Need availability data
PhD outcomes: Convert wind field to wind power
- Develops relationships between historical forecasts and observations to create:

Site-equivalent wind power field
Issued for 20-Jul-2009 07:00 Local Time. Proj time: 9 hrs

Animation of wind power forecast fields
Issued for 20-Jul-2009 07:00 Local Time. Proj time: 9 hrs

Estimated direction and speed of propagation

Animation of wind power forecast fields
Issued for 20-Jul-2009 10:00 Local Time. Proj time: 12 hrs
Animation of wind power forecast fields

Issued for 21-Jul-2009 01:00 Local Time. Proj. time: 27 hrs

Interpreting wind power forecast fields

- Projection time 6 hours
  - High probability of full power generation

- Projection time 15 hours
  - Low probability of single grid point forecast value

- Projection time 15 hours
  - With no misplacement
Interpreting wind power forecast fields

- Projection time 15 hours
  - Misplacement to the SE

- Observation up to 7am*

* Note that all observations and forecasts have had a constant scaling factor applied to assume a level of availability of the wind turbines in the wind farm.
Observations up to 12:30pm

Observations up to 1:30pm

All observations: 30 minutes

All observations: 5 minutes
Interpreting wind power forecast fields

- All observations: 5 minutes

Animated wind power field versus NWP ensembles

- Both show uncertainty information in wind forecast:
  - Wind power field uncertainty based on multiple grid points, and assuming potential misplacement errors. Field highlights potential chronological behaviour
  - Ensembles are based on different (perturbed) initial states of the atmosphere, or different physical assumptions
- Both reduce uncertainty when scenarios are similar
- Spatial resolution is usually compromised to run the NWP system multiple times for an NWP ensemble
- Wind power fields show chronological behaviour between the NWP system time-stamps, ensemble scenarios could suffer from sampling error

Wind farm aggregation

SE SA:
Canunda, Lake Bonney 1 and 2
286 MW total

Legend:
- Wind farm size
  - 0-1 MW
  - 1-10 MW
  - 10-50 MW
  - > 50 MW
Large rapid change event for SE SA

Single grid point forecast

Forecast projection time [hours]

Vind Power Generation [MW]

Local Time [hour] on 20-30 Sep 2009 at South-East South Australia

Issued for 29-Sep-2009 16:00 Local Time. Proj time: 6 hrs

MW, Jawed point [MW]

Issued for 29-Sep-2009 19:00 Local Time. Proj time: 9 hrs

Issued for 29-Sep-2009 22:00 Local Time. Proj time: 12 hrs

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Future work

- To automate provision of time-series traces (potential scenarios) of wind power generation from wind power forecast fields
- The tool could also provide alarms for large rapid changes based on the information in the traces
- Combining the NWP ensembles and spatial fields

Large rapid change with high probability detected
Conclusions

- Wind power forecast spatial fields can characterise some of the uncertainty in NWP forecasts without requiring an NWP ensemble.
- The technique looks promising and will be evaluated by AEMO at the end of this year.
- For some complex sites, further work may be required to extend the method to look in the vertical direction as well as the horizontal.

Thank you & Questions

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