Power curves
- use of spinner anemometry

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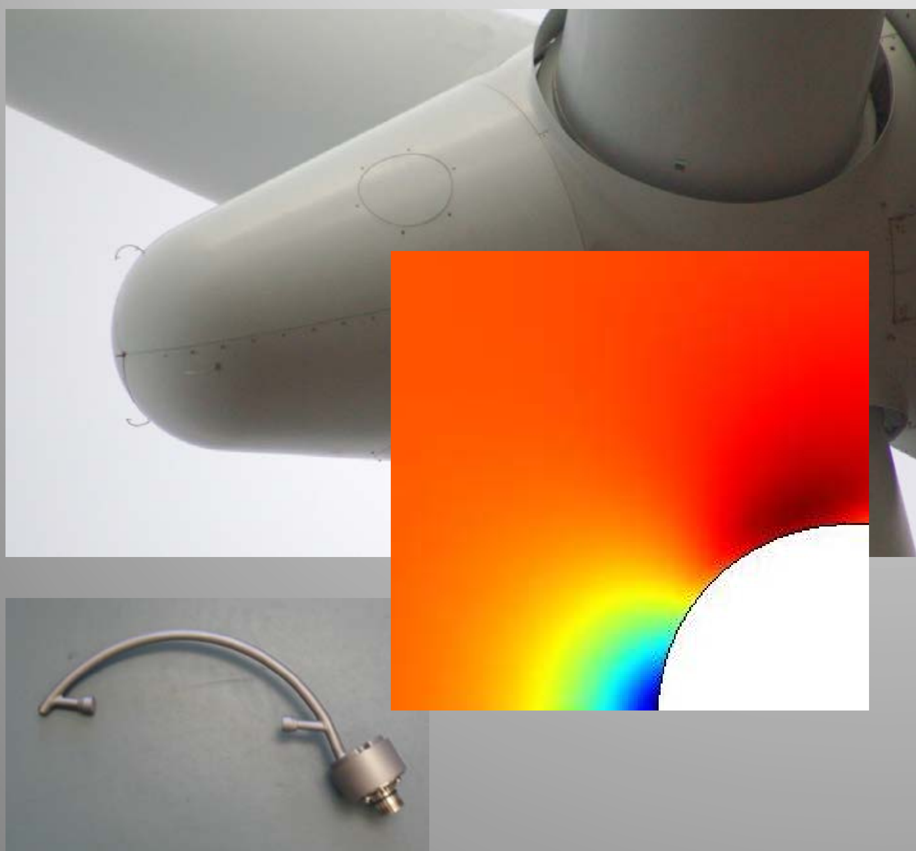
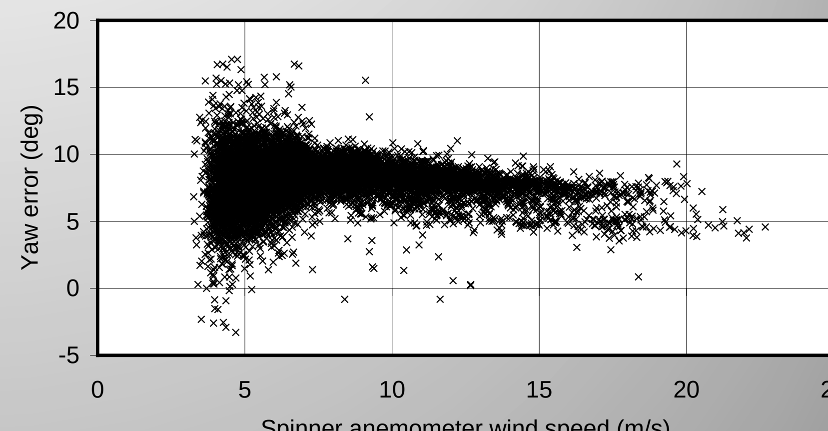
Spinner anemometry

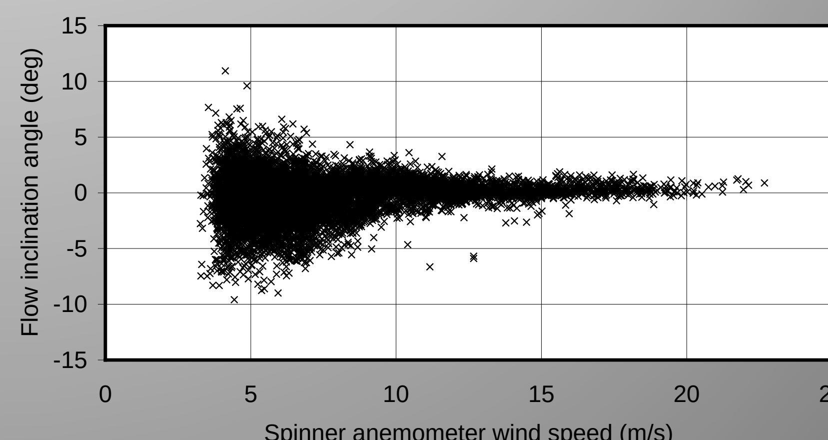
Spinner anemometry – using the airflow over the spinner to measure wind speed, yaw misalignment and flow inclination angle



Yaw error versus wind speed (all sonic sensors)



