Deformable trailing edge geometries and cyclic pitch controller

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Citation (APA):
• **1958** Inaugurated. Purpose: Peaceful utilisation of nuclear energy
• **1976** Oil crises (1973) results in research in other Energy sources
• **1978** Research in Wind Energy starts
• **1985** Political decision of not having nuclear energy in Denmark
• **1994** State-owned enterprise
• **2000** The last nuclear reactor is shut down
• **2007** Merger with DTU, the Danish Institute for Food and Veterinary Research, the Danish Institute for Fisheries Research, the Danish National Space Centre and the Danish Transport Research Institute
Risø National Laboratory
A national laboratory under DTU

Risø total:
900 employees

Wind Energy Dept.:
120 employees

Systems Analysis
Fuel cells
Hydrogen storage
PV polymer cells
Bio Energy
Materials
EllipSys (2D and 3D)
HAWC2 (and HAWC)
HAWTOpt
HAWCStab (soon HAWCStab2)
Introduction (5:8)

Sensors and DTEG positions

Table of DTEF

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<table>
<thead>
<tr>
<th></th>
<th></th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>14.7m</td>
</tr>
<tr>
<td>2</td>
<td>5.3m</td>
</tr>
<tr>
<td>3</td>
<td>8.5m</td>
</tr>
<tr>
<td>4</td>
<td>6.5m</td>
</tr>
<tr>
<td>5</td>
<td>3.7m</td>
</tr>
</tbody>
</table>

Peter B. Andersen, Mac Gaunaa, Christian Bak, Helge Aa. Madsen
Frederik Zahle, Joachim Heinz, Leonardo Bergami, Li Na, Andreas Fisher
DTEG Property assumptions:
10% of chord
+/- 8 degree deflection possible
from +/-8 to -/+8 in simulated “dt” (=0.01s)
no effects of hysteresis
no overshoot or other dynamics
max $\Delta CL(\alpha, \beta=8\text{deg}) = 0.29$
min $\Delta CL(\alpha, \beta=-8\text{deg}) = -0.29$
Controller (1:6)
An “inverse” Theodorsen/Gaunaa model

Possibility to use running averages or reference AOA values. (The $K_\alpha$ factor)

Objective: level out “stochastic” signal AOA / Vrel
An elastic response model

Objective: level out "deterministic" signal $M_j$ (blade root moment)
Pitch communication model

Objective: DTEG and blade pitch work together
pitch servo modeled as a 2nd order system

max pitch rate: 8 degree/sec

Power controller model:

Omega filter to remove "free-free" oscillations
Cyclic pitch controller
Invers Coleman transformation
Notch filter
PI on yaw and tilt
Coleman transformation
additional pitch angle output
Results (1:6)

![Graph showing yaw moment vs wind speed]

- @ 13 m/s
- 23% increase
- 67% increase
Results (1:6)

Yaw moment std

- std - cyc
- std - flap and cyc
- std - flap
- std - plain

@ 20 m/s

16% increase

53% increase

@ 13 m/s

23% increase

67% increase

Wind speed [m/s]

0 500 1000 1500 2000 2500 3000 3500
Results (2:6)

![Graph showing Yaw moment (ave, min, max) vs Wind speed [m/s]. The graph includes lines for average and minimum and maximum values for 'plain', 'cyc', 'flap', and 'cycflap' conditions. The x-axis represents wind speed ranging from 4 to 22 m/s, and the y-axis represents yaw moment in Nm ranging from -20000 to 10000 Nm. The legend indicates different line styles and markers for each condition.]
<13 m/s> results (5:6)
<19 m/s> results (6:6)
Introduction
Controller
Results
Conclusion
Conclusion

- The flaps with a +/-8 degree angle range seem to be able to eliminate almost all of the 30 degree yaw error

- Controllers needs to be integrated to see full potential

- Power production should be a part of the

- Tuning of controllers is very time consuming
Future work...

A “real” turbine

- Acoustic noise reduction
- Power production
- Extreme directional change in wind direction
- Main shaft (fatigue)
- Extreme wind conditions (gusts)
- Position of DTEG

- Blade flapwise, extreme (bending, buckling)
- Dimension of DTEG

- Offshore
- Floating turbines
- Tower welding (fatigue)

- Stand still
- Negative wind shears
- CFD

- Lightning
- Monte Carlo simulations
- Gear (fatigue)

- Wind farm issues
- Pitch regulation
- Sensor dynamics/hysteresis

- IEC Load case
- Two bladed turbine
- Sensor delay

- Stability
- Emergency shut down
- Signal noise

- Emergency shut down
- Foundation (extreme)