Practical Expertise
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Small Turbine Tower Design

AWEA vs IEC 61400-2 vs TIA-222

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SMART Wind Composites Virtual Meeting on Support Structures

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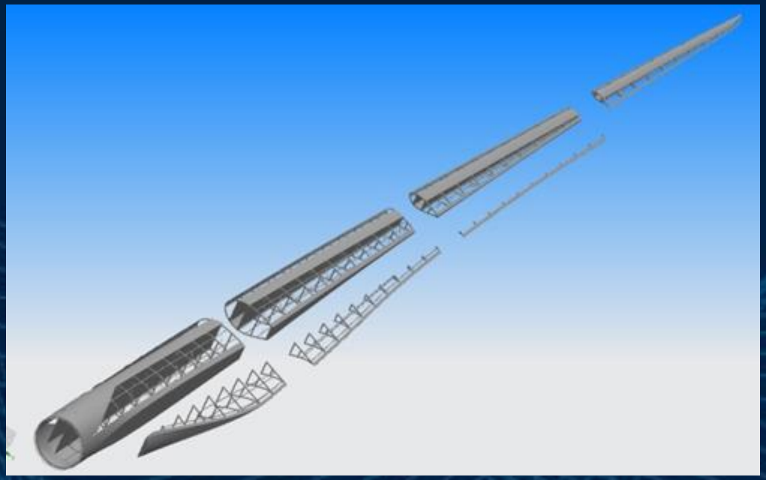
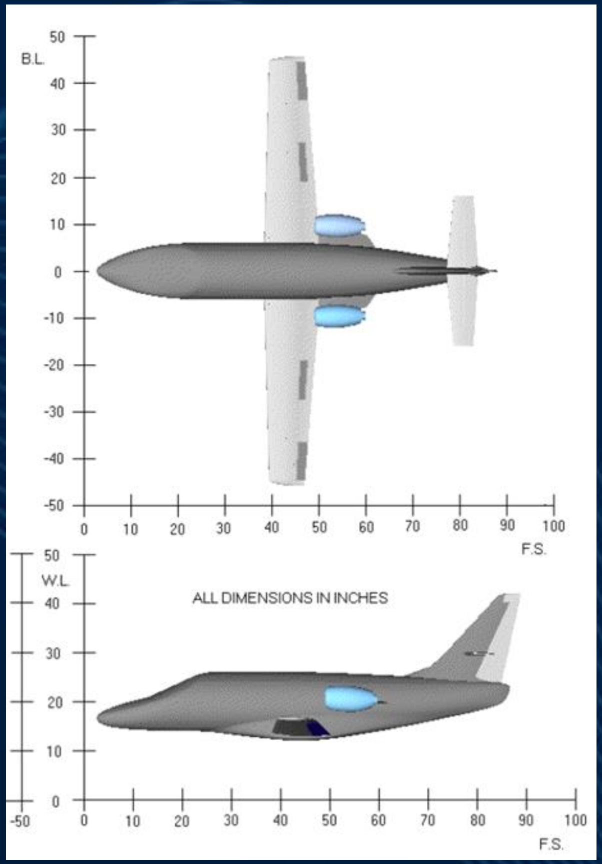
- Engineering Solutions Developer
  - Clients on 4 continents
  - Wind Energy
    - > 50 custom blade designs
    - > 20,000 blades operating
  - Aviation
  - Towers
- Engineering services to
  - OEMs
  - Owners and Operators
  - Insurance Companies
  - And others…





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Purpose of Standards vs Purpose of Engineering

- Purposes of Engineering
  - Ensure no failures
  - Ensure most cost-effective Design
- Purpose of Standards
  - Define “industry accepted” MINIMUM set of requirements

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Failure of Small Turbine Tower Standards

- AWEA Small Turbine Standard
  - Omits Towers
  - Flawed belief that towers are generally not critical to turbine response for small machines
  - Puzzling oversight as to how the industry is to ensure that towers have been minimally engineered

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Failure of Small Turbine Tower Standards

- IEC 61400-2
  - Wind industry standard methods of estimating loads
  - Includes Tower Engineering
  - Does not necessarily conform to requirements of the IBC

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Failure of Small Turbine Tower Standards

