Estimation of 1Hz Distribution based on 10min SCADA Data

Björn Roscher, M.Sc.
Dipl.-Ing. Alexander Werkmeister
Prof. Dr.-Ing. Schelenz
14th of November 2018

CWD Center for Wind Power Drives | RWTH AACHEN UNIVERSITY

Structure

1 Motivation

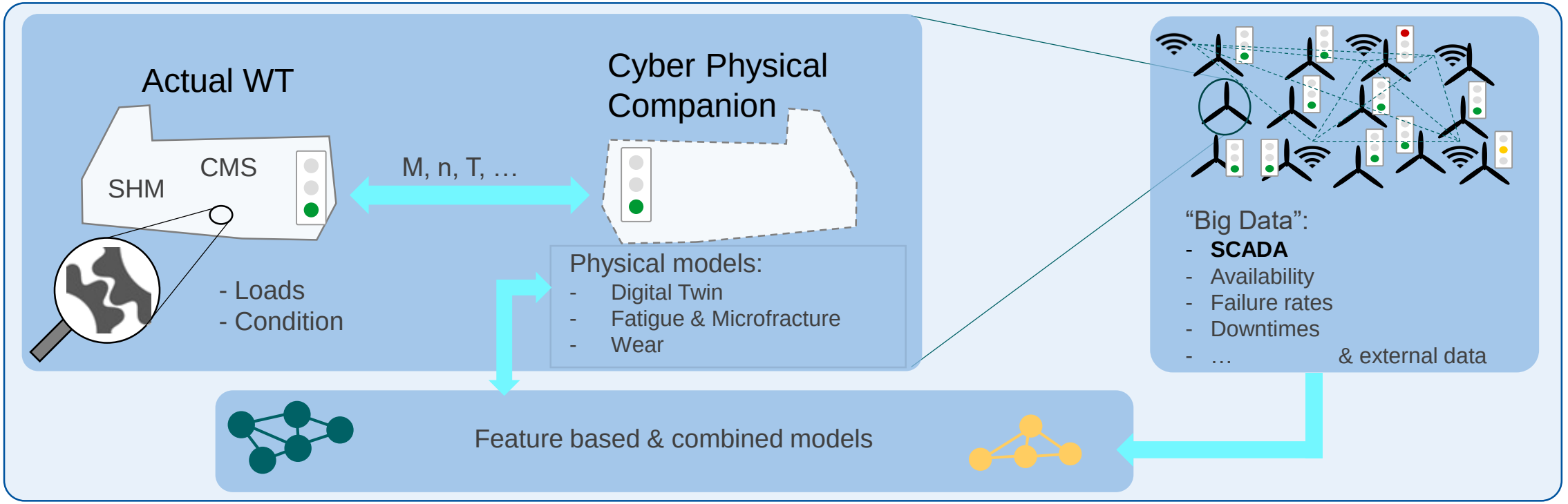
2 Data background

3 Method of Estimation

4 Comparison of Load Duration Distribution

5 Conclusion

What is our aim?
Wind 4.0



Life time extension

Autonomous data interpretation

Optimizing wind farm ➔ AEP

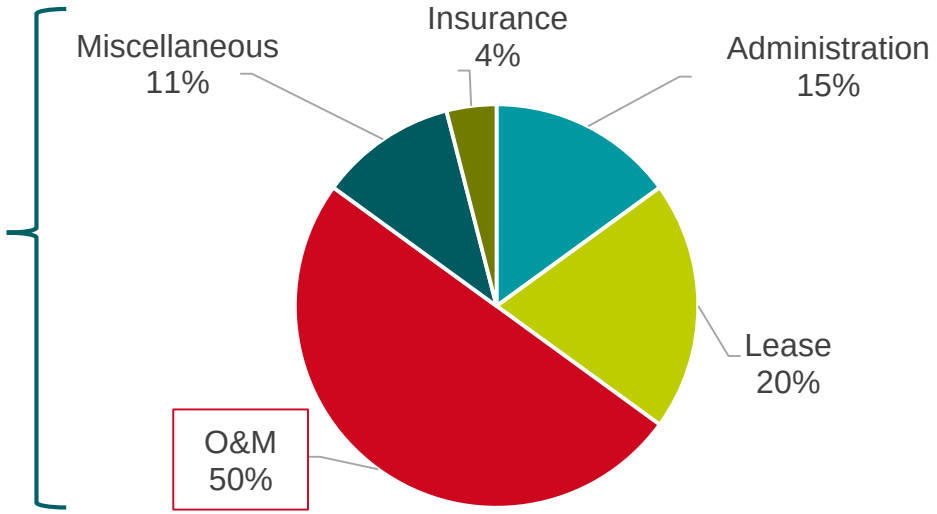
Predictive maintenance

Estimation of 1Hz Distribution based on 10min SCADA Data
Björn Roscher, M.Sc.
Dipl.-Ing. A. Werkmeister; Prof. Dr. Ralf Schelenz
14th of November, Bremerhaven

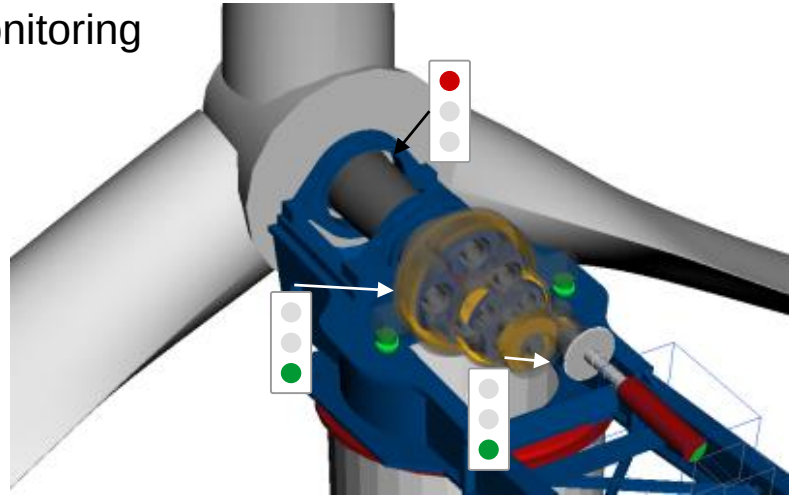
Motivation

- On-shore auction-market announcement of wind farms
  - Increasing cost pressure

$$\min \mathrm{LCoE} = \frac{\mathrm{Investment} + \sum_{t=1}^{\mathrm{life\ time}} \frac{Annual\ Costs}{(1+i)^t}}{\sum_{t=1}^{\mathrm{life\ time}} \frac{AEP}{(1+i)^t}}$$



- Monitoring features
  - Structural Health Monitoring
  - Particle counter
  - Vibration sensors
  - Accelerometer

