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Uncertainty of spinner anemometer wind speed measurements

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Abstract

Wind turbine **power performance** is a crucial measurement task in wind energy: it provides the means for **performance monitoring** and the basis of **energy production guarantees**. On modern, offshore turbines, turbine mounted wind sensors are rapidly replacing the traditional (and expensive) instrumented meteorological masts for this task.

The "**spinner anemometer**" is a wind measurement instrument integrated in the spinner of a wind turbine. It measures wind inflow angles and horizontal wind speed in the rotor centre. The standard IEC61400-12-2 [1] provides a method to obtain a nacelle transfer function that is applied to the wind speed measurement on the spinner, resulting in free wind speed measurements. However, a procedure for **uncertainty assessment** of a spinner anemometer measurement is not included in the standard.

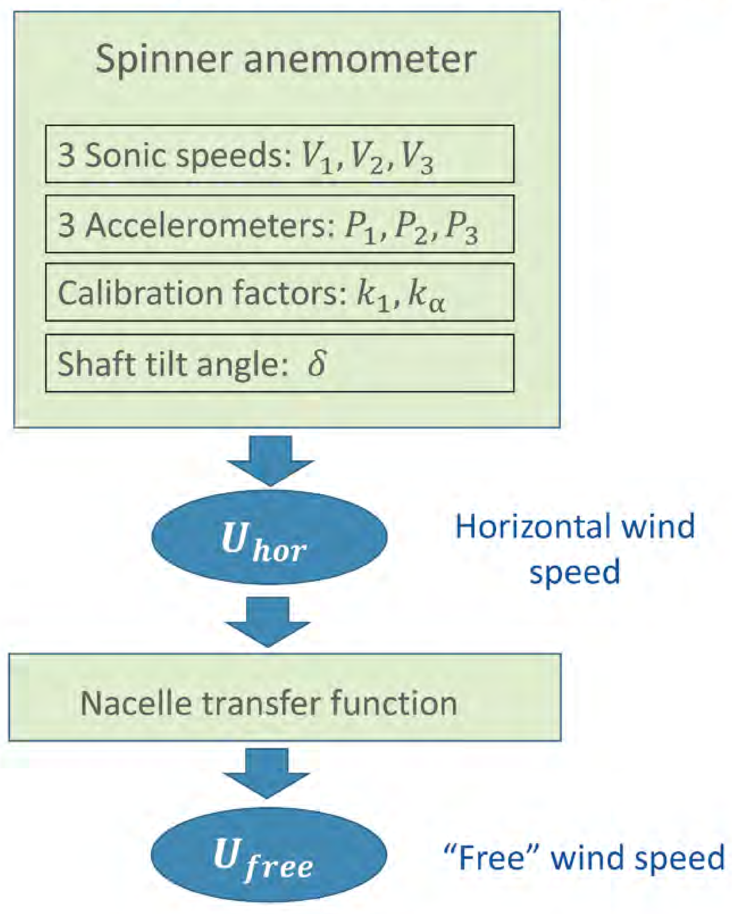
In this work, we investigated the spinner anemometer uncertainty sources, and we developed an uncertainty propagation model to translate those uncertainties into wind speed uncertainties; including an example of an uncertainty assessment using this method.

Objectives

The **Performance Transparency Project (PTP)**, funded by EUDP (project partners ROMO Wind and DTU Wind Energy), aims at demonstrating the robustness of spinner anemometer measurements and providing long-term measurements to evaluate and improve this uncertainty assessment [2].

Method

A) How the spinner anemometer works



B) U_{hor} uncertainty sources

Uncertainty component	Value	Influence on	Symbol
1. Calibrations			u_{U1i}
• Wind tunnel calibration	0.048m/s	V_1	u_{U11i}
	0.097m/s	V_2	u_{U12i}
	0.165m/s	V_3	u_{U13i}
• Angular calibration, k_α	$0.1k_\alpha$	V_{hor}	u_{U41i}
• Angular calibration, k_1	0	V_{hor}	u_{U42i}
2. Operational characteristics			u_{U2i}
• Inflow angle to rotor	-3° to 3°	V_{hor}	
• Turbulence	0.24 to 0.15	V_{hor}	
• Yaw misalignment	-5° to 5°	V_{hor}	
• Accelerometer vibrations	A: 0.35m/s, f: 6Hz	φ (*)	
• Shaft tilt angle	6° to 7°	φ (*) *(rotor azimuth position)	
3. Sonic sensor mounting			u_{U3i}
• Longitudinal position	28mm	V_1, V_2, V_3	u_{U31i}
• Directional uncertainty	2°	V_1, V_2, V_3	u_{U32i}
• Sonic path angle	1°	V_1, V_2, V_3	u_{U33i}
• Sonic azimuth position	10mm	V_1, V_2, V_3; P_1, P_2, P_3	u_{U34i}
• Accelerometer alignment	5°	P_1, P_2, P_3	u_{U35i}
4. Other			u_{Udi}
• Data acquisition system	0.0058m/s	V_{hor}	

C) Obtaining $u(U_{hor})$

- Generate artificial wind files
- Simulate different operation conditions
- Model spinner anemoter operation
- Error propagation for each individual uncertainty component
- Combine output uncertainties

