Load Prediction by Stochastic Model in Global Tech I

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Offshore Wind R & D Conference 2018, Bremerhaven

14.11.2018

Research Alliance Wind Energy

ForWind Center for Wind Energy Research Bremen Hannover Oldenburg

Introduction

- Wind Energy as a solution to global energy problem
- Complex nature of wind dynamics
- Cost pressure to wind farm operators
- To reduce operational loads

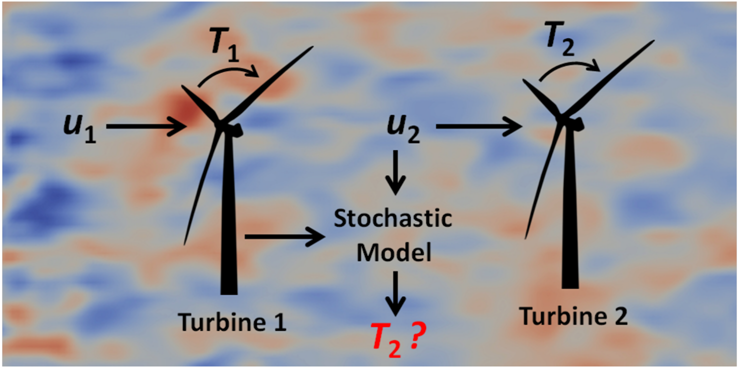
www.windaction.org/

Offshore Wind Park (OWP) Control

- Funded by German Ministry of Economic Affairs and Energy
- Intermediate results from Global Tech I wind farm

www.4coffshore.com/offshorewind/

Proposed Idea



P.Lind 2014, modified

Load Variable to Model

- Generator torque T
- Calculated from power P and rotational speed ω

$$T = \frac{P}{\omega}$$

Stochastic Load Modelling

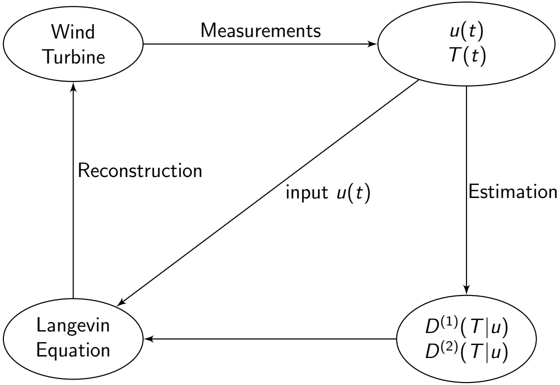
- Langevin Equation

$$\frac{\mathrm{d}}{\mathrm{d}t}T(t) = \overbrace{D^{(1)}(T|u)}^{\text{Deterministic / Drift}} + \overbrace{\sqrt{D^{(2)}(T|u)}\Gamma_t}^{\text{Stochastic / Diffusion}}$$

- Drift(n = 1) and Diffusion (n = 2) coefficients

$$D^{(n)}(T|u) = \frac{1}{n!}\lim_{\tau\to 0}\frac{\left\langle (T(t+\tau) - T(t))^n \,|_{u(t)=u,\, T(t)=T}\right\rangle}{\tau}$$

