Training requirements of a neural network used for fatigue load estimation of offshore wind turbines

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Introduction

Background

To estimate fatigue loads, neural networks (NNs) have been proven to be a reliable method [1-3]. After training the neural network with a set of load measurements and SCADA signals it is able to predict the loads with SCADA signals solely. However, load measurements are costly [2].

Objectives

- assess the minimum needed length of consecutive load measurements
- investigate the time dependence of the training samples (seasonal effects)
- check the representativeness of the training samples to validate the processed samples sizes

Measurements

- Baltic 1: 21 Siemens 2.3-93 wind turbines
- Examined wind turbines:
  B01 (mainly free flow)
  B08 (predominantly in wake)
- Period: Mar2013 - Mar2014
- Sampling rate: 10-minute statistics
- Availability:
  B01: 60.83% (32062 records)
  B08: 56.81% (29943 records)

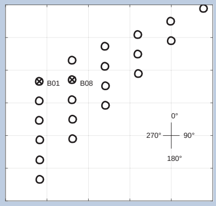

Fig. 1: Layout of Baltic 1.

Methods

Feed forward neural network

- One hidden-layer
- 30 neurons
- Estimator: 8 SCADA statistics
- Target: flapwise blade root bending moment

Prediction error

- relative mean squared error
- $rMSE = \frac{1}{n}\sum_{i=1}^{n}\left(\frac{\hat{y}_i - y_i}{y_i}\right)^2$

number of records n, estimated loads $\hat{y}_i$, measured loads y_i

Statistical testing

- K-fold cross validation (with overlap)
- Smallest size: about two days (144 records)
- Largest size: about 45 days (4032 records)
- Step size: about two days (144 records)

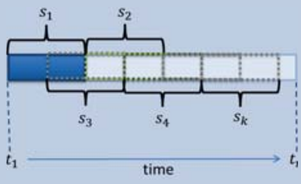

Fig. 2: Scheme of k-fold cross validation with overlap.

Representativeness of training samples

- Filling degree of capture matrix of training sample compared to filling degree of capture matrix of whole measurement

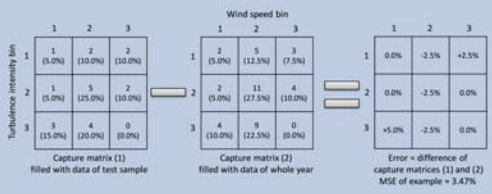

Fig. 3: Example scheme for calculation of MSE.

Results

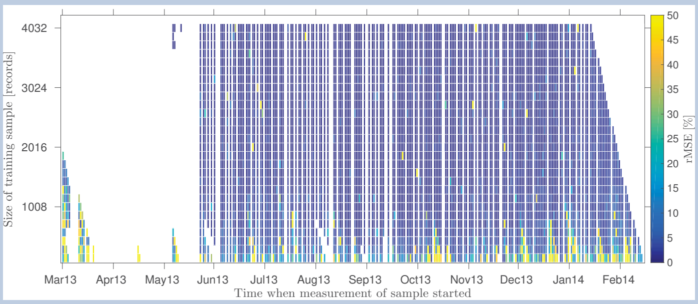

Fig. 3: Prediction error in relation to the time the training sample was measured for one blade B01. The gaps within the data are caused by the data availability and filtering of overly large time periods per training sample which were as caused by missing measurements.

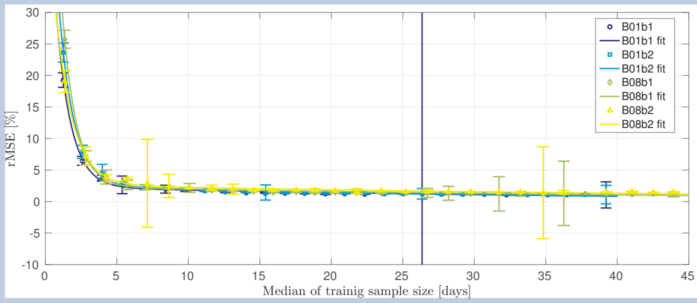

Fig. 5: Relation of prediction error (rMSE) and training sample size. For each training sample size, the median of the time periods needed to gather the number of records is plotted with its standard deviation. The sample size of about 26 days (2736 records) shows a standard deviation greater than 15% which occurred due to a falsified prediction of one out of 204 training samples.

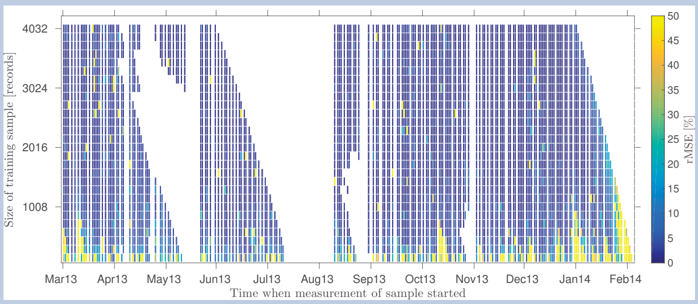

Fig. 4: Prediction error in relation to the time the training sample was measured for one blade B08. The gaps within the data are caused by the data availability and filtering of overly large time periods per training sample which were as caused by missing measurements.

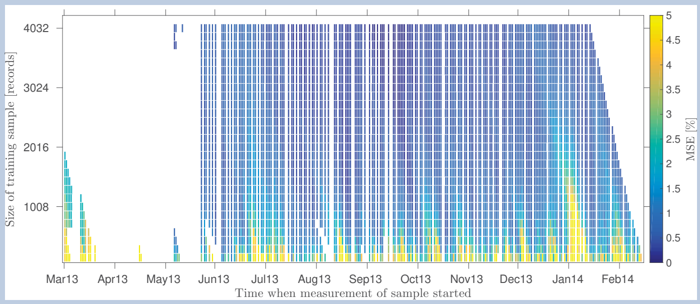

Fig. 6: Representativeness of training samples for one blade of B01 assessed with the MSE of the filling degree of their capture matrices according to the example scheme.

Conclusion

- Reliable fatigue load prediction is possible even for small sized training samples of 2016 records (about 20 days)
- Representativeness of small sized training samples (2016 records, about 20 days) is given
- Seasonal effects are neglectable low and do not affect the prediction accuracy
- To generalise these findings the evaluation has to be extended for other loads

Acknowledgements

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