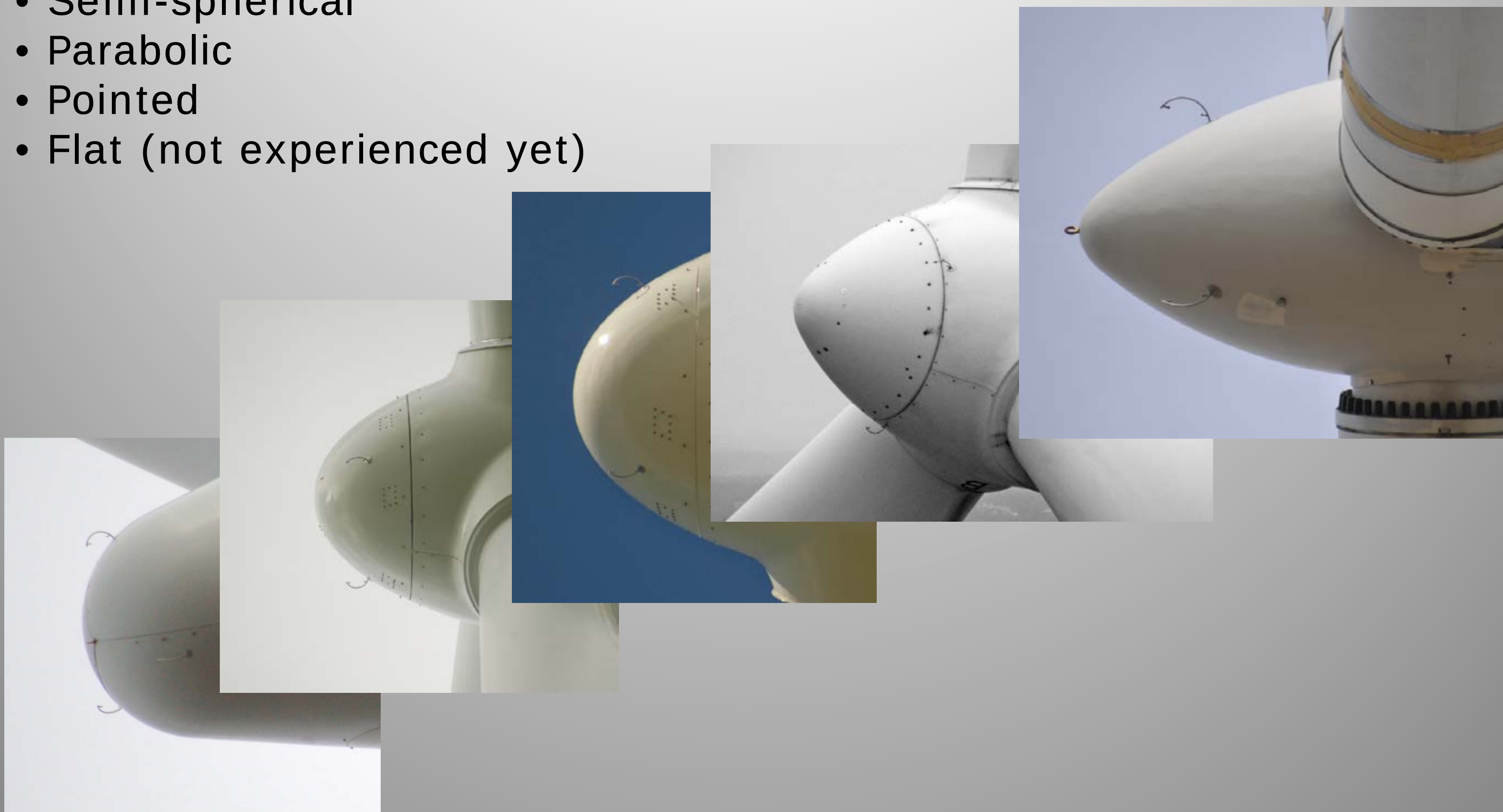
Flow inclination angle versus wind speed (all sonic sensors)



Spinner anemometry

Spinner anemometry can be used on all types of spinners

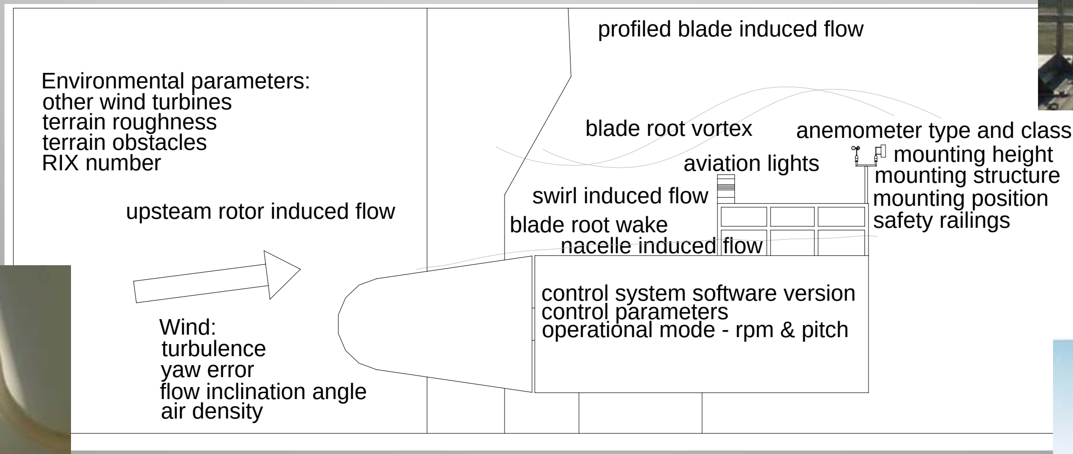
- Semi-spherical
- Parabolic
- Pointed
- Flat (not experienced yet)



Spinner anemometry

Why use of spinner anemometry?

