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Short-term Forecasting of wind energy production using CFD simulations

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Abstracts

More and more governments require wind farm owners to deliver production forecasts for their wind farms. In Italy, the government required regular forecasts from beginning January 2013. This has increased the demand from Italian wind farm owners to find good in-house forecasting solutions which can be adjusted based upon experience.

To meet these requirements, a forecasting tool has been developed combining wind speed forecasts from numerical weather prediction models (NWP), artificial neural network (ANN) corrections, and high resolution CFD simulations. Downscaling NWP by CFD simulations have proven added value, but there are some bottlenecks. These include the quality of the weather forecasts, and the accuracy of the power curve used for the energy calculation. To overcome these problems, a ANN correction is used to adjust the forecasted wind speeds before they are used by the CFD. The CFD power output can be corrected by one ANN or many ANNs to improve the performance of the forecast.

Objectives

The objective of this study is to compare results of the forecasted power using some of the different approaches available.

The site chosen for test with is a wind farm located in central Italy, it consist of 20 turbines of 80m height.

The nominal power of the WTG is 2MW and the rotor diameter is 60m.

The layout is quite wide, the main diagonal is almost 10km, the anemometer used as reference for the whole wind farm is just 30m high but has a long time series of data.

The anemometer data and the SCADA data available are covering almost 3 years, form April 2010 to May 2012, the whole 2011 data are used to train the ANNs, a complete year is used for training to avoid seasonal bias. The other periods are used to validate the performance of the different methods.

This site has many complexity aspects: The NWP in central Italy is quite difficult due to the complex orography and the presence of a warm sea; the wind farm is wide and the anemometer is much lower than the turbines hub.