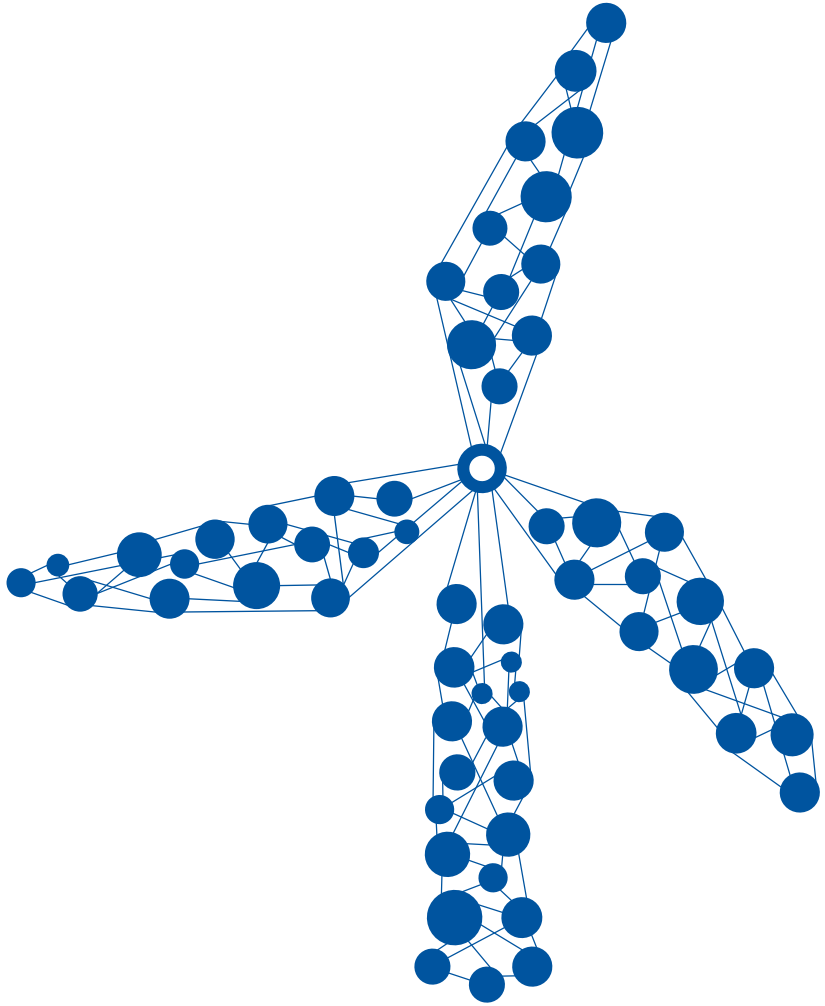


Motivation

- Every wind turbine equipped with SCADA-System
  - 200-1000 signals
  - 10 min Mean, Min and Max value
- Integrated monitoring system
- Recording of individual past

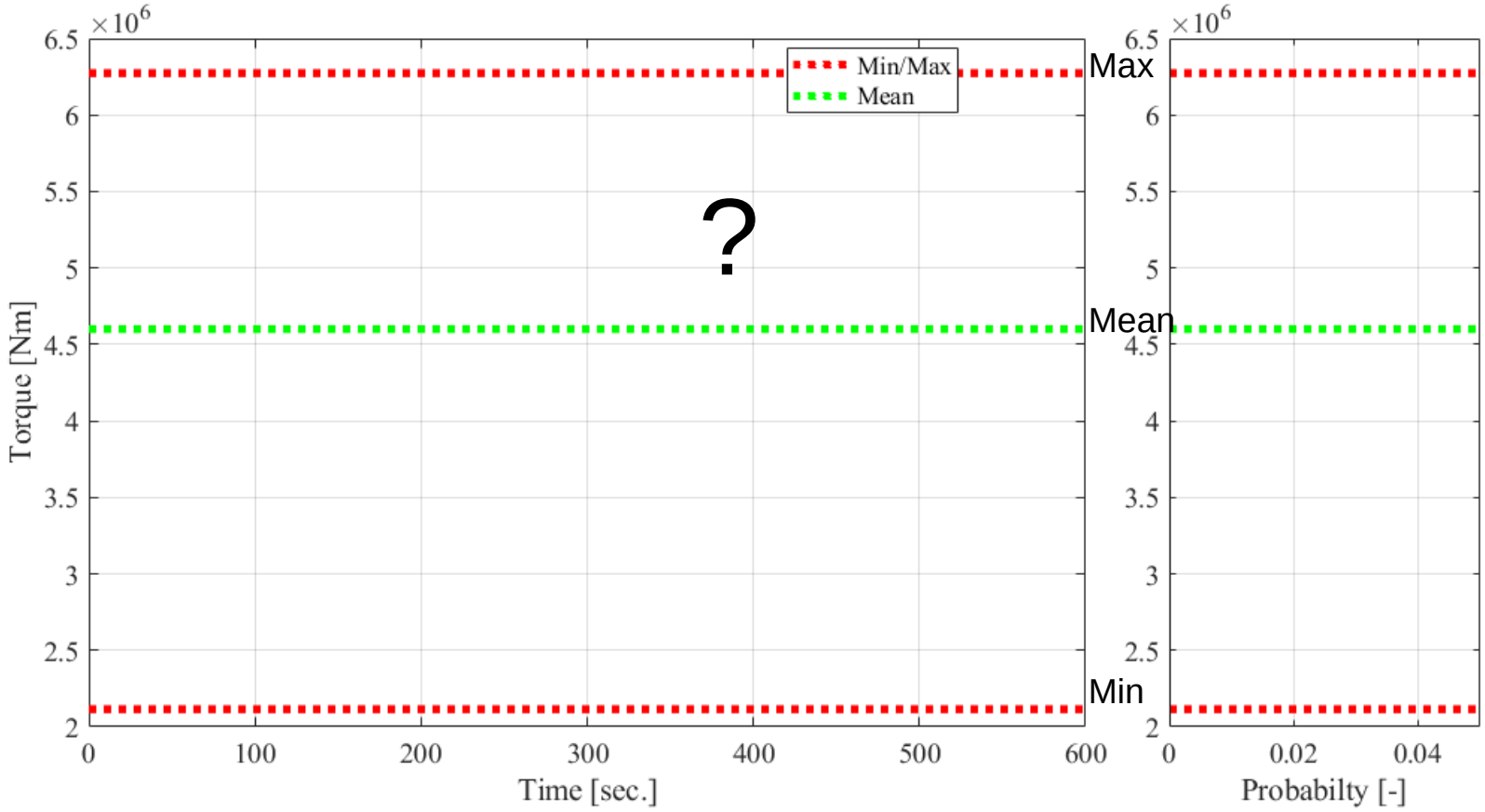
➔ Direct rating of utilization of each wind turbine

➔ Identification of fault behavior and trends



SCADA System setup

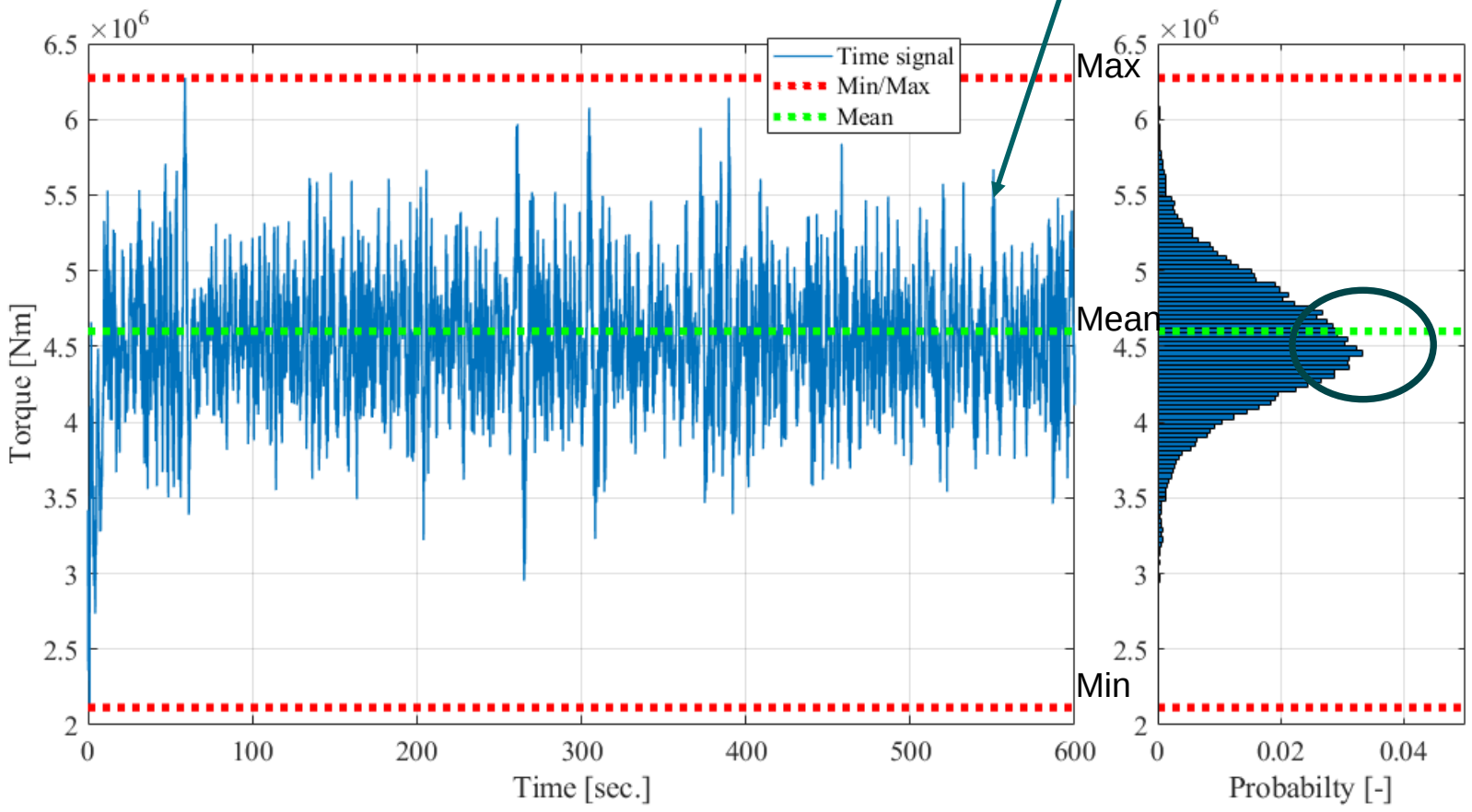
- Drawback: SCADA-System
  - Sampling of 10min (Mean, Min, Max)