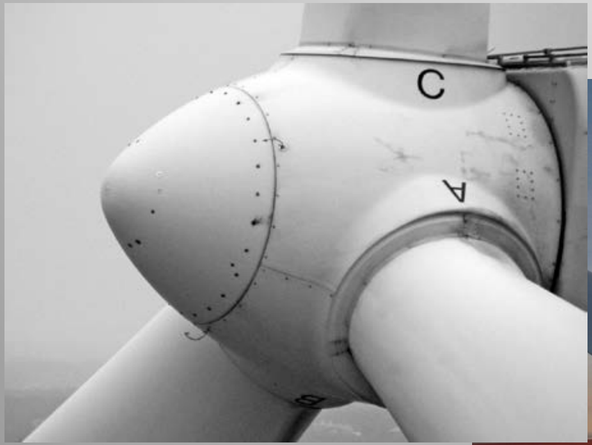
- A spinner anemometer has the advantage of measurements being performed in front of the rotor without flow distortions disturbing the sensor
- Due to rotation a spinner anemometer measure flow angles without mounting and adjustment errors

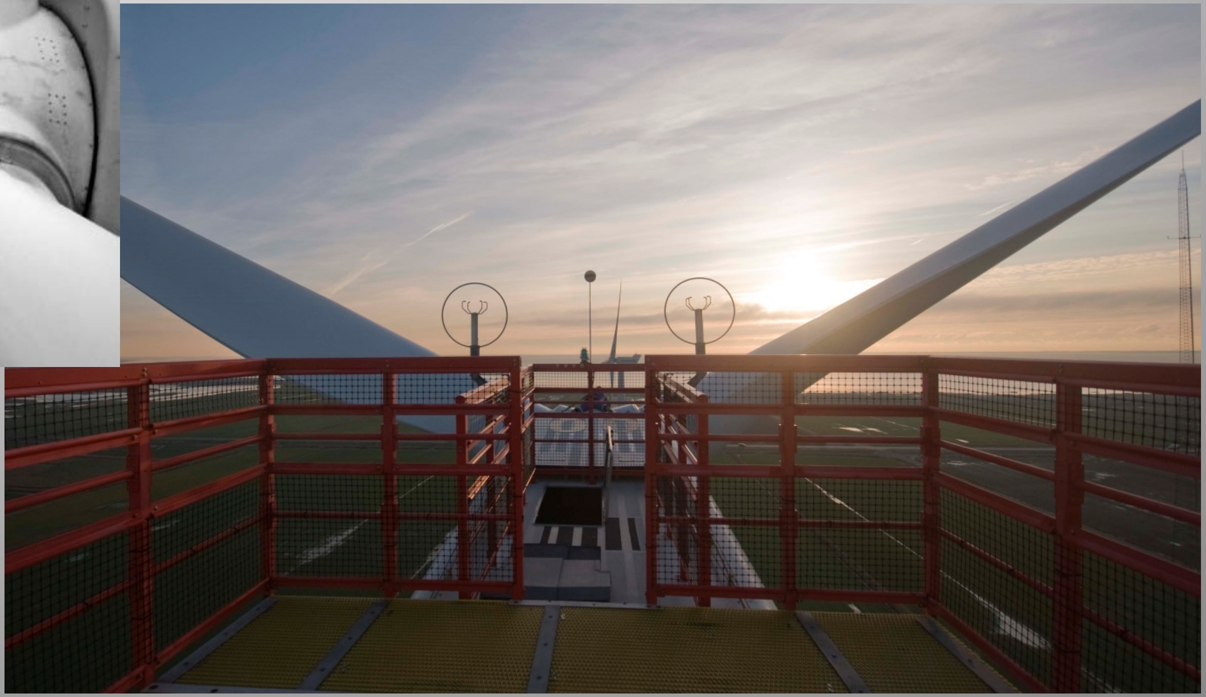


Spinner anemometry

Measurements on Vestas V80 2MW (Horns Rev I type)