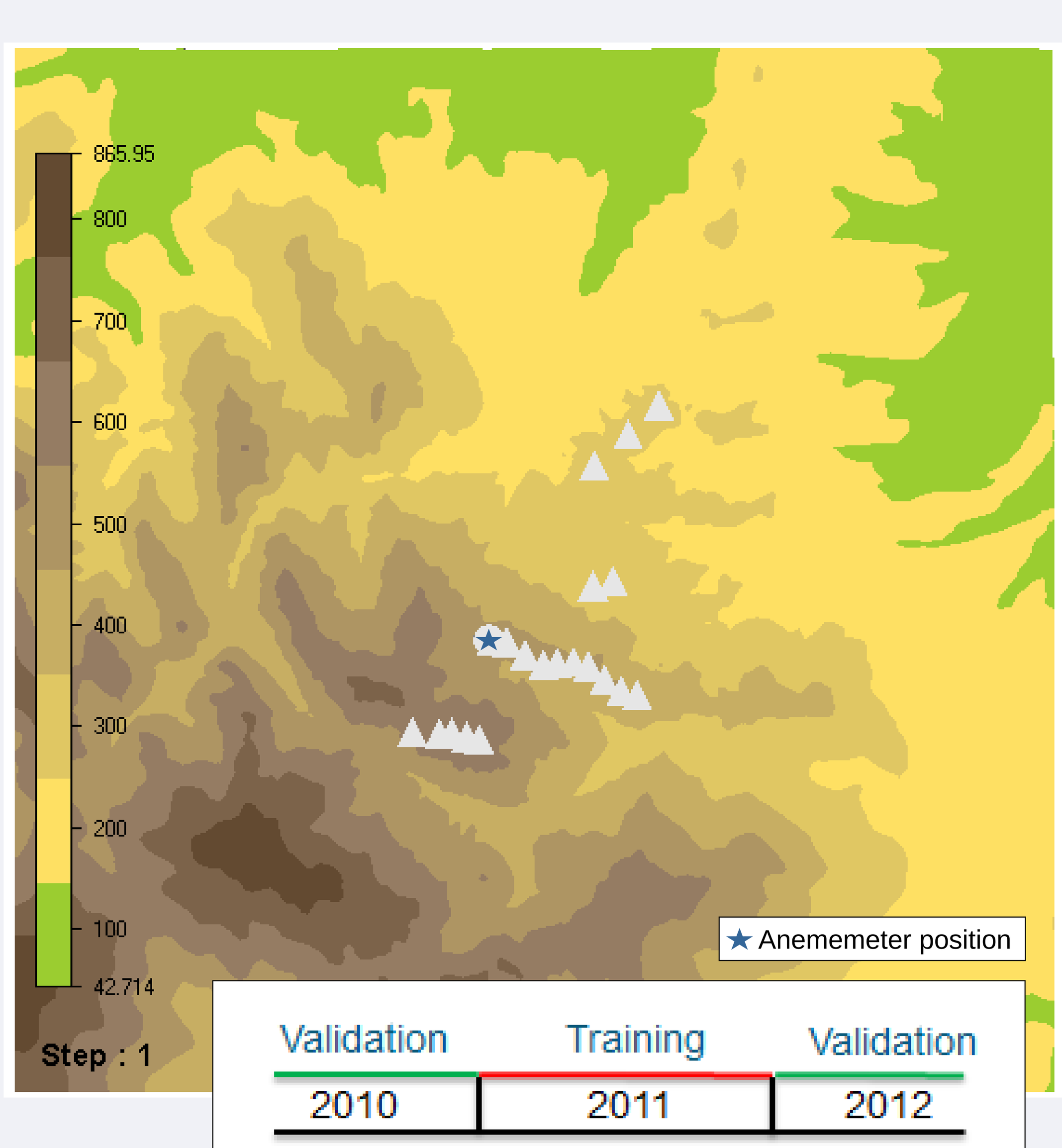

Fig. 1: Site Layout and time series of wind and power data used for Training and Validation (error calculation and performance detection).

Methods

The method developed is explained in Fig.2, a ANN is trained to correct the NWP climatology at the position of the met mast. Using the obtained data as real measurements a CFD power forecast is performed (Fig.2 a).

That ANN is trained using long time series of NWP forecasts and wind measured data, the cleaning of these data is important to avoid an error effected training.

The added value of a ANN correction for the wind speed forecasts is known, this method has been proven in earlier published works [1], the methods that we show here are more focused on the correction of the CFD output.

The first correction performed uses a single ANN for the whole wind farm power production (Fig.2 b), while the second uses a ANN for each turbine (Fig.2 c).

