A Vector Auto-Regressive Model for Onshore and Offshore Wind Synthesis Incorporating Meteorological Model Information

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Objectives

To aid the quantification of the system-wide impact, in both planning and operation, of wind generation, a characterisation or synthesis of wind power output will be developed from large sets of data that capture

– the range of likely wind conditions;
– the frequency of occurrence of those conditions; and
– the correlations between wind farm outputs at different locations.

The work is being progressed in a number of strands:

– longer-term issues;
– short-term electricity market issues;
– system operation issues;
– Grid Code issues;
– questions of public perception of the wind resource.
Data Available

British Atmospheric Data Centre
One station per Ten Year Statement Study zone
Finer resolution and offshore model under development
COSMO Model

Meteorological model to act as pseudo-data offshore
Rotated grid so irregular on lat-longs (circa 15km)
Characterisation of Wind

Physics

Different for different sites, terrain and region – capture via statistical models

E.g.

- thermal winds in hills
- sea breezes on coast
- more “memory” on flat terrain (?)
Vector Auto-regression

Allows for influences from nearby sites

\[ \underline{y}(t) = A_1 \underline{y}(t - 1) + A_2 \underline{y}(t - 2) + \underline{e}(t) \]

Auto-Regressive parameters (memory terms) now matrices, \( a_{ij} \) element of \( A \) denotes influence of site \( i \) on site \( j \). Vectors \( y \) are de-trended windspeeds for all sites.

Assess modelling ability via

a) inspection of acf of residuals

b) rms error plots compared with persistence and univariate model
Detrending

Fit annual component, \( \Omega, 2\Omega, 3\Omega \)

\[ \sum_{k} A_k \sin(k\Omega t + \lambda_k) \]

Calculate (seasonal) diurnal profile

Fit Diurnal Components, \( \omega, 2\omega \)

Subtract trends to form detrended series to be modelled
Annual Trends
Diurnal Trends

Winter

Spring

Summer

Autumn

Hour of Day

Wind Speed (m/s)

TainRange

Hour of Day

Wind Speed (m/s)
Symmetry Before/After De-trending

‘t’-Test on ‘scores’ of skewness state de-trended less skewed
→ Gaussian assumption in a VAR model less imperfect
Results – Forecast Errors

Improvements over Persistence – rises to 19% at 6hrs ahead
Inclusion of additional data improves predictability
Benchmarking of VAR

Verify residuals contain no information

Forecast ability

Simulation of probability density functions (pdfs)

Model simulation of calm periods
Probability Density Functions (pdfs)

Coningsby – good agreement
Probability Density Functions (pdfs)

Leuchars – not such good agreement
Calm Analysis

34% one hour or more at this one site
BUT biased heavily by small number of long periods of calm
AND reduced when more sites taken into account

Good agreement at individual sites (this is Leuchars)
Calms Analysis

Varying number of sites defining the calm period (<4m/s)

Only 9% (11.5% modelled) of time in year are >=8 sites becalmed

Around 0.06% for whole country (14 sites)
Work in Progress

Supply more data stations (now working with 50 sites),
\[ p \leq 3\sqrt{N/k} \]
where \( p \) is number of parameters, \( N \) observations and \( k \) sites.

Extension to offshore using COSMO model as pseudo-data.

Validation against capacity factors.

Interpolations for off node info – e.g. cubic splines, Delaunay triangulation, Kriging.

Threshold VAR – parameters depend on \( y \)-values in ‘bands’.
Estimation of Capacity Factors

Onshore validation requires interpolation methods
Achievements and Advantages

Decomposed wind variability into
diurnal
annual
stochastic components

Obtained a parsimonious model which:

Distinguishes differences between sites

Acts as a short term forecasting tool and
may provide measure of
predictability across terrain type (in future!)

Provides powerful tool to assess scenarios
via wind synthesis
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