- Tjæreborg site
- Met mast at distance 1.5D
- Cup and vane at hub height 60m

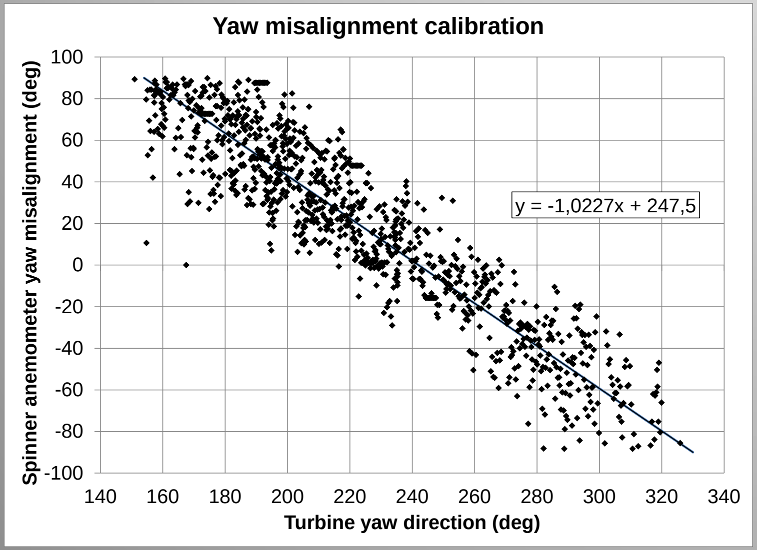


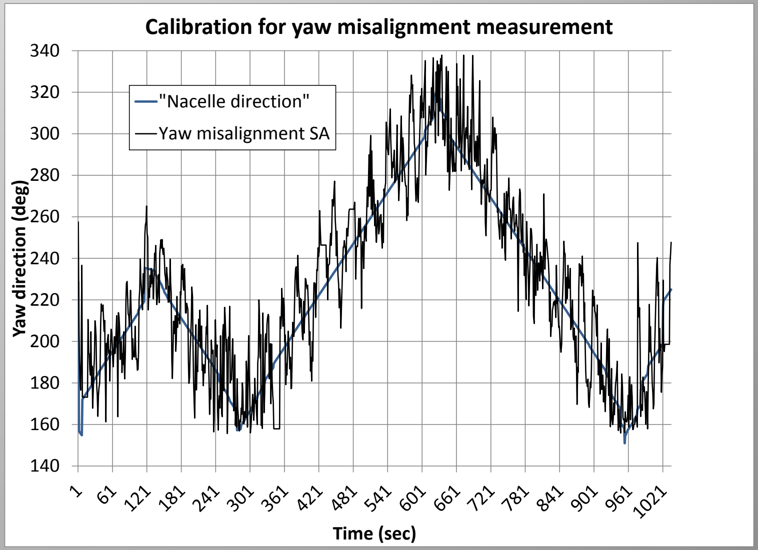


Spinner anemometry

Calibration of two spinner anemometer constants k_1 and k_2

Calibration for angular measurements $k_\alpha = k_2/k_1$



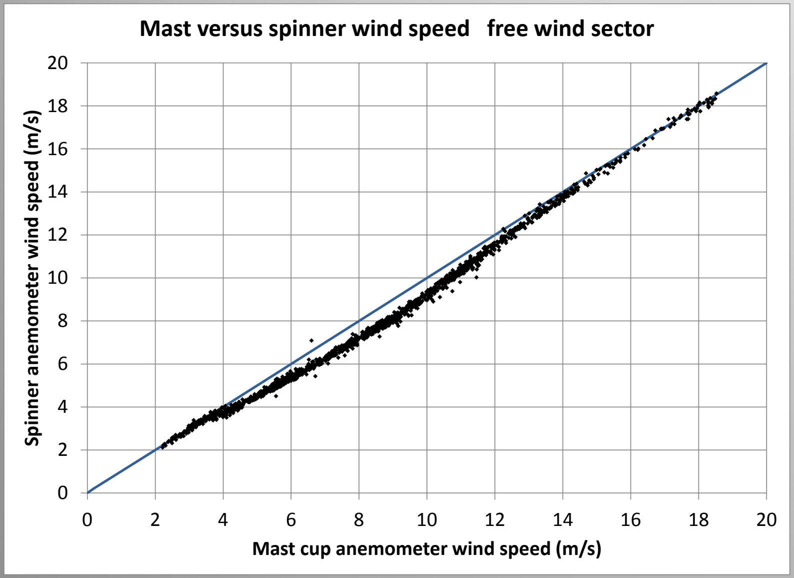


Spinner anemometry

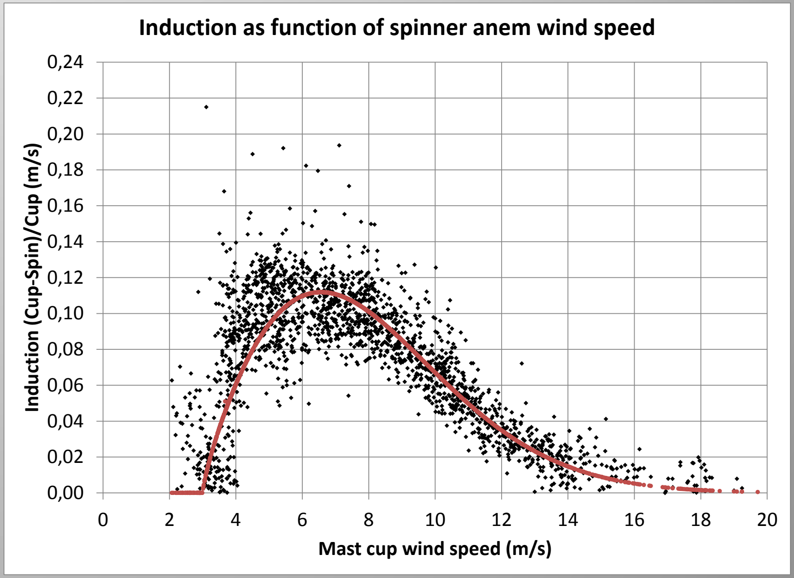
Calibration of k_1 constant and extraction of induction function

Determination of Nacelle Transfer Function (NTF – IEC61400-12-2)

