A Detached-Eddy-Simulation study

Proper-Orthogonal-Decomposition of the wake flow behind a model wind turbine

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Introducing the UT2 (Circulating tank 2) at the TU Berlin

• One of the biggest circulating water tanks worldwide
• Built in 70’s and recently renovated
• Suitable for studies of ship properties as well as of floating wind turbine models

• Drive: 2 motors, 1.6 MW each
• Pump: \( Q = 60000 \text{ l/s at } H = 2 \text{ m} \)
• Flow speed up to 9 m/s
Real problem in the wind park optimization?

A DES study: POD of a wake flow behind a model wind turbine
LDA-Experiment conditions

(a) Test wind turbine

(b) Tip speed ratio

\[ \lambda \]
Simulation conditions

(a) CFD – test area
(b) Sliding mesh and grid size
Detached-Eddy-Simulation (DES)

Methods

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A DES study: POD of a wake flow behind a model wind turbine

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18.01.2018
Proper-Orthogonal- Decomposition (POD)

Methods

Proper-
Orthogonal-
Decomposition (POD)

\[ S = U \cdot \Sigma \cdot V^T \]

Snapshot 1
Snapshot 2
...
Snapshot n

Spatial information

Time information

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Operating points in the wake flow

x/D: 1 3 6

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Normalized streamwise velocity $u^* = \bar{u} / u_{ref}$

Results

Position: $x/D=3$

Note:
- Direction of the streamwise velocity = Main wind direction
Normalized turbulence kinetic energy $k^* = \frac{k}{u_{ref}^2}$

### Results

#### DES-Simulation:

- $k = \frac{1}{2} \cdot u'^2 + v'^2 + w'^2$
- Shear flow information

#### LDA-Experiment:

- Position: $x/D=3$
- Position: $x/D=6$

Note:

- $k = \frac{1}{2} \cdot \sqrt{u'^2 + p'^2 + w'^2}$

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POD of the flow field in $x/D=1$

$$S = U \cdot \Sigma \cdot V^T$$

Relative energy

![Graph showing eigenvalues or POD-Modes](image)

Note:
POD-Modes: Different characteristics which describe the energy influence of the flow field.

Note:
Phase angle of a velocity signal: $\alpha$

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Normalized coherent streamwise velocity $\tilde{u}^* = \tilde{u}/u_{ref}$ (coherent motions)

Tip vortex

Root vortex

Note:
Coherent motions: Large eddies with an important influence of the flow field.

$u = \tilde{u} + u' + \bar{u}$
Results

Fluctuation loads (significant frequencies)

Note:
1p: Interaction between the rotation frequency of one blade and the tower.
Validation of the frequency
Conclusion

1. DES and POD
   a. Velocity components, turbulence kinetic energy
   b. Coherent motions (tip vortex, root vortex)
   c. Fluctuation load (1p frequency)

2. Future studies
   a. Different inflow/boundary conditions
   b. Wake flow analyses for more than one turbine
   c. Optimization of the wind park planning
Thank you for your attention...

...Questions?
References:

(1) http://www.envision-energy.com/2016/08/17/optimizing-energy-production/ 14.01.2018