SCADA System setup

- Drawback: SCADA-System
  - Sampling of 10min (Mean, Min, Max)

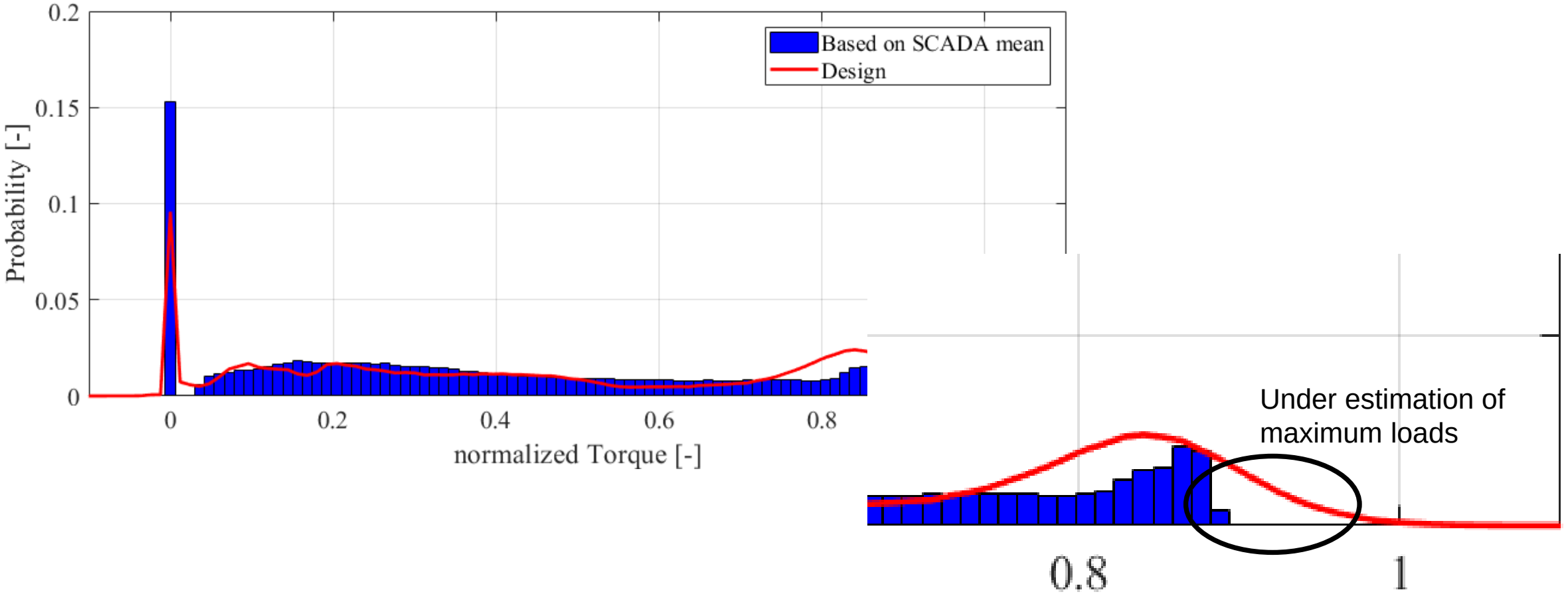
Validated simulation results



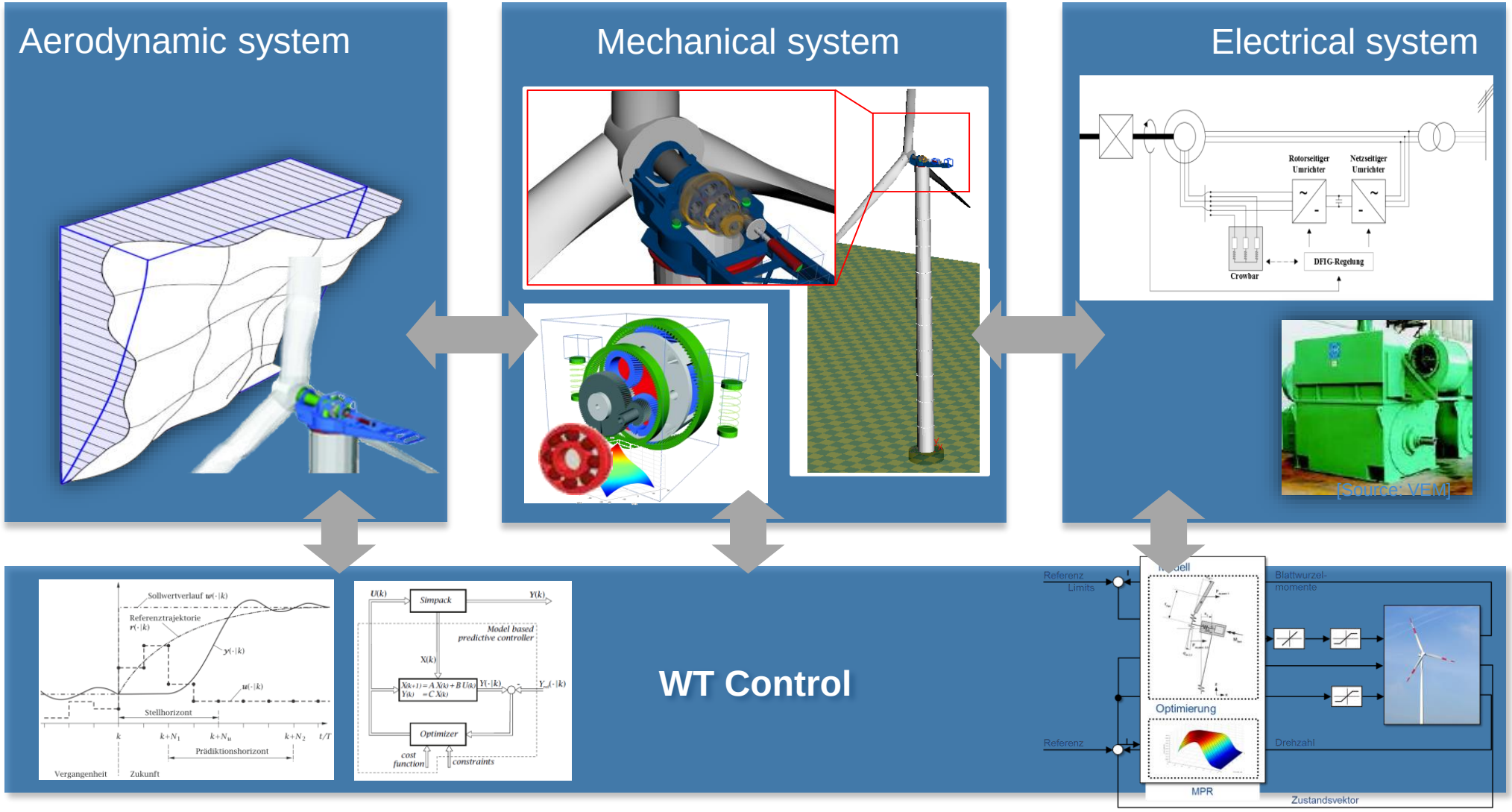
Mean and Maximum of distribution have an offset

