Comparative evaluation of wind power forecasts for Portuguese transmission system operator

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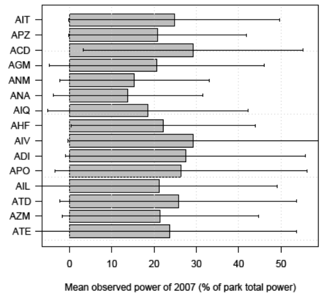
INTRODUCTION

Wind power capacity in Portugal has been growing with Europe's tendency and by June 2007, there were 1908 MW installed with 700 MW (17 parks) being telemeasured and 3273 MW already licensed. Figure 1 is a map of parks location and figure 2 presents mean measured power per park.

Grid integration concerns have applied different methodologies to wind power forecast, that do not allow a quantitative comparison of the performance of each method. We present a comparative study of different wind power forecasts, for Portugal, from the point of view of system operator. We compare statistical corrections of numerical forecasts made with persistence weighting to improve short-term predictability (intra-daily) of wind power.



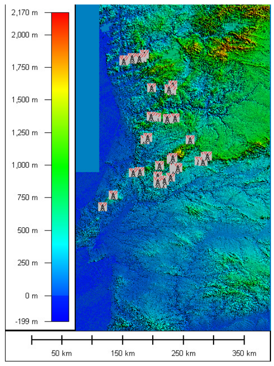


Figure 1 (above) – Mean observed power per park in 2007 (% of park total power). Parks are ordered by total power, increasing from bottom to top.

Figure 2 (right)– Spatial location of telemeasured Portuguese wind parks.

MM5 Verification

MM5 numerical meteorological model is running operationally 4 times per day (0,6, 12 and 18h) for 3 days in advance. From the higher resolution domain (9km), time series for wind park locations are interpolated both in horizontal and vertical (to turbine height). Turbine manufacter's curves are used to convert wind speed to power.

A summary of DMO forecasts for the first day of prediction (00d0, 06d0, 12d0, and 18d 0) is presented in figure 3 with values as fractions of park total power, where it can be seen that the error between the different simulations is similar and depends on park location, not on power size. The decomposition of RMSE (equations in figure 4) of the total power forecasted shows that phase errors are dominant (high contribution of disp) and there is a clear diurnal cycle.

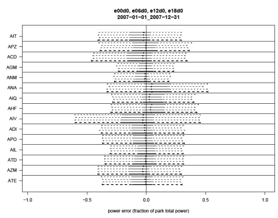


Figure 3 – Summary of error of DMO for 00d0, 06d0, 12d0 and 18d0 simulations. Parks are ordered by total power, increasing from bottom to top.

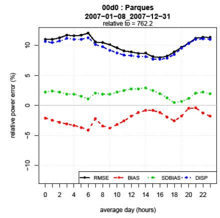


Figure 4 – RMSE decomposition for 00d0 DMO for all parks summed for 2007

$$rmse^2 = bias^2 + sde^2 = bias^2 + sdbias^2 + disp^2$$

$\varepsilon = x_{prd} - x_{obs}$	Error
$rmse = \sqrt{\overline{\varepsilon^2}}$	Root Mean Square Error
$bias = \bar{\varepsilon}$	Bias
$sde = \sigma(\varepsilon)$	Standard Deviation of Error
$sdbias = \sigma(x_{prd}) - \sigma(x_{obs})$	Variability Error
$disp = \sqrt{2\sigma(x_{prd})\sigma(x_{obs})(1-r)}$	Dispersion (phase error)

Equations 1:7 – Methodology for RMSE decomposition. Bias and sdbias comprise amplitude errors and disp the phase errors.

Statistical Corrections for short term power forecast

The statistical correction made of direct model output (DMO) by linear weighting persistence up to 10h, every 6h, showed an improvement of 30% in RMSE (Trancoso et al, 2007). To further improve this correction, we tried to find optimal coefficients for the weighting of persistence.