Stochastic Load Modelling

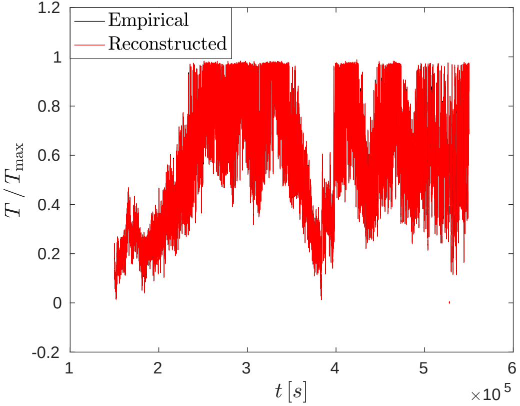


Stochastic Load Modelling

www.4coffshore.com/offshorewind/

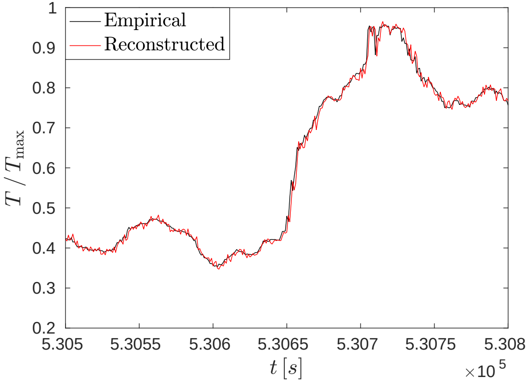
- Model parameter from Turbine 58
- Apply the model to Turbine 59

Time-Series Reconstruction of Torque from Wind Speed in Turbine 59



- Correspondence with empirical data in large scale

Time-Series Reconstruction of Torque from Wind Speed in Turbine 59

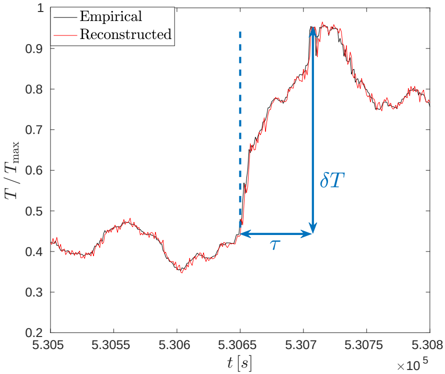


- Correspondence with empirical data in small scale

Reproduction of 2-Point Statistics

- Increment statistics

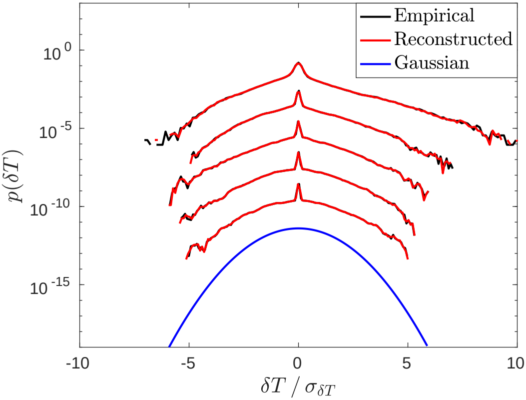
$$\delta T = T(t+\tau) - T(t)$$



Reproduction of 2-Point Statistics

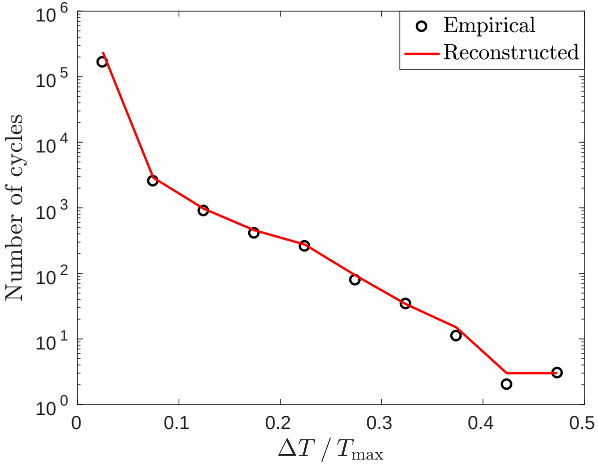
- Increment statistics

$$\delta T = T(t+\tau) - T(t) \;\; ; \;\; \tau = (10, 60, 600, 3600, 5400)\,\mathrm{s}$$



Fatigue Load Analysis

- Rainflow Cycle Counting



Summary and Conclusion

- Stochastic Modelling on Global Tech I Turbines
- Model parameters from Turbine 58
- Apply the model to Turbine 59
- Reconstruct the torque and compare with empirical data
- Statistically convincing results
- Also in rainflow counting analysis

> Stochastic model could be a cost-efficient method for load monitoring of wind farms.

Thank you!

Supported by:

Federal Ministry
for Economic Affairs
and Energy

on the basis of a decision
by the German Bundestag