Time series of C3X126 @U=18 m/s and 15% turbulence

Load distribution based on SCADA using Mean Signal



Approach of the research project
Multi-body Simulation



Estimation of 1Hz Distribution based on 10min SCADA Data
Björn Roscher, M.Sc.
Dipl.-Ing. A. Werkmeister; Prof. Dr. Ralf Schelenz
14th of November, Bremerhaven

CWD Center for Wind Power Drives | RWTH AACHEN UNIVERSITY

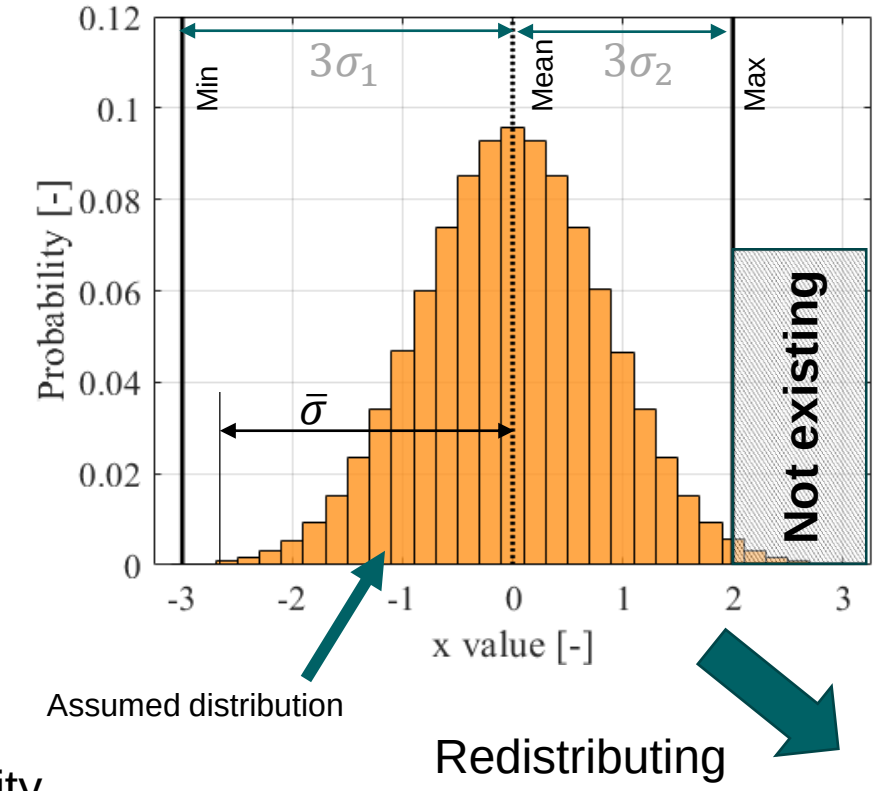
From 10min Scada-data to 1s data
Normal Distribution – Method 1

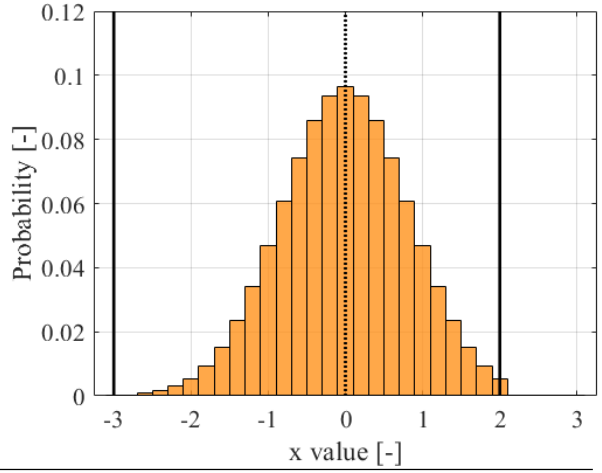
- Input: SCADA 10min values
- Assumed values are normal distributed

$$f(x) = \frac{1}{\bar{\sigma} \cdot \sqrt{2\pi}} \cdot e^{0.5 \cdot \left(\frac{(x - x_{mean})}{\bar{\sigma}}\right)^2}$$

where: $\bar{\sigma} = \frac{\sigma_1 + \sigma_2}{2}$

- x_{mean} the mean value for 10min
- Assuming normal distribution
  - Standard deviation is mean of :
    - Min value at $-3 \cdot \sigma_1$
    - Max value at $3 \cdot \sigma_2$
- Redistributing the out of bounds probability along interval
- Sum of the area equals 1 for each 10min value interval





From 10min Scada-data to 1s data
Normal Distribution – Method 2

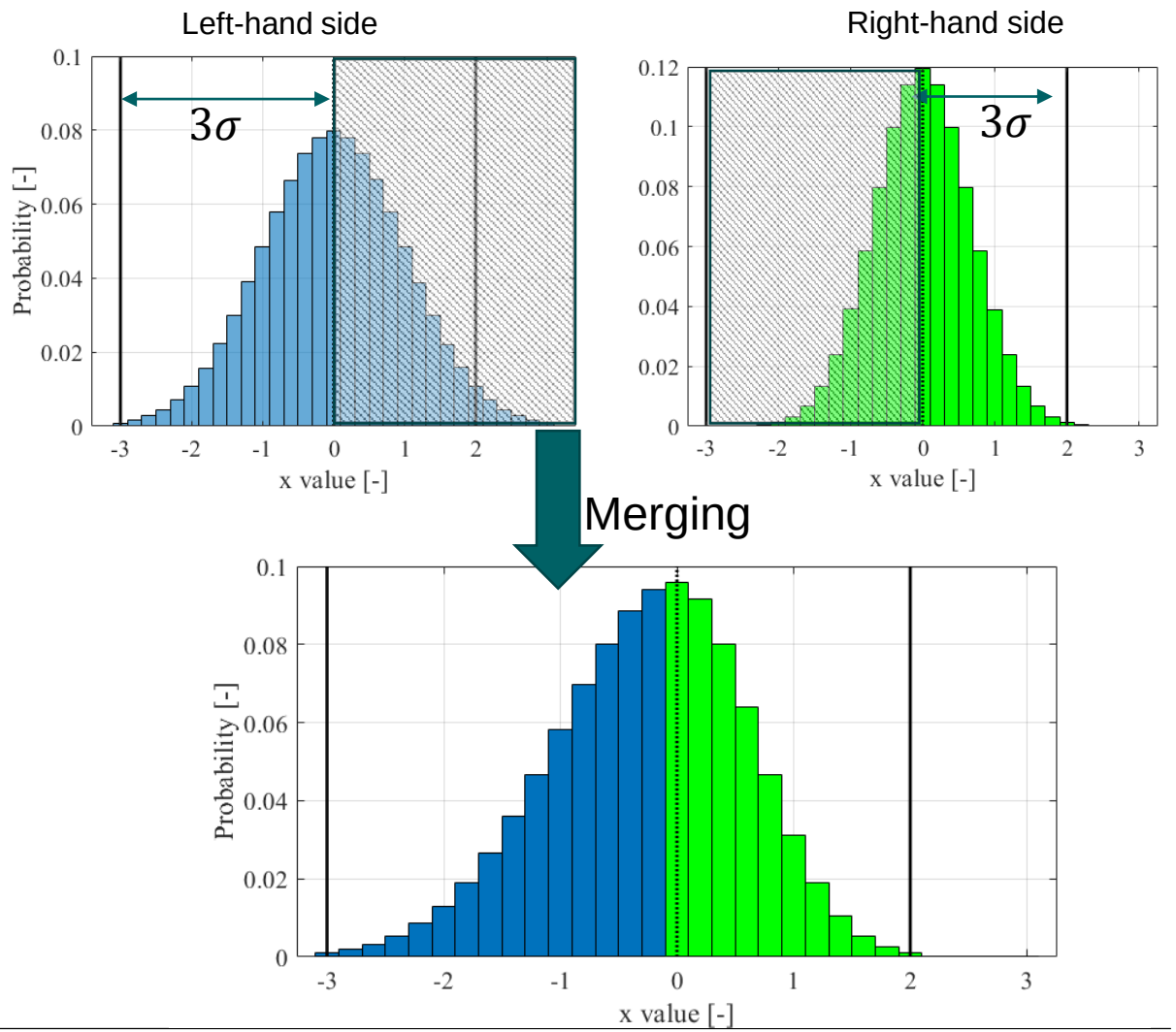
- Using two different normal distributions for left-/right-hand side of mean value

