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The Importance of System Dynamic Modeling for Small Wind Turbines

Part 3: Modeling Wind Turbines in FAST

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What Is FAST?

- FAST is an aeroelastic computer-aided engineering tool for HAWTs.
- In the past it has been supported by NREL/NWTC.

What Is the Process for Its Use?

- Define the turbine, controls, and wind input characteristics.
- Use FAST.exe to simulate turbine operation.
- Produce output files of calculated loads, deflections, etc.

How Are the Results Used?

- To determine (extract) ultimate and fatigue loads.
- To inform the design of SWT components, such as blades, towers, gearboxes, and generators.
- During certification of SWTs to the IEC 61400-2 standard.

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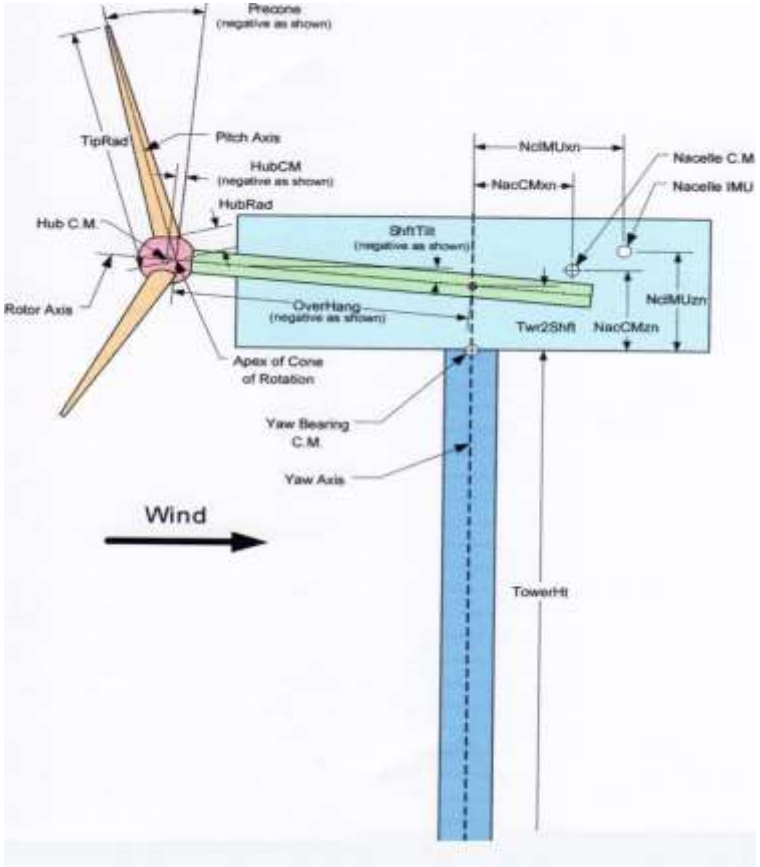
Specifications Needed to Build a FAST Model

- Component locations, masses, and centers of gravity.
- Blade airfoil shapes, twist, and mass along the span.
  - Tower and blade natural frequencies are calculated by BMODES code available from NREL.
- Tower geometry and material properties.
- Gearbox and generator information.



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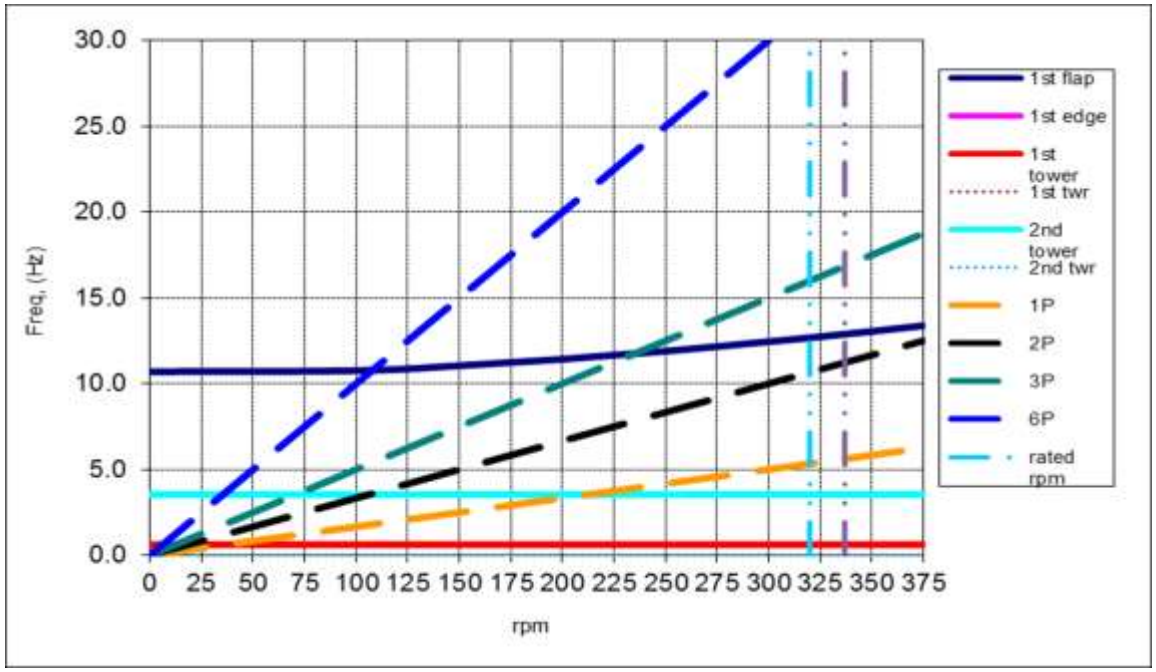
Avoiding Rotor-Tower Resonance

- Do not allow blade passing frequencies to coincide with tower natural frequencies at common operating RPMs.
- Example: tower natural frequency = 3 Hz; turbine rated RPM = 180.