Results

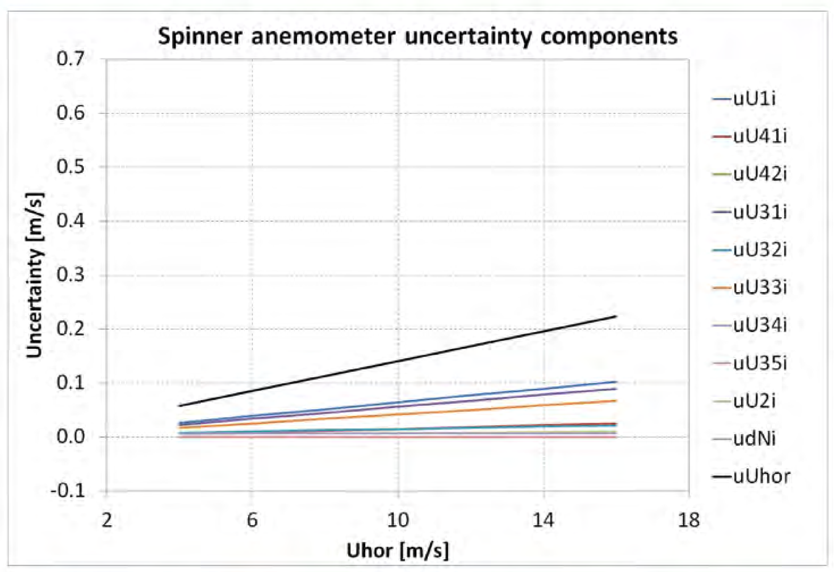


Figure 1. Contributions from different uncertainty sources, and combined horizontal wind speed uncertainty, $u(U_{hor})$

Source: report DTU Wind Energy E-0166 [3]

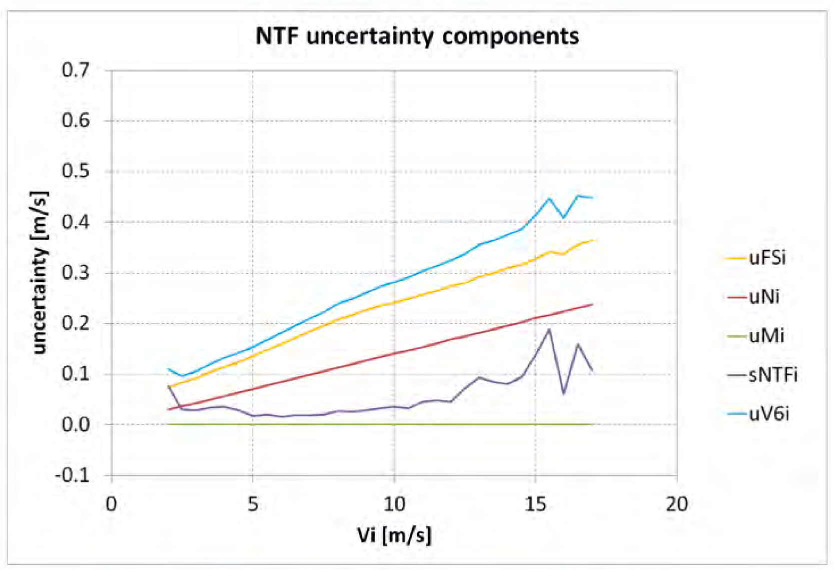


Figure 2. NTF uncertainty components and combined NTF uncertainty ($u_{V6,i}$), as a function of the free wind speed (V_i); [1]

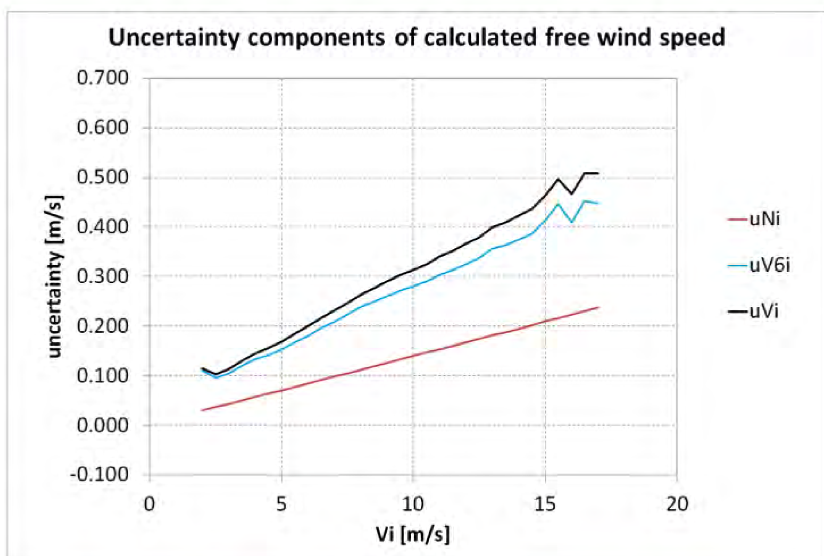


Figure 3. Horizontal wind speed uncertainty ($u_{N,i}$), NTF uncertainty ($u_{V6,i}$), and resulting free wind speed uncertainty ($u_{V,i}$), as a function of the free wind speed (V_i); [1]

	Measured AEP, AEP_{meas}	Standard uncertainty in AEP, $u(AEP_{meas})$
Cup anemometer, mast-mounted	100.0%	4.4%· $AEP_{meas,cup}$
Spinner anemometer	99.9%	5.6%· $AEP_{meas,spin.anem.}$

Estimated Annual Energy Production (AEP) for an average hub height annual wind speed of 8m/s. The reference air density is 1.225kg/m³

Conclusions

This method provides the basis to complement the IEC61400-12-2 with an uncertainty assessment for spinner anemometer wind speed measurements. This uncertainty assessment method will be further evaluated and improved under the scope of PTP.

References

1. *IEC 61400-12-2 Ed. 1, 2013*
2. *www.ispin-ptp.com*
3. *Spinner Anemometer – uncertainty analysis. DTU Wind Energy E-0166. April 2018.*

Acknowledgements

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