$$f(x) = \frac{1}{\sigma \cdot \sqrt{2\pi}} \cdot e^{0.5 \cdot \left(\frac{(x - x_{mean})}{\sigma}\right)^2}$$

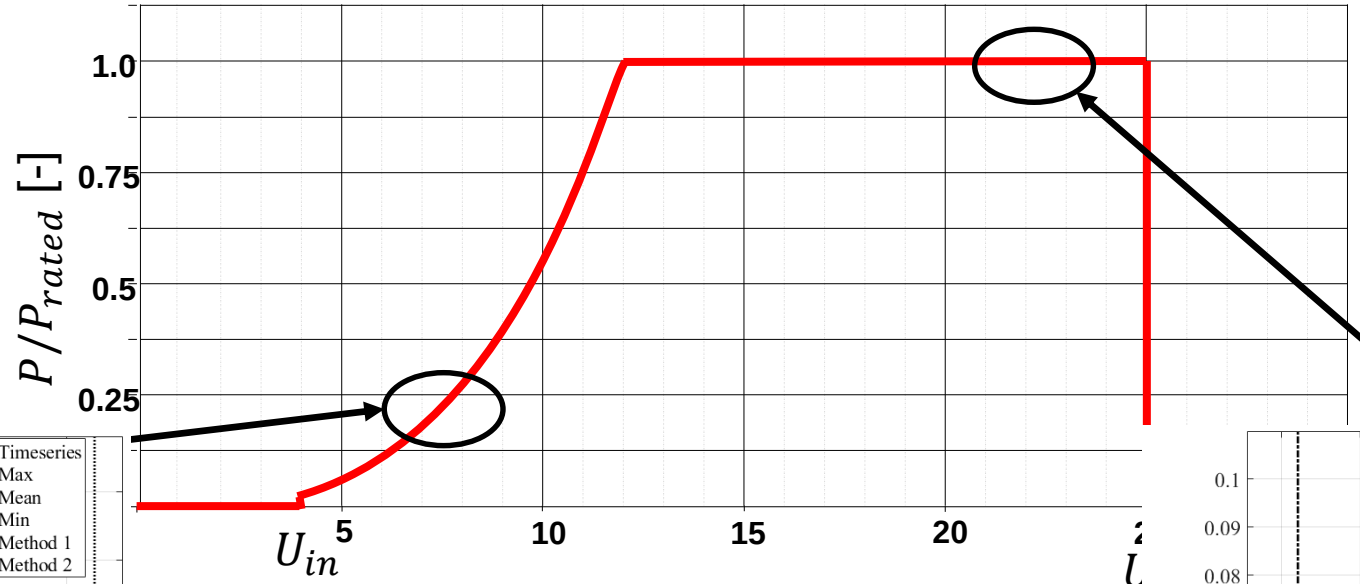
- Assuming max./min. value of 10min SCADA are at 3σ
  → Probability of max./min. value at 0.15%

- Merging distributions at mean

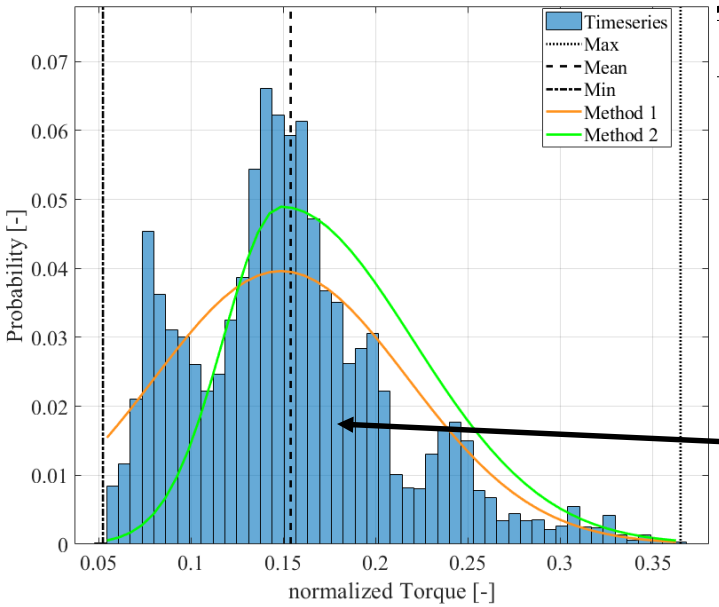
- Sum of the area equals probability of 1 for each 10min value interval



