

Wind Turbine Brain

Publieke samenvatting / Public summary

Background

Current wind turbine controller architectures are mostly based on a rotor speed controller supported by additional control loops targeting specific loads or specific wind conditions. However, for wind turbine design the design equivalent loads (DEQL) and extreme loads are more relevant than the rotor speed. Furthermore, the DEQL are a non-linear function of the variation in the loads. This results in very indirect tuning of the controller where the trade-off between yield and loads is very opaque. By using machine learning (ML) algorithms, the controller can be tuned to minimise DEQL and extreme loads directly. However, the performance of the controller is still very dependent on its structure, so improving the controller structure itself, such that load and (improved) wind estimations are available, should allow superior controllability of the wind turbine. Furthermore, due to a high number of degrees of freedom, artificial networks (AN) can be expected to detect changes in the wind and control the loads better than a more conventional controller structure. The application of ML to ANs can therefore highlight opportunities for improvement in the controller.

Objective

The goal of the project is to improve the wind turbine controller and its design process. This will be achieved by using machine learning (ML) to tune the controller in the design phase. The controller will contain conventional estimators and controller structures. Neural or Bayesian networks (hereafter:

Projectinformatie / Project information

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Algemene informatie / General information

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Publicaties en materialen / Publications and attachments

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artificial networks (AN)) will be used to search for opportunities to further improve the conventional controller design.

Situations where improvements are sought are low, normal and highly turbulent winds, starts and stops and extreme wind conditions, such as extreme operating gusts or extreme direction changes.

The improvement is expected to reduce DEQL on the blades by 5-10% and the wind turbine tower of 1-5% and to reduce extreme loads by up to 10% relative to a current market conform controller, at equal annual energy production. These reductions can directly reduce the cost of a wind turbine by up to 5%, reducing the overall levelised cost of energy (LCoE) by up to 2%. Alternatively, the load reduction on the blades can be used to employ longer blades, resulting in higher production, again, this is expected to reduce the LCoE by up to 2%.

Short description of activities

There are 6 main activities to achieve the objective of reduced loading using machine learning (ML) and artificial networks (AN):

1. ML methods and AN architectures: AN types are compared and the architecture of an AN-based controller is selected. Based on that selection, appropriate ML methods are selected.
2. Target function and load case selection: to ensure a fair comparison, the target function and design load cases to tune and evaluate the controllers are carefully selected.
3. Conventional state-of-the-art controller: ECN's current controller PI-based architecture is effective, but model/estimator based controllers are considered more state-of-the-art. A state-of-the-art controller is necessary to highlight the true benefit of the AN-based control.
4. Conventional controller tuning with ML: The selected target function may be difficult to capture for the conventional controller. ML can tune the parameters based on the target function directly.
5. AN-controller: Incorporate AN in the controller and tune it.

6. Tuning and testing: The new controller structures are tuned for on at least three manufacturer and theoretical wind turbine models

Results

The results of this project are:

- An improved conventional controller structure
- A method to tune conventional structures using ML methods.
- A working AN wind turbine controller.
- A clear understanding of when artificial networks achieve a clear benefit over conventional state-of-the-art controllers for wind turbines
- An overall design equivalent loads reduction of 5-10% on the blades, 1-5% on the tower and up to 10% reduction in extreme loads

De data in deze applicatie is afkomstig van de Rijksdienst voor Ondernemend Nederland (RVO) en wordt in samenwerking met de Topsector Energie ontsloten.

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