Induction: $a = (U_{cup} - U_{spin}) / U_{cup}$



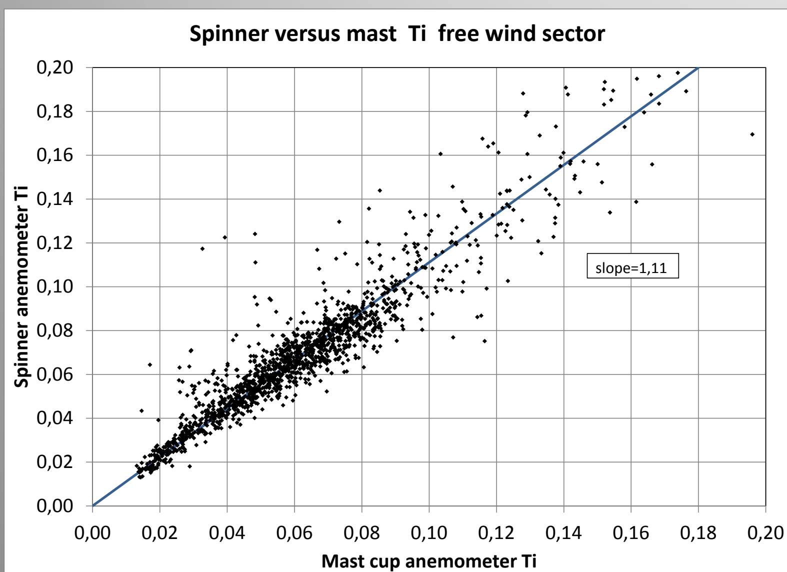
Extracting induction function



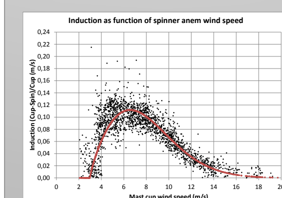
Spinner anemometry

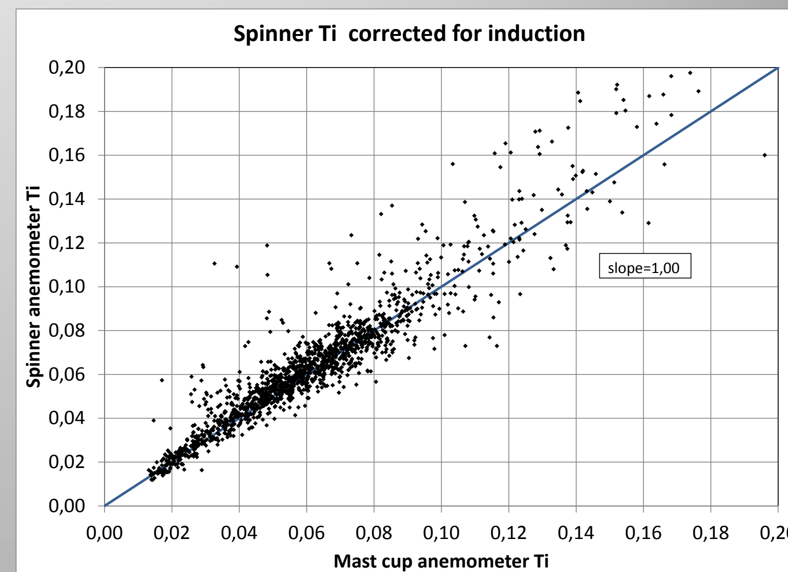
Wind speed standard deviation of spinner anemometer is equal to that of the mast cup anemometer

Turbulence is measured correctly by the spinner anemometer when the wind speed is corrected for the induction