Distributions along Power Curve

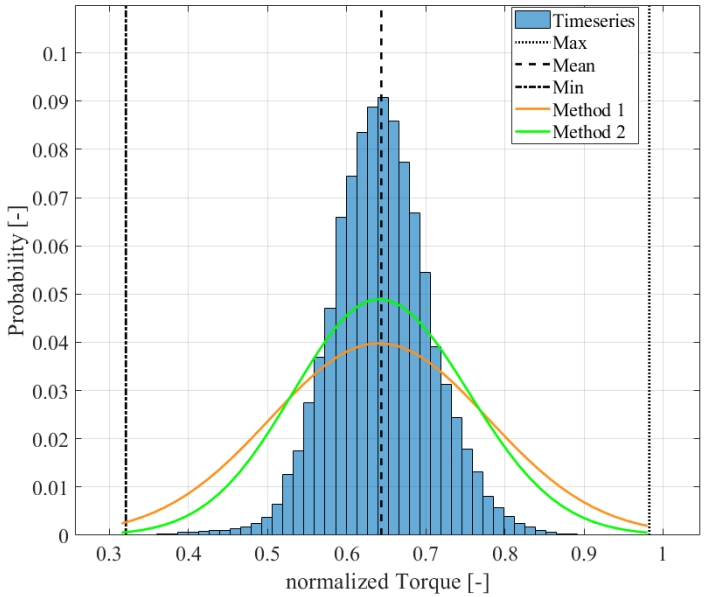


10 min distribution



Bin counting of a load simulation

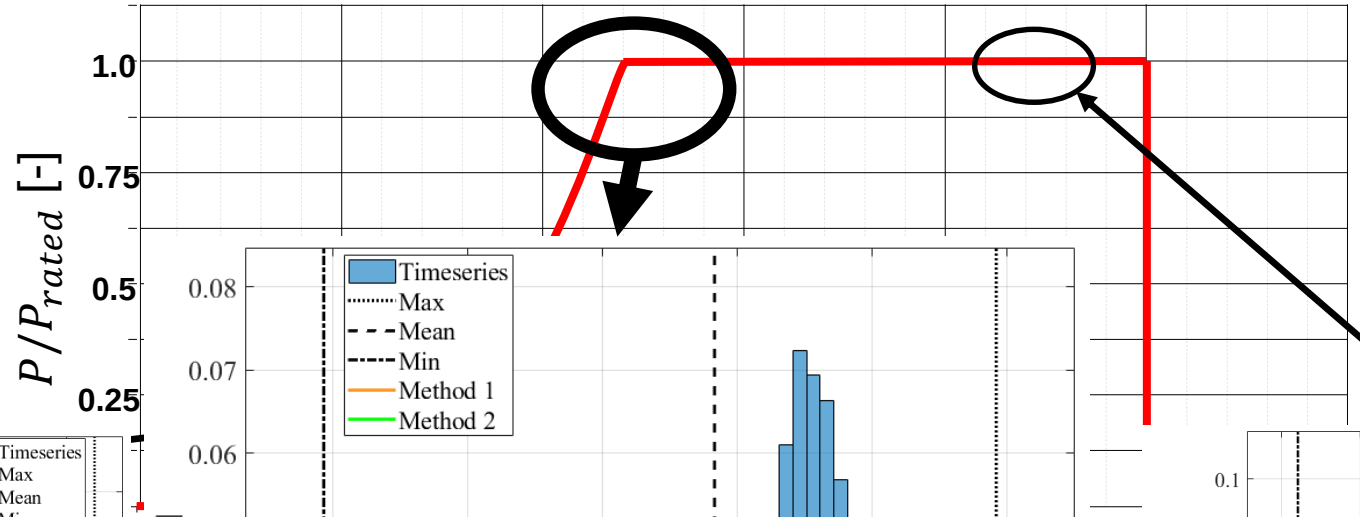
10 min distribution



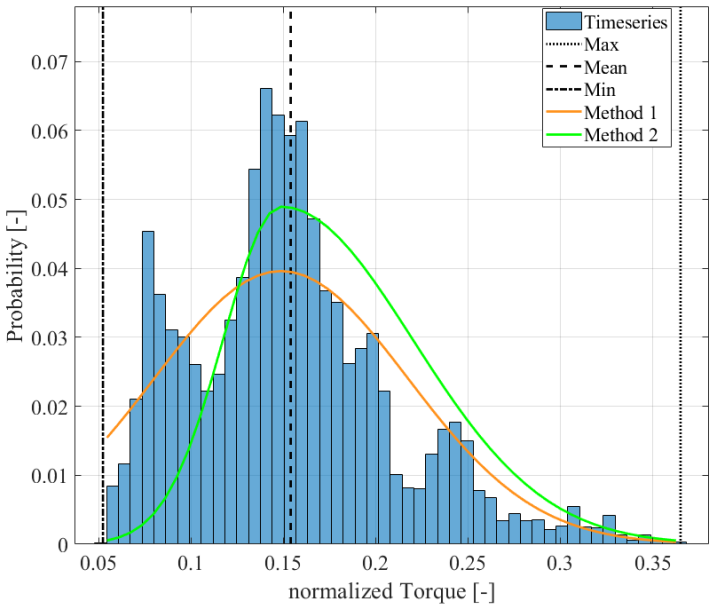
Estimation of 1Hz Distribution based on 10min SCADA Data
Björn Roscher, M.Sc.
Dipl.-Ing. A. Werkmeister; Prof. Dr. Ralf Schelenz
14th of November, Bremerhaven

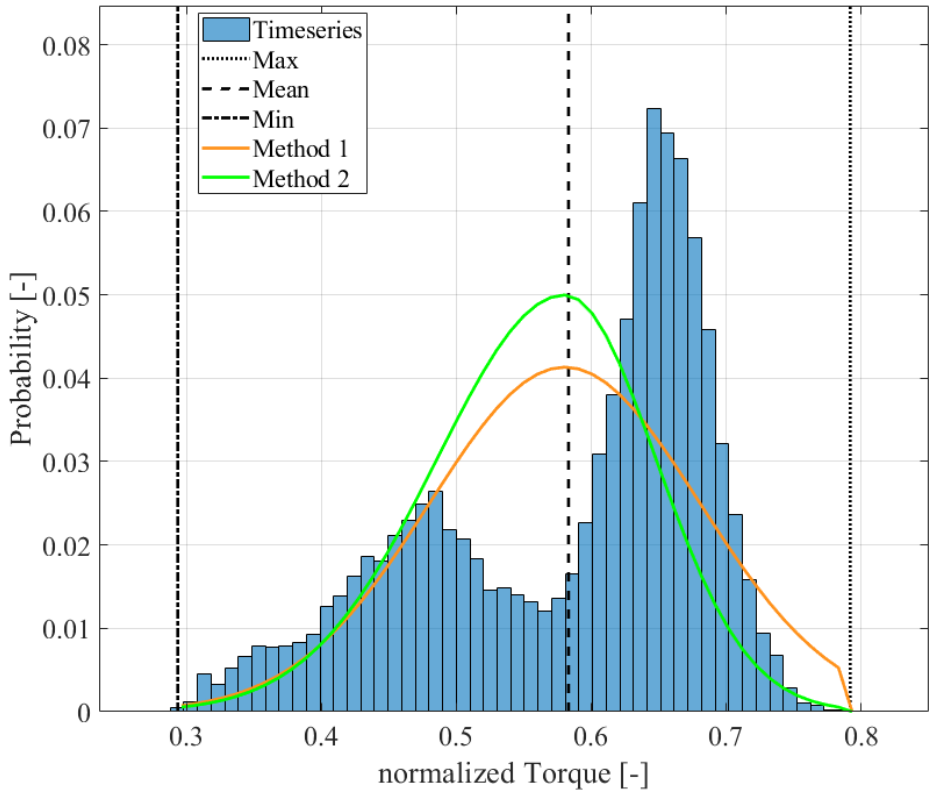
CWD Center for Wind Power Drives | RWTH AACHEN UNIVERSITY