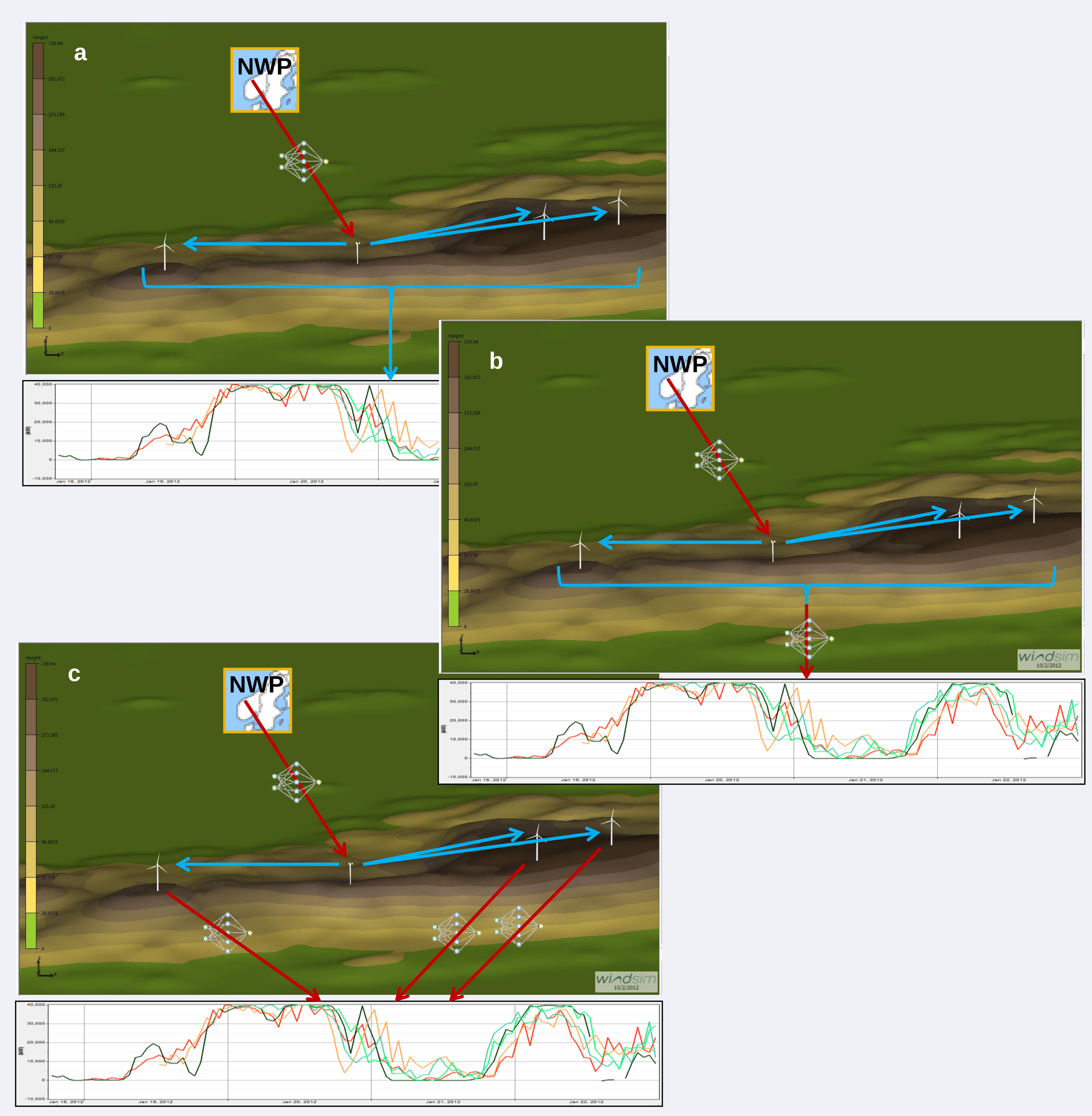

Fig. 2: Schematic view of power forecasting methods using CFD.

The ANNs are trained using long time history of power production data from SCADA, the same measured data are used for the calculation of the performance but on a time period not used in the training (Fig.1 "Validation").

First is calculated the energy forecast of the CFD model, this time series is then used as input of a ANN.

Three cases are presented, in each are used different ANN inputs:

- Case 1 : CFD power, pressure and temperature .
- Case 2 : CFD power, wind speed and direction.
- Case 3 : Use both the power series of case 2 and CFD raw power output in a hybrid solution.

We notice that the performances of CFD raw output and the ANN corrected output change at different power levels. The CFD is more accurate in the extreme cases: high production periods and calm periods.

Fig.3 displays the measured and the forecasted production during a period of March and April 2012.

The two yellow lines divides the power time series horizontally in three areas.

In the central area the ANN corrected time series is the better forecast while in the up an down areas the CFD raw output describe better the power production. The hybrid solution depending on the area use the method performing better.

All three cases are calculated both using a single ANN for the complete Wind Farm production and with 20 ANNs, one for each turbine.

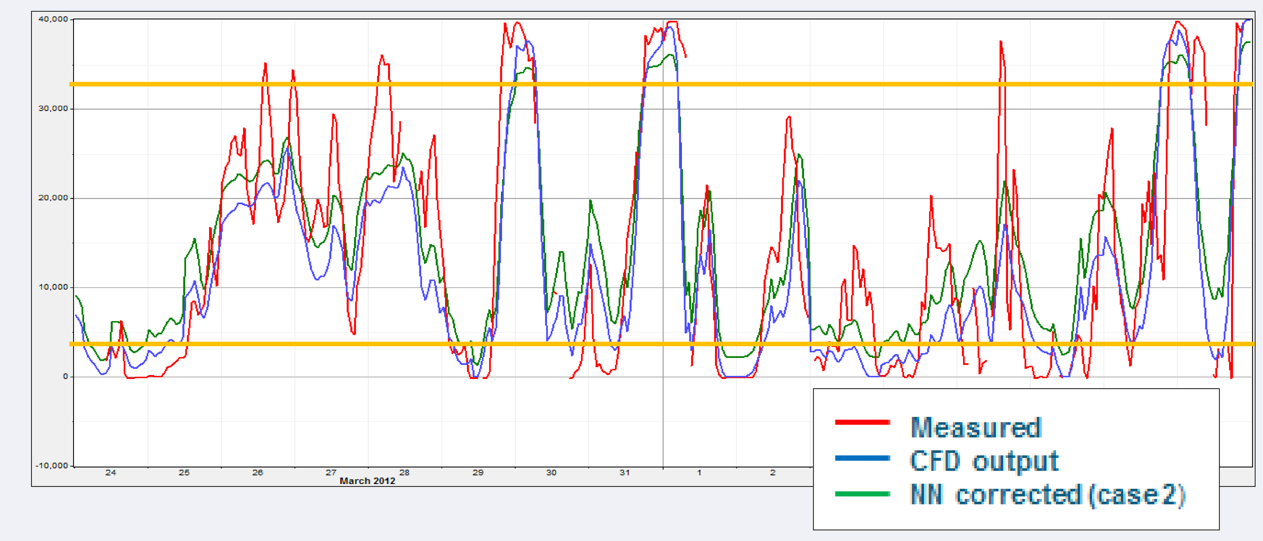

Fig. 3: Comparison of observed, CFD power output and ANN corrected time series .