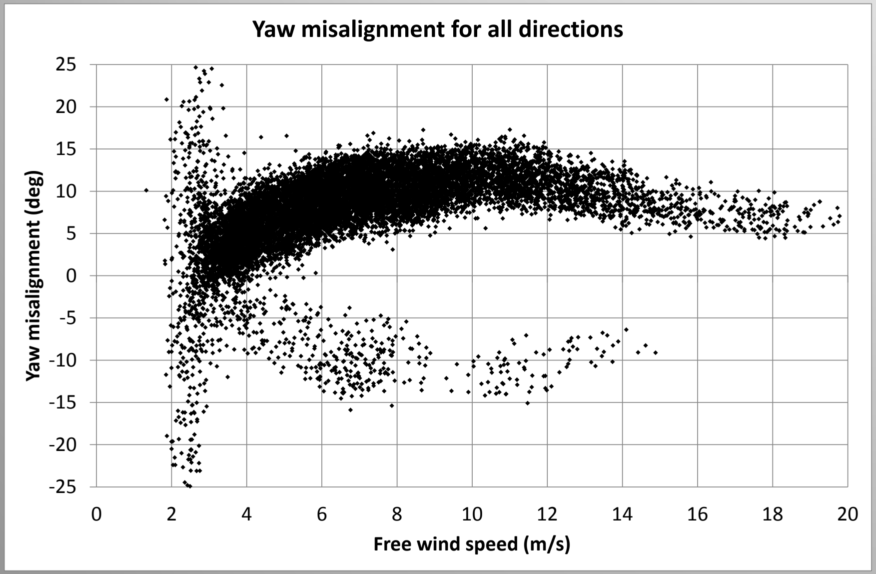
Correction for induction

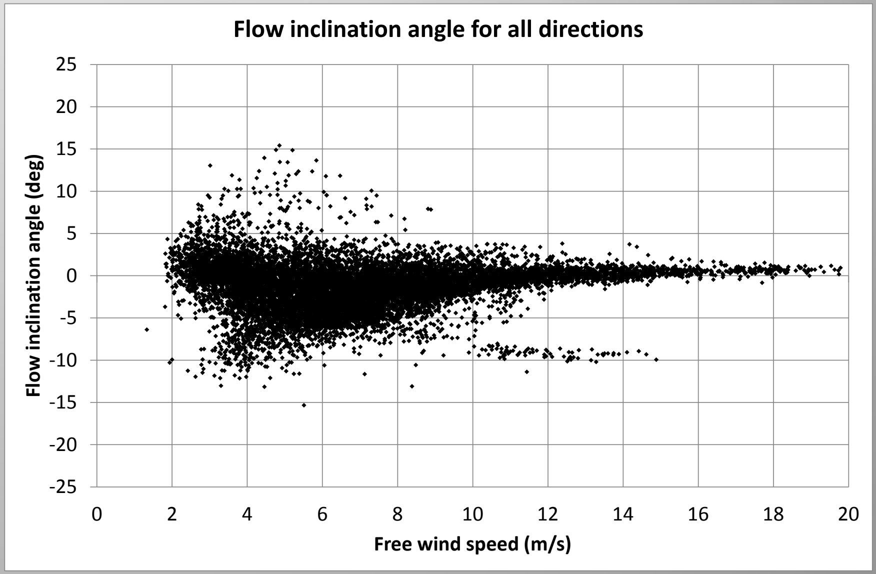




Spinner anemometry

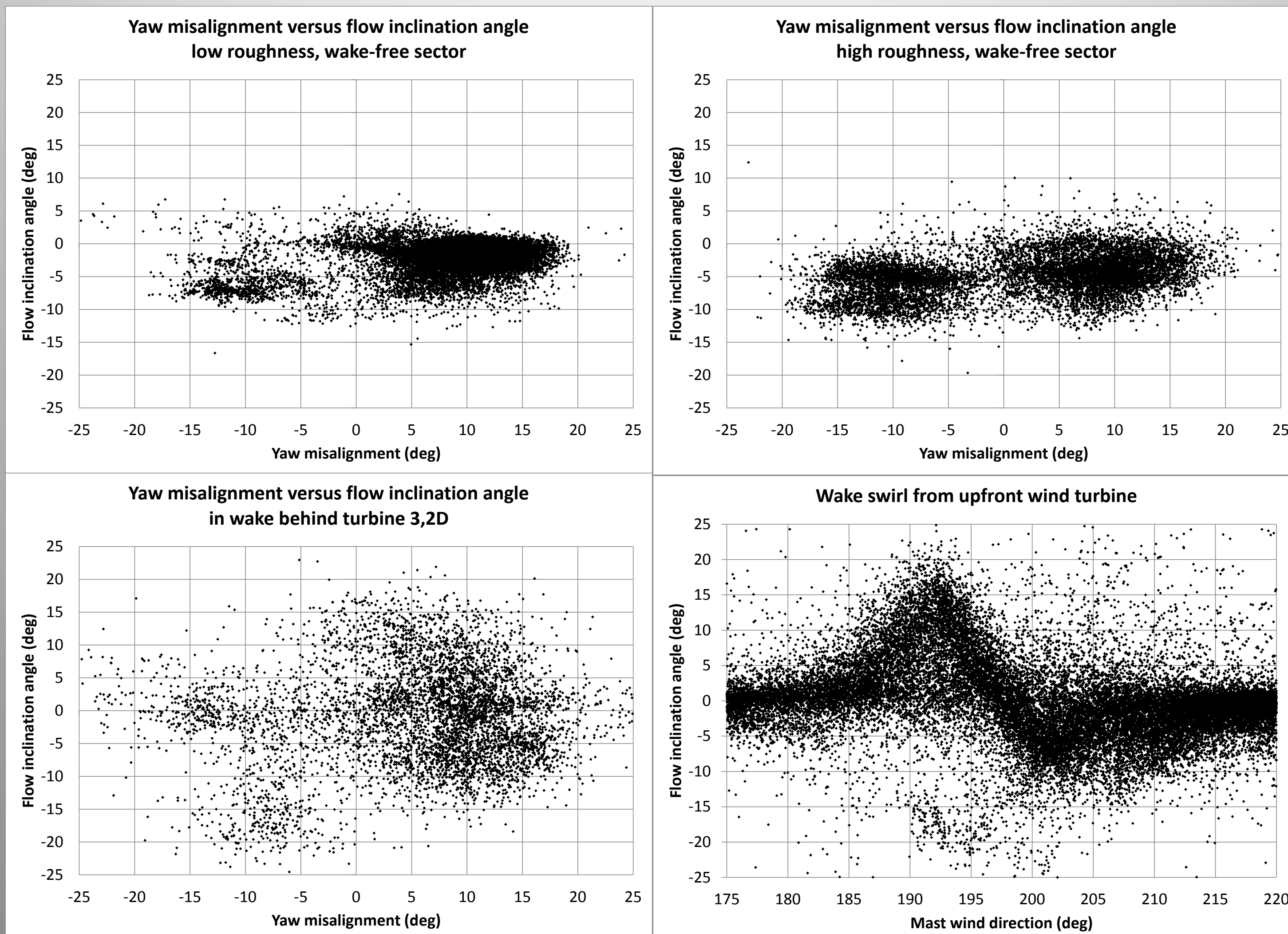
Measurement of yaw misalignment and flow inclination angle





Spinner anemometry

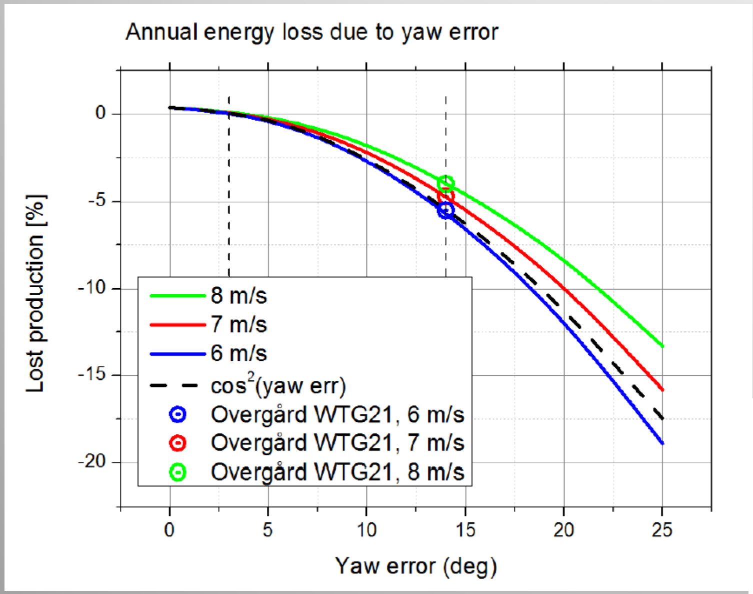
Measurement of yaw misalignment versus flow inclination angle from different sectors in wind farm, 30sec averages