Distributions along Power Curve

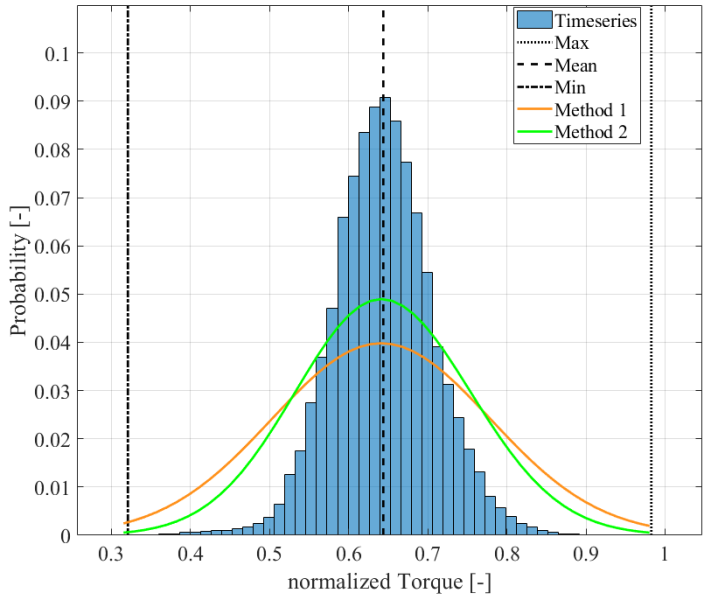


10 min distribution





10 min distribution



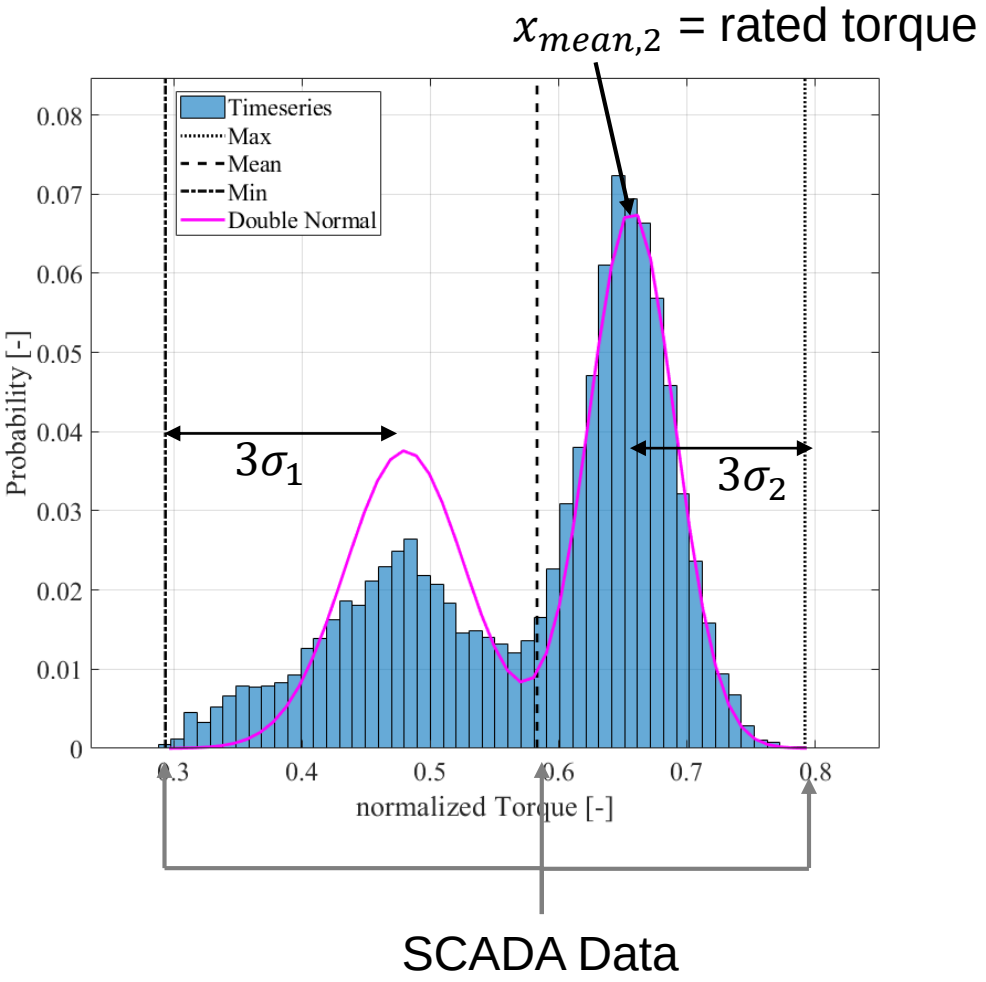
Estimation of 1Hz Distribution based on 10min SCADA Data
Björn Roscher, M.Sc.
Dipl.-Ing. A. Werkmeister; Prof. Dr. Ralf Schelenz
14th of November, Bremerhaven

From 10min Scada-data to 1s data
Double Normal Distribution

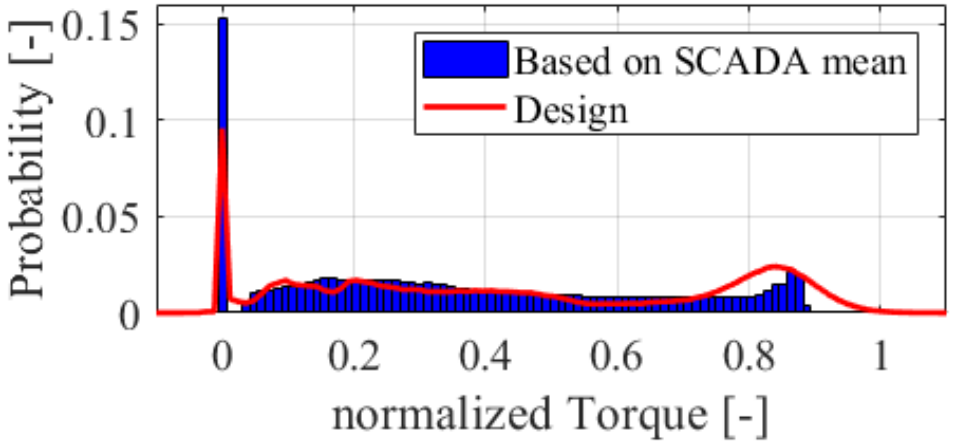
- The values within 10min are normal distributed

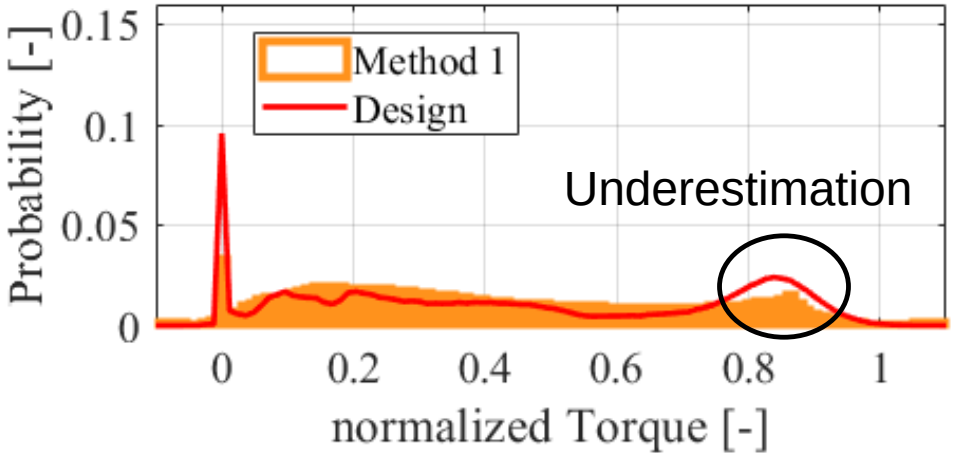
$$f(x) = (w) \cdot \frac{1}{\sigma_1 \cdot \sqrt{2\pi}} \cdot e^{0.5 \cdot \left(\frac{(x - x_{mean,1})}{\sigma_1}\right)^2} + (1 - w) \cdot \frac{1}{\sigma_2 \cdot \sqrt{2\pi}} \cdot e^{0.5 \cdot \left(\frac{(x - x_{mean,2})}{\sigma_2}\right)^2}$$

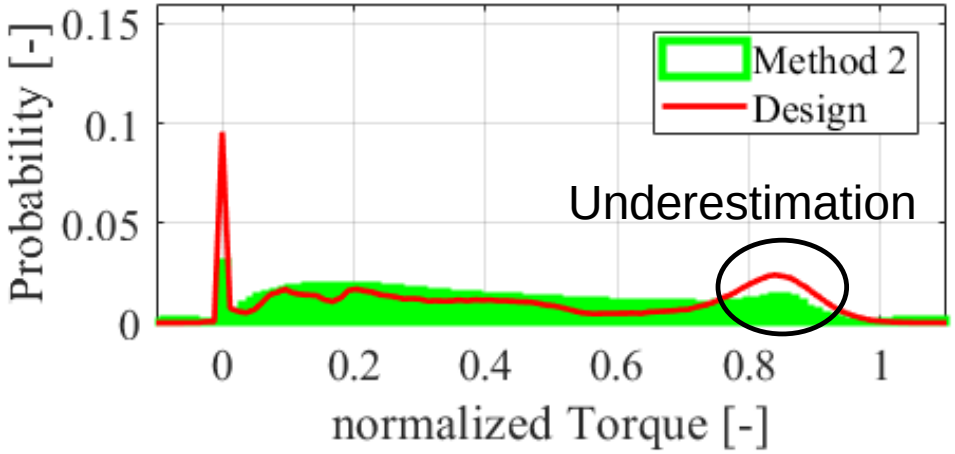
- Using two different distributions for left-/right-hand side of mean value
- Assuming max./min. value of 10min SCADA are at 3σ of each normal distribution
- $x_{mean,2}$ at rated torque
- $x_{mean,1}$ determined iteratively
  - $x_{mean,1} < x_{mean,SCADA}$
  - Overall mean of distribution fits mean of SCADA
- Weighting w determined by SCADA Pitch signals

