On the impact of non-Gaussian wind statistics on wind turbines - an experimental approach

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Motivation



source: youtube.com





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- wind turbines are subjected to **atmospheric turbulence**!
- potential impact on...
 - ...power output: grid fluctuations
 - ...torque: drive train failure
 - ...loads: lifetime

[Carrasco et al., 2006; Sørensen et al., 2007]

[Musial et al., 2007; Feng et al., 2013]

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Numerics

- turbulence models
- computational costs

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• validation?



























Describing turbulence

• industry standard for wind field description:

10 min mean values, turbulence intensity

 $TI = \sigma_u / \langle u \rangle$





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velocity increment
$$u_{\tau} := u(t + \tau) - u(t)$$







velocity increment
$$u_{ au} := u(t + \tau) - u(t)$$

time series of increments









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IEC 61400-1-ED3, 2005 wind turbines, design requirements

turbulence: Mann model (1998) / Kaimal model (1972)



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offshore wind data

• non-Gaussian, intermittent increments

underestimation of extreme events

[[]Wächter et al. 2012]

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IEC 61400-1-ED3, 2005 wind turbines, design requirements

turbulence: Mann model (1998) / Kaimal model (1972)





Field data vs model

Time series	$\langle u \rangle [{\rm ms^{-1}}]$	$\sigma_u [\mathrm{ms^{-1}}]$	TI [%]
Kaimal	7.51	0.54	7.21
FINO1	7.50	0.54	7.18

• datasets nearly equal acc. to mean + TI





Field data vs model

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Impact on wind turbines?



[Schottler et al., 2017]



















- 16 axes w/ stepper motors
- individually tunable
- defined, turbulent flows
- reproducible:
 - time series
 - statistics







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Setup



- model wind turbine
- D=58cm
- active load control
- hot wire measurements upstream of rotor
- TSR = 7
- turbine data:
 - thrust (load cell)
 - torque (generator current)
 - power (electric)



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Main idea

Inflow A)

Inflow B)

























Does the turbine ,see' the difference?









[Schottler et al. 2017]







[Schottler et al. 2017]







Time series	$\langle u(t) \rangle [{\rm ms^{-1}}]$	$\sigma_u [{ m ms}^{-1}]$	TI [%]
А	6.92	0.39	5.59
В	6.96	0.38	5.50

[Schottler et al. 2017]













 effect of properties beyond mean + TI (intermittency) isolated









67ms

80ms (~rotor diameter)

2s







15



67ms

80ms (~rotor diameter)

2s















Turbine reaction - all quantities







Turbine reaction - all quantities



Intermittent characteristics remain present in turbine data !





One second data, multi MW nearshore turbine

[P. Milan]

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Impact on wind turbine

One second data, multi MW nearshore turbine



[P. Milan]





Impact on wind turbine

One second data, multi MW nearshore turbine



[P. Milan]





Thank you for your attention!



Funded by the Reiner Lemoine Stiftung

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Further information:

Wind Energ. Sci., 2, 1–13, 2017 www.wind-energ-sci.net/2/1/2017/ doi:10.5194/wes-2-1-2017 © Author(s) 2017. CC Attribution 3.0 License.



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Load Control

P [W]	cp [%]
w [Hz]	
n [m/s]	
TSR [-]	





Load Control