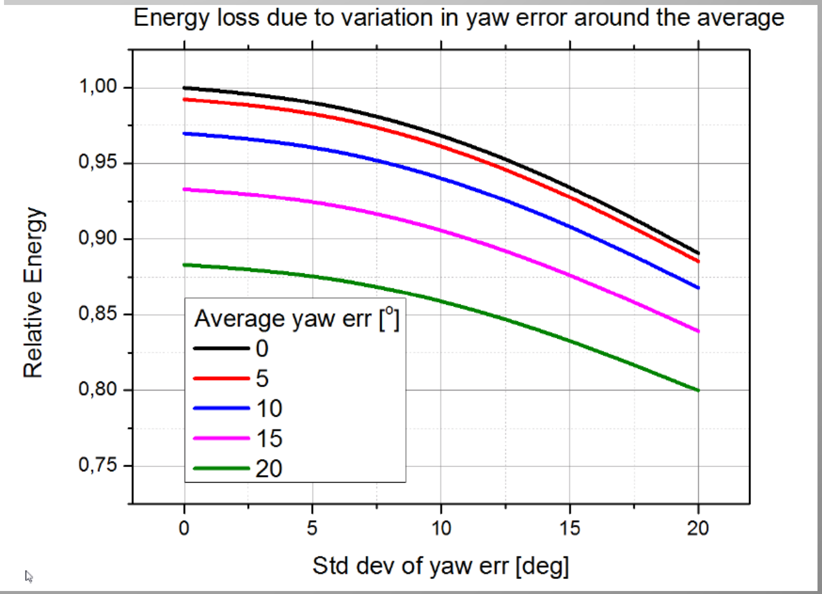


Spinner anemometry

Energy loss due to yaw misalignment

Re. www.romowind.com

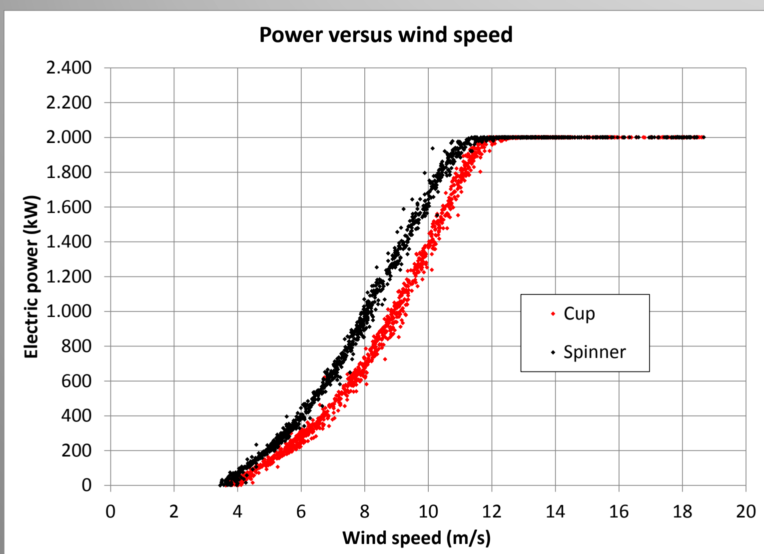




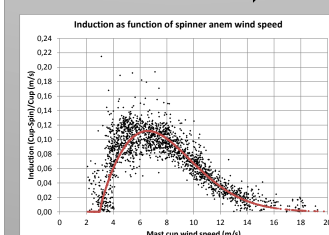
Figures re. J.Højstrup

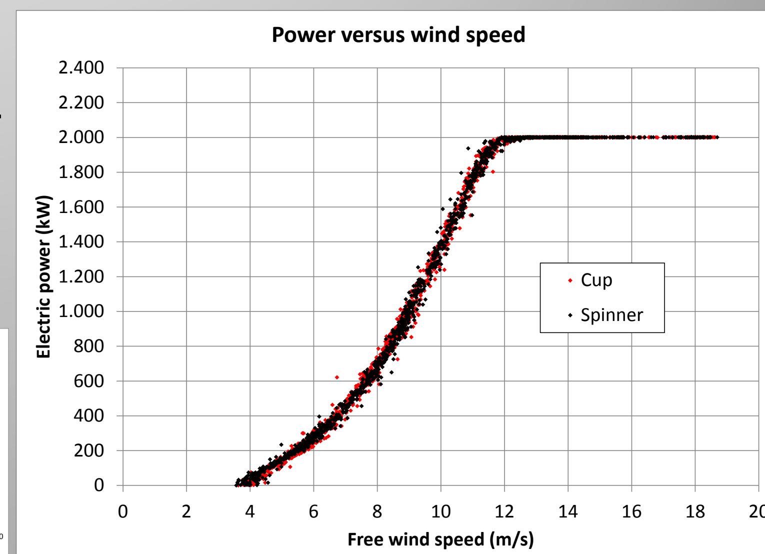
Spinner anemometry

Measurement of nacelle power curve according to IEC61400-12-2 (NPC)



Correction for induction



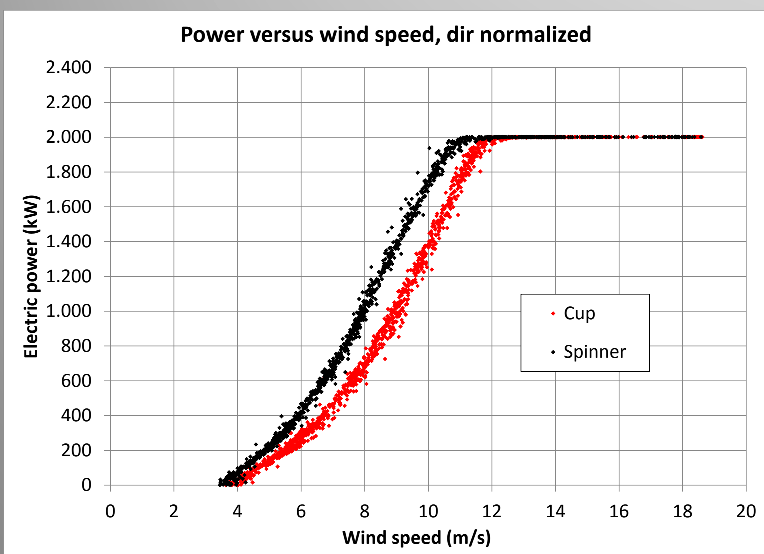


Spinner anemometry

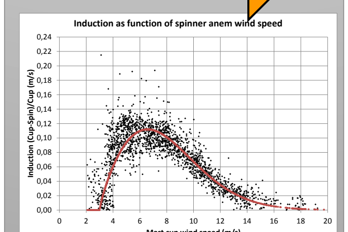
Measurement of rotor power curve (RPC)