Example Frequency Plot from BMODES Results

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Standard FAST Inputs

- FAST.ipt: geometry, masses, CG's, degrees of freedom.
- Aerodyn.ipt blade aerodynamics: twist, chord, Cl-Cd-α.
- Blade.dat blade mass and stiffness properties.
- Tower.dat tower mass and stiffness properties.
- Speed-Torque.dat for a variable speed generator.
- Furl.dat tail and furl degrees of freedom.
- Wind Input file turbulent wind, gust, etc.

```
* ---------- SIMULATION CONTROL ----------
* 620.0    TMax      - Total run time (s)
* 0.002    DT        - Integration time step (s)
* 12ms.wnd           - Name of Wind Input File

* ---------- FEATURE FLAGS ----------
* True     FlapDOF1  - First flapwise blade mode DOF (flag)

* ---------- TURBINE CONFIGURATION ----------
* 4.728    TipRad    - The distance from the rotor apex to the blade tip (meters)
* 0.1689   HubRad    - The distance from the rotor apex to the blade root (meters)

* ---------- MASS AND INERTIA ----------
* 184.16   NacMass   - Nacelle mass (kg)

* ---------- BLADE ----------
* "C:\Data\WTIC\31-20\Airfoils\120inch_2D.dat"
* "C:\Data\WTIC\31-20\Airfoils\144inch_2D.dat"
* RNodes   AeroTwst   DRNodes   Chord   NFoil   PrnElm
* 0.248    0.00       0.1591    0.202   1       NOPRINT
* 0.528    0.00       0.40      0.202   1       NOPRINT
* 0.928    9.00       0.40      0.245   1       NOPRINT
* 1.328    12.20      0.40      0.271   2       NOPRINT
```

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Example FAST Outputs

Time	HorWindV	RotSpeed	Azimuth	GenPwr	YawPzn	RootMyc1
(s)	(m/s)	(rpm)	(deg)	(kW)	(deg)	(kN·m)
200.00	19.60	178.0	115.00	19.30	33.50	0.79
200.01	19.40	177.0	126.00	19.30	33.70	1.07
200.02	19.20	177.0	136.00	19.20	33.90	1.35
200.03	19.20	177.0	147.00	19.20	34.10	1.61
200.04	19.10	178.0	157.00	19.10	34.20	1.77
200.05	19.00	178.0	168.00	19.10	34.40	1.81
200.06	18.90	178.0	179.00	19.10	34.50	1.78
200.07	18.90	178.0	189.00	19.10	34.50	1.72

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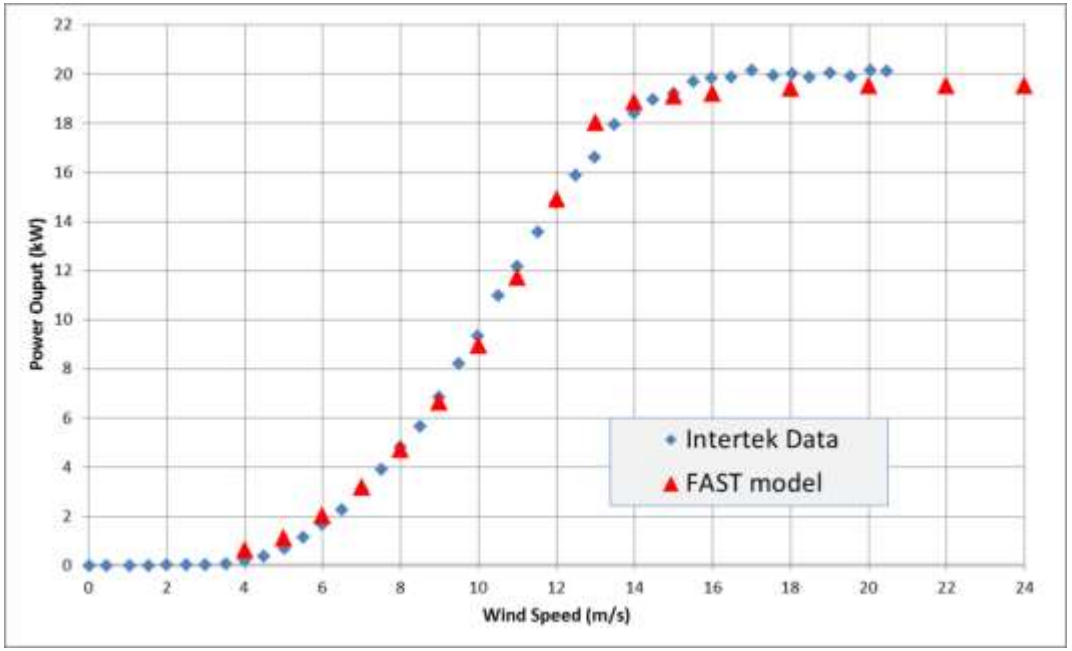
Analyzing FAST Results

- "Tune" FAST to Match Test Data.
- Run all design load cases per IEC 61400-2 (typical = 120 simulations).
- Determine ultimate and fatigue loads at critical locations.
  - blade root
  - rotor shaft
  - tower top

- Are design changes warranted to improve performance or cost effectiveness?
- Does the turbine meet criteria for certification?



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How Much Does It Cost?

- Turbine and tower manufacturer must provide all necessary inputs.
- $3,000 to $5,000 to build the FAST model.
- $3,000 to $5,000 to run simulations and document results.

Conclusion

- It's worth it!