AEOLUS TOOLBOX for dynamic wind farm modeling, simulation, and control

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Features of Aeolus simulation tool:

- Toolbox is open source
- Based on MATLAB/SIMULINK
- Suitable for wind farm control design
- Flexible for any wind farm layout and number of wind turbines
- Flexible for different wind condition simulations (Turbulence generation uses Veers method)
- Usable for all pitch regulated turbines
- Wake effects are included by means of dynamic wake meandering
- Fatigue load analysis on turbine components
Main components for wind farm simulation

The model includes four main blocks in the top level which operate in a closed loop:

- **Wind Turbine Dynamics**
  includes electromechanical model of pitch regulated wind turbine, simplified aero-elastic model, and fatigue load analysis

- **Wind Field Dynamics**
  includes ambient wind field generation, wake deficit, meandering and merging

- **Wind Farm Controller**
  Simple proportional controller as well as dedicated centralized controllers and decentralized controllers

- **Network Operator**
  Capable for simulating different options such as absolute active power mode, Delta mode, balance model, rate limiting mode, frequency control mode
SimWindFarm Overview

- Turbines
  - $P_{\text{dem}}$ [W]
  - $V_{\text{nac}}$ [m/s]
  - $V_{\text{rot}}$ [m/s]

- Wind Field
  - $V_{\text{nac}}$ [m/s]
  - $V_{\text{rot}}$ [m/s]

- Farm Control
  - $P_{\text{meas}}$ [W]
  - $V_{\text{meas}}$ [m/s]
  - $w_{\text{gen}}$ [m/s]
  - Pitch [deg]
  - Aux

- Network Operator
  - $P_{\text{farm_dem}}$ [W]
  - $P_{\text{avail}}$ [W]
  - $f_{\text{grid}}$ [Hz]

- Grid
  - $P_{\text{farm}}$ [W]
  - $P_{\text{grid}}$ [W]

- Post processing

- Network Load

Total power $\sum$

$P_{\text{grid}}$ [W]
Ambient wind field

**Inputs:**
- Mean wind speed
- Turbulence intensity
- Lateral displacement
- Simulation time
- Sample time

**Processing:**
- Two spectral matrices are provided

**Output:**
- Lateral and longitudinal wind speed matrices
Wake deficit and wake meandering

Wake meandering of a turbine defined by the wake center location and the wake expansion.
In SimWindFarm, fatigue loads are evaluated in a post processing tool using rain-flow counting where the stress cycles and their ranges are counted in order to create a histogram of cycles. For each stress range, the partial damage can be computed as $D_i = n_i/N_i$ where $n_i$ is the number of cycles for the $i$'th stress range, and $N_i$ is the number of cycles to failure.
The main operating modes:
- Absolute active power control
- Frequency control
- Delta mode
- Power rate limiter
- Balance mode

<table>
<thead>
<tr>
<th>mode number</th>
<th>mode</th>
<th>settings</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Active power control</td>
<td>power demand [kW]</td>
</tr>
<tr>
<td>2</td>
<td>Delta mode</td>
<td>Delta [kW]</td>
</tr>
<tr>
<td>3</td>
<td>Balance mode</td>
<td>power level [kW]</td>
</tr>
<tr>
<td>4</td>
<td>Rate limit</td>
<td>max power rate [kW/s]</td>
</tr>
<tr>
<td>5</td>
<td>Frequency control</td>
<td>(dead-band [Hz], Control band [Hz], min/max power [kW])</td>
</tr>
</tbody>
</table>
### Benchmark

<table>
<thead>
<tr>
<th>Property</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rated power</td>
<td>5MW</td>
</tr>
<tr>
<td>Configuration</td>
<td>Upwind, 3 Blades</td>
</tr>
<tr>
<td>Control</td>
<td>Variable speed, collective pitch</td>
</tr>
</tbody>
</table>

**Wind**
- Cut-in: \(3 \text{m/s}\)
- Rated: \(11.4 \text{m/s}\)
- Cut-Out: \(25 \text{m/s}\)

**Rotor**
- Cut-in: \(6.9 \text{rpm}\)
- Rated: \(12.1 \text{rpm}\)
- Diameter: \(126 \text{m}\)

**Hub**
- Diameter: \(3 \text{m}\)
- Height: \(90 \text{m}\)

Turbine properties and layout of the benchmark for simulation in SimWindFarm.
A snapshot of the wind flow in SimWindFarm.
Power production

Power and load during the simulation. The available power is the farm controller estimate, the power demand is the network operates desired farm production.