Results

To define the performance of the different methods the Normalized Mean Average Error (NMAE) is used :

$$NMAE\ \% = 100 \times \frac{1}{N}\sum_{i=1}^{N}\frac{\left|P_m^i - P_f^i\right|}{C}$$

P_m^i and P_f^i are the measured and forecasted energy output at time step i ,
N is the number of time steps used and C is the capacity power of the wind farm.

The left plot of Fig.4 describes the gain in term of NMAE of the ANN correction for the single NN and is shown an improvement of the performance in the three cases. The right plot display the gain using 20 NNs instead of one.

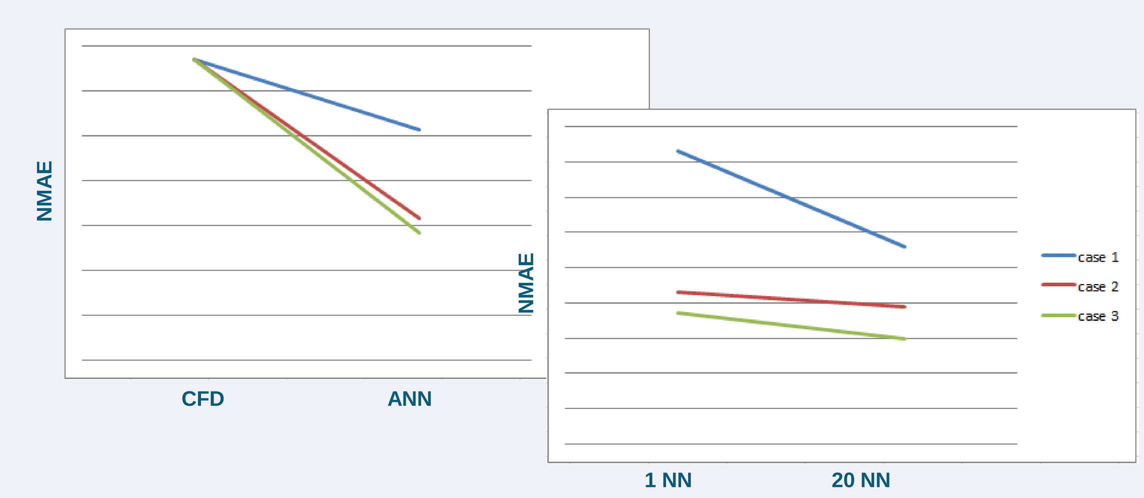

Fig. 4: Plots of NMAE gain in the different cases.

The results describe an improvement of the performance using as ANN inputs the forecasted wind speed and direction, instead of pressure and temperature and a further improvement using an hybrid solution. All three cases perform better training 20 ANNs instead of one.

Increasing the number of ANN, both the training computation time increase and the time spent in the preparation of the production data used in the training.

Notice that the CFD raw output dose not need any production data but only the wind farm layout info.

Conclusions

A short-term power production forecasting system has been developed which has several forecasting modes, different training cases and number of ANNs set up are used.

Depending on the data availability and data quality of the wind farm, the forecasting can be further improved by using a neural network approach.

The ANN methods can correct both the forecasted wind speed and the calculated energy output of the wind farm. Validation results are promising, but using ANN on the energy CFD output needs special attention: the quality of the production data used in the training can effect significantly the performance.

The CFD permit also to forecast better the high production and the calm periods, this is used to set a hybrid solution between CFD and ANN forecasts.

References

[1] "A NEURAL NETWORK ALTERNATIVE TO TRADITIONAL MEASURE-CORRELATE-PREDICT ALGORITHMS IN WIND RESOURCE ASSESSMENT" David E. Weir, Regina Sweet, Dr. Cathérine Meißner; Poster at EWEA 2012

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