Data-driven fatigue load monitoring in a wind farm

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1. Tittle

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2. Abstract

The expected lifetime of wind turbines is a factor directly proportional to their energy output. Thus, its better estimation should lead to a better valuation of their financial appealing. Moreover, their expected lifetime is a choice made by manufacturers, with typical values around 20 to 25 years, and as such affects their design. The number of years wind turbines should operate is used to calculate the accumulated fatigue loads they should withstand during their operational lifetime.

To monitor accumulated fatigue loads with additional purpose-specific sensors would be a logic step to monitor the lifetime of wind turbines. However, this is an expensive and complex option and is typically left to prototypes. But, since most commercial wind turbines record their operational conditions with Supervisory Control and Data Acquisition (SCADA) systems, monitoring their accumulated fatigue loads from SCADA data became a field of research on its own more than a decade ago.

This thesis contributes to the field by elaborating on how to define a methodology based on data mining techniques that describe the relation between 10-minute statistics of SCADA data and accumulated fatigue loads. Special attention was given to the case when turbines are placed in wind farms. Furthermore, efforts were centred on how to transform implementation challenges into scientific questions, where scientific contributions were conceived to clarify or to improve the usability of the methodology.

The first two chapters are used to frame the problem and to justify simplifications taken to scope the research carried out. The first chapter defines what can be understood as fatigue load monitoring and provides a list of challenges. The second chapter clarifies concepts around modelling and monitoring, which serve to frame the research decisions made to form the specific methodology.

Afterwards, in chapters three to five, brief introductions to specific problems are provided next to original scientific contributions; each chapter attempts to target key dilemmas: chapter three evaluates alternative methods to select sets of input variables; chapter four proposes metrics to evaluate quality of prediction and assess the impact that wake conditions have on prediction quality; chapter five quantifies the deterioration of prediction quality when fatigue loads are assessed on other turbines. Then, chapter six brings all previous steps together and presents an example of how to implement the methodology in a commercial wind farm. Before last, chapter seven discusses valid alternatives approaches not considered in the specific methodology. Finally, chapter eight closes the thesis with a brief summary and outlook.

3. Summary

The draft version of the thesis has an extension of 158 pages, including 59 graphs and 187 bibliographic references. Its content is structured as:

Ch. 1: Introduction

- Defines the baseline approach

Ch. 2: Modelling and monitoring wind turbines

- Clarifies concepts needed to frame the problem

Ch. 3: Robustness – The selection of input variables

- Discusses alternatives to define a set of predictors
- Vera-Tudela, L., Kühn, M., On the selection of input variables for a wind turbine load monitoring system, *Procedia Technology* 15 (2014) 727-737

Ch. 4: Quality – The influence of wind farm conditions

- Introduces quality metrics to assess its usability
- Vera-Tudela, L., Kühn, M., Analysing wind turbine fatigue load prediction: The impact of wind farm flow conditions, *Renewable Energy* 107 (2017) 352-360

Ch. 5: Generalisation – The selection of regression algorithms

- Explores regression algorithms and quality deterioriation when used in other turbines
- Vera-Tudela, L., Kühn, M., Monitoring fatigue loads in wind farms from SCADA data – Quantifying quality, 2018 (to be submitted)

Ch. 6: Synthesis – Implementation in a wind farm

- Present results as part of a process to be implemented in commercial wind farms

Ch. 7: Alternative approaches

- Describes other challenges investigated and related problems
- Bustamante, A., Vera-Tudela, L., Kühn, M., Evaluation of wind farm effects on fatigue loads of an individual wind turbine at the EnBW Baltic 1 offshore wind farm, *Journal of Physics: Conference Series* 625 (2015) 012020
- Seifert, J., Vera-Tudela, L., Kühn, M., Training requirements of a neural network used for fatigue load estimation of offshore wind turbines, *Energy Procedia* 137C (2017) 315-322

- Lind, P., Vera-Tudela, L., Wächter, M., Kühn, P., Peinke, J., Normal behaviour models for wind turbine vibrations: an alternative approach, *Energies* 10 (2017) 1944

Ch. 8: Summary and outlook

- Describes contribution made and maps the road ahead

Appendix: Lists scientific contributions

4. About the author

- Electro-Mechanical Engineer with a M.Sc. in renewable energy
- Active in wind energy in Germany for 10 years, as design engineer & researcher
- Previous 5 years work experience in Peru at different industries (oil & gas, beverages and packaging) with roles centred around project and process management
- Hobbies in both humanities (literature / philosophy) & social sciences (psychology / economics)

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