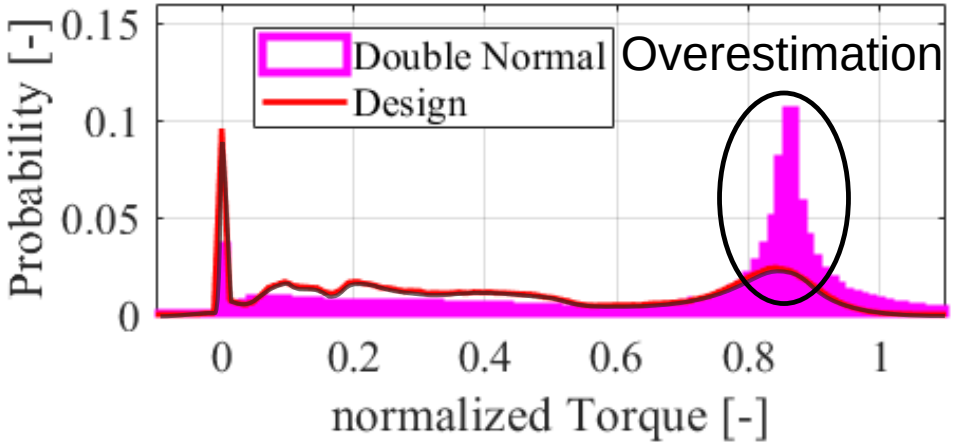


Resulting LDD per Method



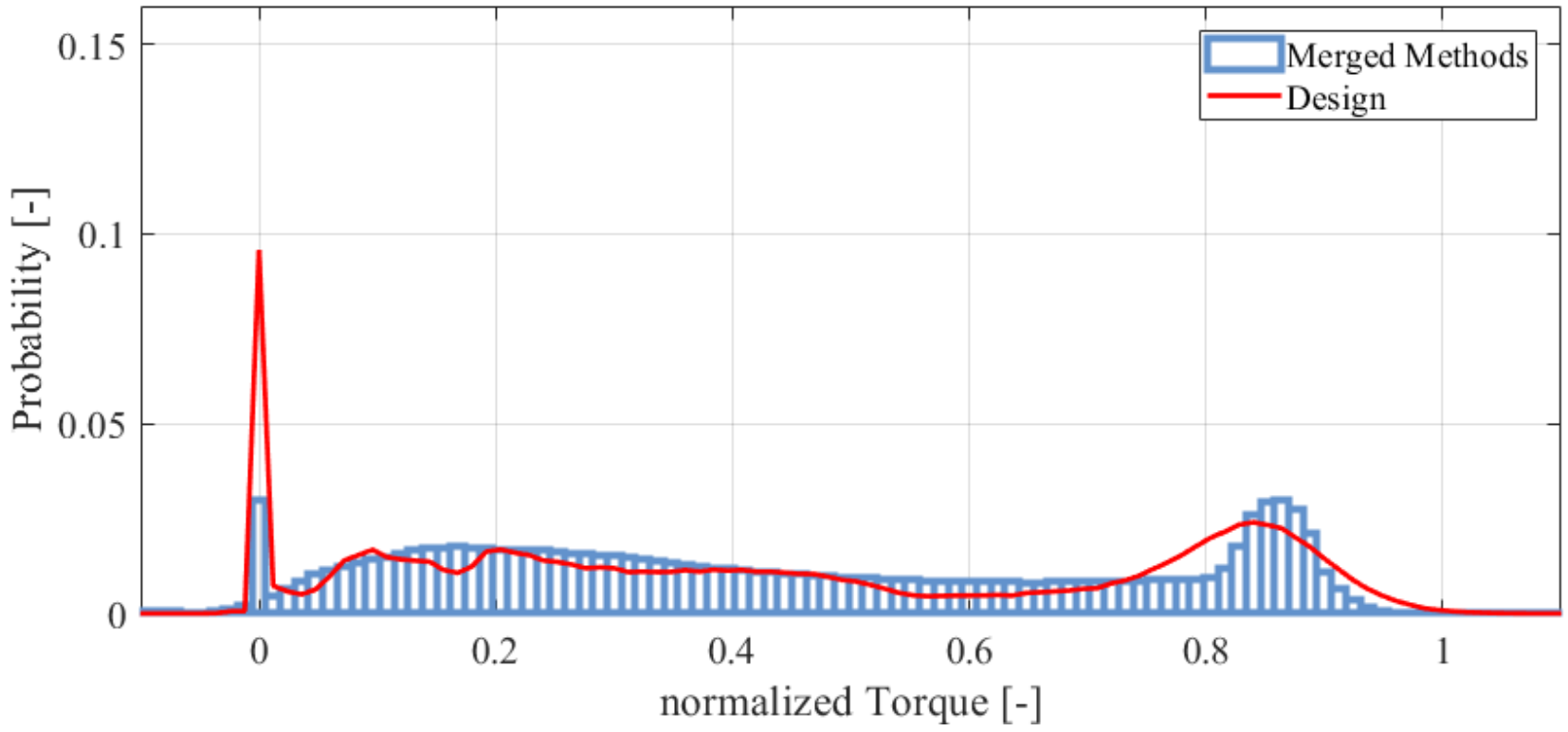






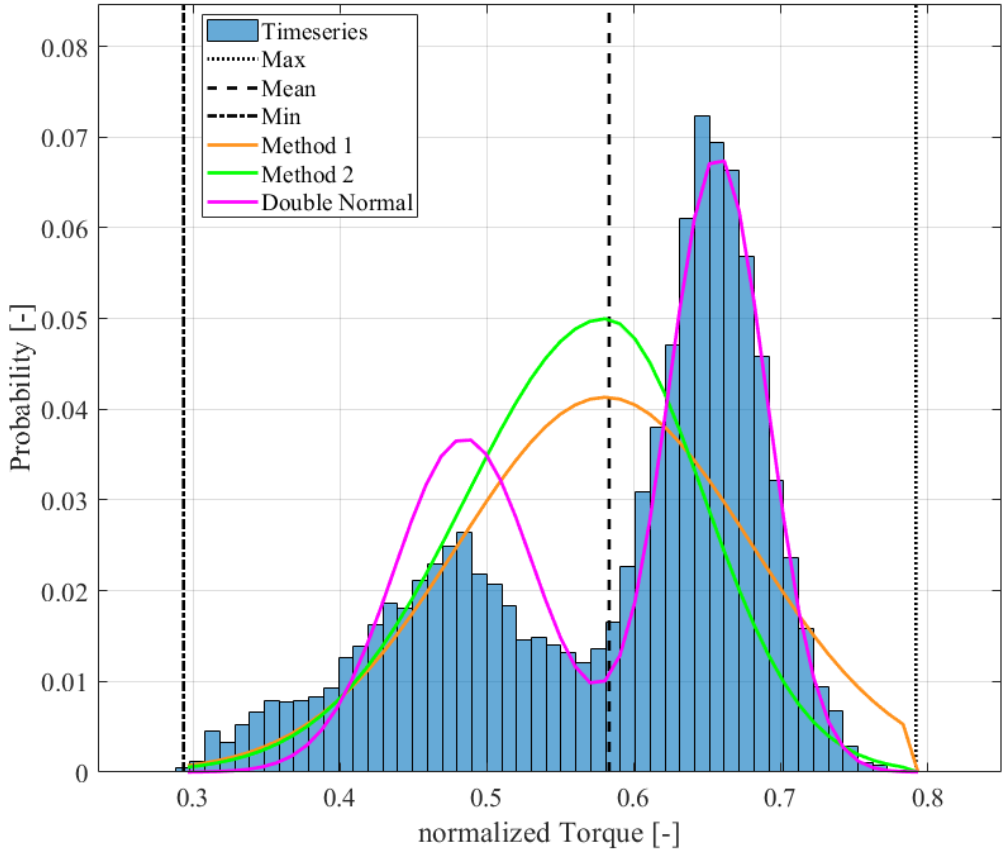
Resulting LDD
Combination of Methods

- Combination of Methods along power curve
  - Below rated: Method 1
  - Above rated: Method 2
  - At rated: Double Normal Distribution



Conclusion

- 10 min SCADA data can be used to estimate a 1Hz distribution
- Above rated condition distribution similar to tilted normal distribution
- Below rated condition distribution widely spread
- At rated a double normal distribution required
- Combination of Methods based on operational status leads to results similar to design loads



Thank you for your attention.