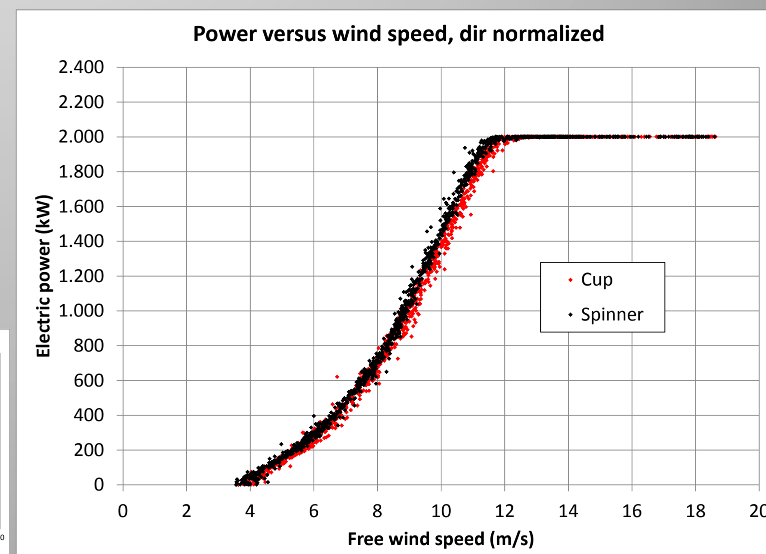
A normalized power curve for horizontal (or axial) flow wind speed:

- Corrected for induction
- Normalized for air density
- Normalized for yaw misalignment by cos^2 relation
- Normalized for flow inclination angle by cos^2 relation
- Could additionally be normalized for turbulence intensity



Induction correction and normalization



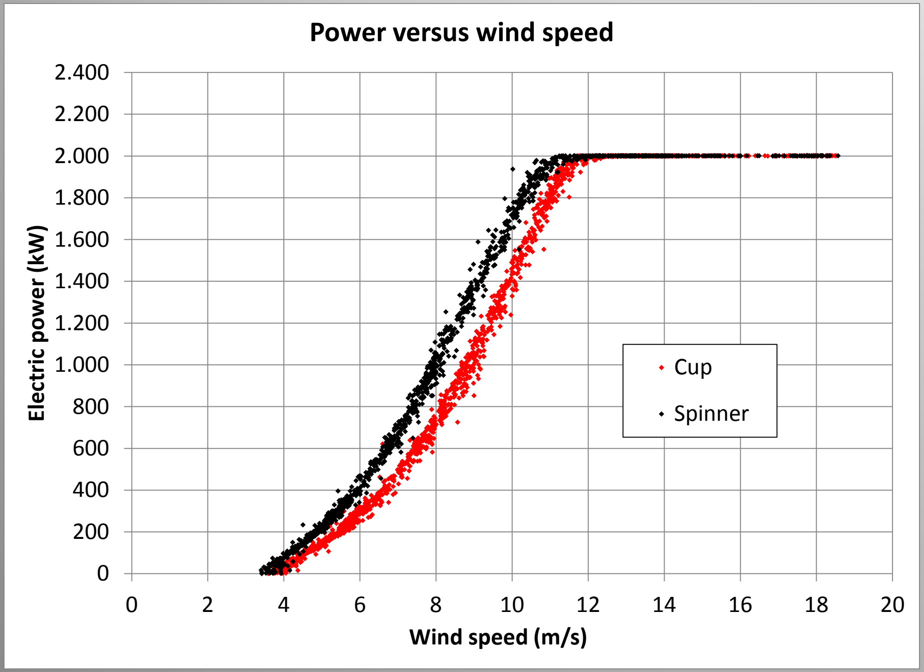


Spinner anemometry

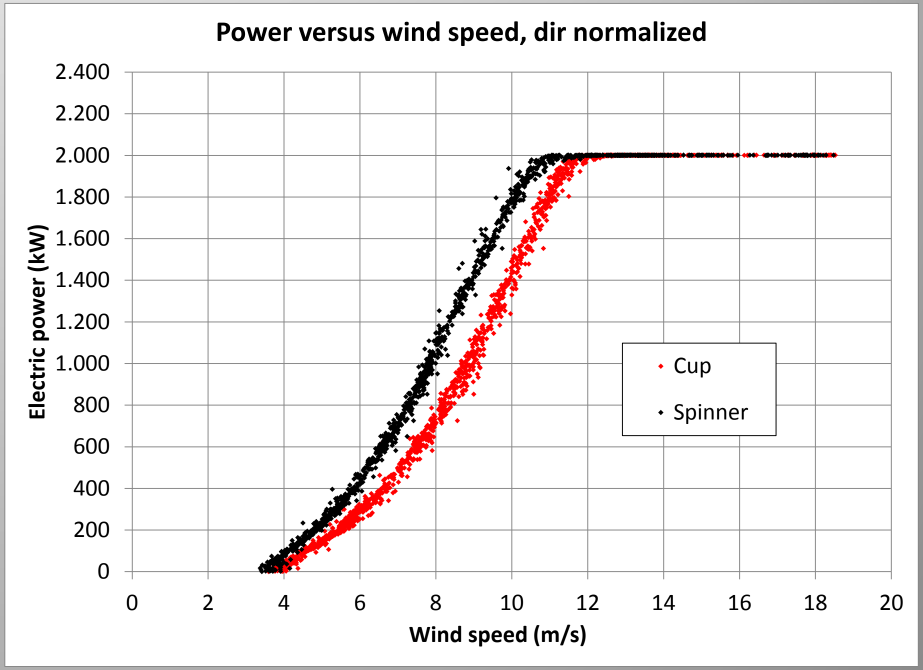
Measurement of rotor power curve (RPC)

- Compared to IEC standard power curve

Standard IEC power curves



Rotor power curve



Spinner anemometry

Conclusions

- Spinner anemometer measures horizontal wind speed, yaw misalignment and flow inclination angle
- Calibration of angular measurements by yawing turbine in and out of the wind
- Calibration of wind speed measurements by measurements during operation and relating wind speed to met mast or lidar
- Calibration gives k_1 and k_2 spinner anemometer constants and induction function
- By correction for induction function the spinner anemometer measures turbulence intensity correctly
- By correction for induction the spinner anemometer measures power curves according to IEC61400-12-2 (NPC)
- A proposed generic rotor power curve (RPC), corrected for induction, and normalized for air density, yaw misalignment and flow inclination angle reduces scatter and increase power curve