Modal identification of time-varying systems using simulated responses on wind turbines

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Outline of the presentation

Problem statement

The considered wind turbine (NREL technical report, 2009)

Rating :	5 MW
Rotor diameter :	126 m
Hub height :	90 m

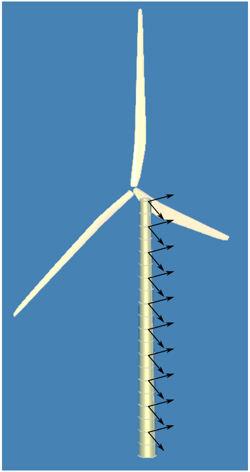
Wind speeds :

- Cut-in : 3 m/s
- Rated : 11.4 m/s
- Cut-out : 25 m/s

Rotor speeds :

- Cut-in : 6.9 r.p.m.
- Rated : 12.1 r.p.m.

A numerical model is built to simulate structural response



Beam elements model the tower and blades

Aero elements compute aerodynamic loads on the blades

Lumped masses simulate the nacelle and the bedplate

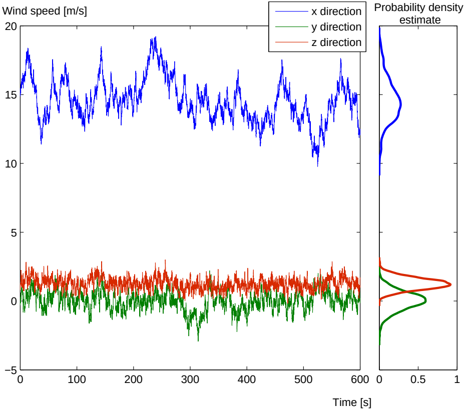
Hinges are used in the rotor and yaw mechanism

10 measurement points are considered along the tower

The wind is simulated with the *TurbSim* simulator coupled with *S4WT*

The wind is generated based on the ***Kaimal*** model

A set of load cases is generated considering different mean wind speeds



Operational analysis requires output-only identification method

Some techniques are suitable for output-only modal analysis :

- *(E)FDD*
- *p-LSCF (PolyMAX)*
- ***SSI***

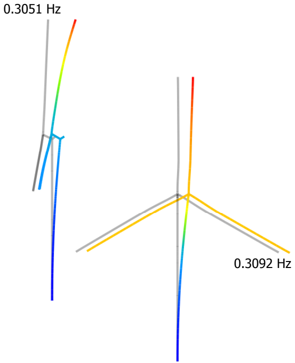
The working assumptions of the *SSI* methods are not completely fulfilled

Assumptions of :

- Linear time-invariant system
- Whiteness of the Gaussian process noise

Because of the dynamic properties of the system and the deviation from working assumptions, some difficulties appear

The dynamic properties of the structure



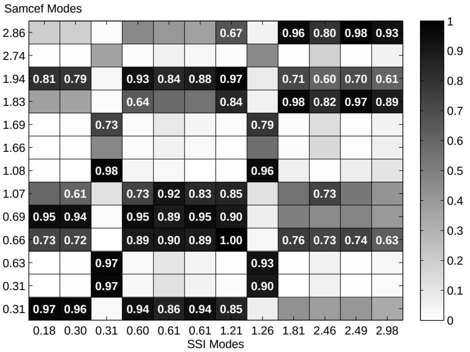
The very low frequencies of the system require long time responses

Due to high symmetry, the eigen modes are close in frequency

The limited number of sensors causes high spatial aliasing

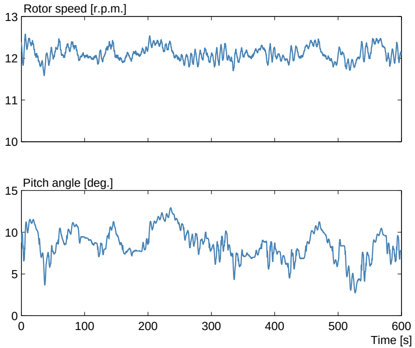
Tower bending modes are well identified

Blade modes are seen as tower bending modes



The method becomes sensible to the input parameters due to non constant operational conditions

The rotor speed and pitch angle slightly vary even under stationary winds



One can use some tools to try to overcome these difficulties

Stabilisation with an automated clustering approach (Reynders et al., 2012)

Several simulations for different input parameters

Projection channels used as references (Jacobsen al., 2008)

The automated stabilisation diagram does not require thresholds any more

The method in three steps :

- Separation between *possibly physical* and *certainly spurious* modes
- Grouping of similar modes
- Selection of a representative mode

The number of criteria to distinguish modes is more substantial

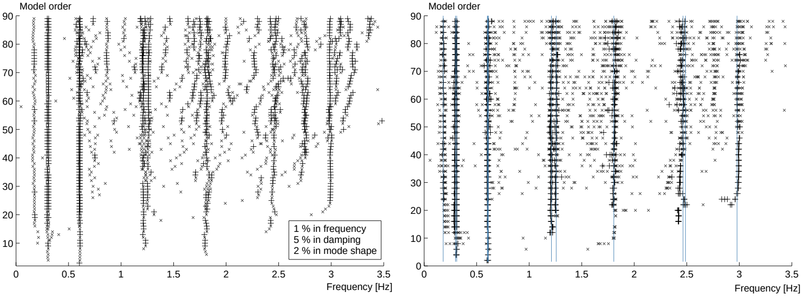
Classical stabilisation :

- Frequency deflection
- Damping deflection
- Mode deflection

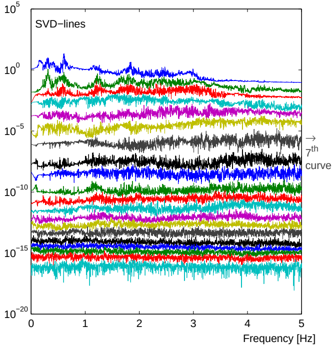
Automated stabilisation :

- ...
- Pole deflection
- Mode shape complexity

The automated method adaptively selects the physical modes



The use of projection channels reduces the CPU time

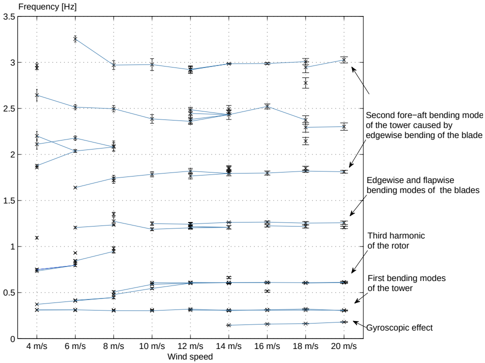


Reduction of the size of correlation blocks in the Hankel matrix

- Choice of the number of projection channels
- Selection of the first one
- Selection of the others

Results

Mean wind speed [m/s]	Mean rotor speed [r.p.m.]
4	7.4336
6	8.2786
8	9.9039
10	11.8921
12	12.1079
14	12.1091
16	12.1161
18	12.1240
20	12.1314



Conclusions

A series of load cases were generated and applied on a numerical model

Identifications were performed with the *SSI* method

Some difficulties were pointed out in such an application

Some tools were used to try to overcome these difficulties

One can conclude that the traditional *SSI* method is not accurately applicable to such an application

Thank you for your attention