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Improving short-term forecasting during ramp events by means of Regime-Switching Artificial Neural Networks

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Since nowadays wind energy can't be neither scheduled nor large-scale storaged, wind power forecasting has been useful to minimize the impact of wind fluctuations. In particular, short-term forecasting (characterised by prediction horizons from minutes to a few days) is currently required by energy producers (in a daily electricity market context) and the TSO's (in order to keep the stability/balance of an electrical system). Within the short-term background, time-series based models (i.e., statistical models) have shown a better performance than NWP models for horizons up to few hours. These models try to learn and replicate the dynamic shown by the time series of a certain variable.

When considering the power output of wind farms, ramp events are usually observed, being characterized by a large positive gradient in the time series (ramp-up) or negative (ramp-down) during relatively short time periods (few hours). Ramp events may be motivated by many different causes, involving generally several spatial scales, since the large scale (fronts, low pressure systems) up to the local scale (wind turbine shut-down due to high wind speed, yaw misalignment due to fast changes of wind direction). Hence, the output power may show unexpected dynamics during ramp events depending on the underlying processes; consequently, traditional statistical models considering only one dynamic for the hole power time series may be inappropriate.

This work proposes a Regime Switching (RS) model based on Artificial Neural Nets (ANN). The RS-ANN model gathers as many ANN's as different dynamics considered (called regimes); a certain ANN is selected so as to predict the output power, depending on the current regime. The current regime is on-line updated based on a gradient criteria, regarding the past two values of the output power. 3 Regimes are established, concerning ramp events: ramp-up, ramp-down and no-ramp regime. In order to assess the skillness of the proposed RS-ANN model, a single-ANN model (without regime classification) is adopted as a reference model. Both models are evaluated in terms of Improvement over Persistence on the Mean Square Error basis ($IoP_{\%}$) when predicting horizons form 1 time-step to 5.

The case of a wind farm located in the complex terrain of Alaiz (north of Spain) has been considered. Three years of available power output data with a hourly resolution have been employed: two years for training and validation of the model and the last year for assessing the accuracy. Results showed that the RS-ANN overcame the single-ANN model for one step-ahead forecasts: the overall $IoP_{\%}$ was up to 8.66% for the RS-ANN model (depending on the gradient criterion selected to consider the ramp regime triggered) and 6.16% for the single-ANN. However, both models showed similar accuracy for larger horizons. A locally-weighted evaluation during ramp events for one-step ahead was also performed. It was found that the $IoP_{\%}$ during ramps-up increased from 17.60% (case of single-ANN) to 22.25% (case of RS-ANN); however, during the ramps-down events this improvement increased from 18.55% to 19.55%.

Three main conclusions are derived from this case study:

- It highlights the importance of considering statistical models capable of differentiate several regimes showed by the output power time series in order to improve the forecasting during extreme events like ramps.
- On-line regime classification based on available power output data didn't seem to contribute to improve forecasts for horizons beyond one-step ahead. Tacking into account other explanatory variables (local wind

measurements, NWP outputs) could lead to a better understanding of ramp events, improving the regime assessment also for further horizons.

- The RS-ANN model slightly overcame the single-ANN during ramp-down events. If further research reinforce this effect, special attention should be addressed to understand the underlying processes during ramp-down events.