Regression analysis for each park and figure 5 show that there is a high dispersion of coefficients between parks, which is due to their different layouts and not on size, as they are ordered by park total power. All regression R2 > 0.7. Coefficients for the 06Z simulation weight more heavily the DMO than others because DMO's RMSE is lower in the middle hours of the day (not shown here).

Two different statistical corrections were tested, following McCollor & Stull (2008), by removing moving averages of past error: (1) MA - unweighted moving average; (2) LIN - linear weighted moving average, with recent errors more heavily weighted. Results presented in figure 6 show that LIN is much more stable than MA, but the maximum decrease in RMSE for a minimization of BIAS is 1.6% for a 5.5 days window length for the moving averages.

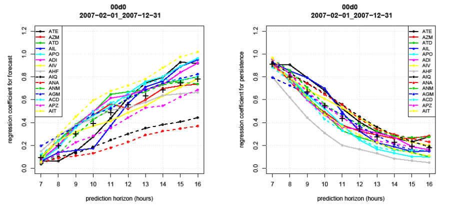


Figure 5 – DMO (left) and persistence (right) weighting coefficients for each park. Parks are ordered by total power, increasing from top to bottom. Crosses are mean values.

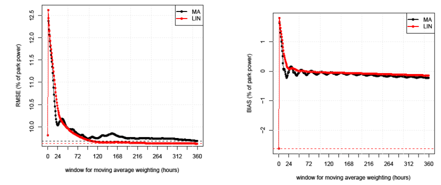


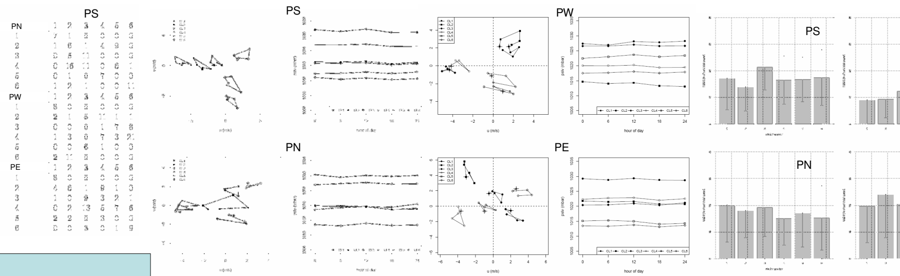
Figure 6 – Evolution of RMSE (left) and BIAS (right) as fractions of total power.

Cluster Analysis with PCA

10m wind components and mean sea level pressure at t=0,16,12,18,24 h for the year of 2007 were decomposed into principal components (PC) and cluster analyzed. We selected that 6 PC and then 6 clusters.

We analyzed 4 parks for the differences (PS – the southest park, PN – the northest, PW – the westest in between the above, PE – the eastest (same latitude as PW).

Results show that clusters are well identified in each park, but have lower correspondence between sites. Therefore, the RMSE per clusters depends on the clusters characteristics.



Conclusions

- Direct model output (DMO) RMSE has a diurnal cycle and it's mainly comprised by phase errors.
- The regression analysis made for each park and found that there is a high dispersion of coefficients between parks, which is due to their different layouts and not on size. Coefficients for the 06Z simulation weight more heavily the DMO than others because DMO RMSE is lower in the middle hours of the day.
- Correction of DMO with linear weighted moving average, with a 5.5 days window length allows for the reduction of 1.6\% of DMO's RMSE, 0.7\% of DMO's MAE and 98\% of DMO's bias.
- Cluster analysis with principal components reveals that weather regimes are site dependent, i.e., we can classify wind and pressure variability in 6 six clusters for all parks, but these have different characteristics from park to park. This can be due to 2 specialties of Portuguese wind farms: (1) the complexity of terrain in the Northern part of Portugal. (2) the influence of the sea.
- Future Work: Understand, characterize and correct DMO wind power phase errors.

References:

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