- TIA-222-G-4-2014
  - Does not reflect acceptance or input of wind turbine engineers – reflects need to stamp drawings to satisfy US building code enforcement bodies (IBC)
  - Over-reach by non-industry standard-writing body with little to no understanding of wind turbine engineering
  - Loads calculations are inconsistent with standards of the wind industry
  - Poor Fatigue Analysis Methods

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Failure of Small Turbine Tower Standards

- TIA-222-G-4-2014
  - Claims to be “derived from” IEC 61400-2, but errors in derivation are significant
  - “Turbine shall be modeled as a mass and an effective projected area” – misses key characteristics of rotor aerodynamics and dynamics that are important for estimating loads – treats rotor as an antenna
  - This is a completely unacceptable method of estimating loads

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Failure of Small Turbine Tower Standards

- TIA-222-G-4-2014
  - Design Load Condition – 49m/s (110mph) 50-year return, 3-second gust at 10m height, exposure Category C, Topo Category 1, Extreme Wind Condition using the appropriate TIA Importance Factor
  - Standard implies this is conservative approach in lieu of performing fatigue
  - Notes that 110mph requirement is independent of IEC Wind Class

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Failure of Small Turbine Tower Standards

- TIA-222-G-4-2014
- Loads Calculation

Note SF=1.60

1. $1.2\,D + 1.0\,D_g + 1.6\,W_o$
2. $0.9\,D + 1.0\,D_g + 1.6\,W_o$
3. $1.2\,D + 1.0\,D_g + 1.0\,D_i + 1.0\,W_i + 1.0\,T_i$
4 $1.2\,D + 1.0\,D_g + 1.0\,E$
5. $0.9\,D + 1.0\,D_g + 1.0\,E$

D = dead load of structure and appurtenances, excluding guy
D_g = dead load of guy assemblies;
D_i = weight of ice due to factored ice thickness;
E = earthquake load;
T_i = load effects due to temperature;
W_o = wind load without ice;
W_i = concurrent wind load with factored ice thickness.

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Failure of Small Turbine Tower Standards

- TIA-222-G-4-2014
  - 110mph requirement can be nonconservative as a 50-year, 3-second extreme
  - Previous work by WEI for Anemergonics – dynamic sims (FAST) with modified inflow

	Wind Class →		Modified 2	Modified 3	S
Reference Wind Speed	V_{ref}	m/s	42	36	32
Average Hub-Height Wind Speed	V_{avg}	m/s	8.5	7.5	7.5
Mean Turbulence Intensity	I_{15}		14%	14%	14%
Cut-in Wind Speed	V_{in}	m/s	4	4	4
Cut-out Wind Speed	V_{out}	m/s	NA	NA	NA
Extreme Hub-Height Wind Speed	V_e	m/s	65	54	49
		mph	144	120	109

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Compared to TIA steady inflow with direction change

Failure of Small Turbine Tower Standards

- TIA-222-G-4-2014
    - 110mph requirement can be nonconservative as a 50-year, 3-second extreme
    - Previous work by WEI for Anemergonics
        - Load estimations were very sensitive to the particular turbine configuration – dynamics of the tower, height of the tower
        - Generally OK match on tower base loads
        - TIA inflow generally underestimated tower top bending moments by as much as 30%

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Failure of Small Turbine

Tower Standards

- TIA-222-G-4-2014
  - TIA-222-G omits fatigue
  - Addendum 4 recognizes fatigue is important for wind turbines
  - Method of Calculating fatigue loads is obscure and based on the idea of the rotor diameter as a disk with a constant 30mph wind
  - Accounts for some stress concentrations using handbook methods

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Recommendation

- Loads (Static & Fatigue-Equivalent)
  - Calculate Loads per IEC 61400-2 (or better yet 61400-1) using the applicable IEC Load Case and the TIA-prescribed inflow and terrain conditions
  - Calculate Loads per TIA
  - Use the most conservative set

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Recommendation

- Strength & Fatigue
  - Calculate stresses and fatigue damage per IEC 61400-2 (or GL guidelines)
  - Calculate stresses and fatigue per TIA-222-G-4
  - Go with the more conservative result
    - If there is a significant conservative discrepancy from TIA, then ask for an exception based on sound engineering
    - Engineers stamping drawings have leeway to use professional judgment – standards simply provide cover

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Recommendation

- Options by DWEA
  - Secure acceptance by IBC for IEC 61400-2
  - Include towers in AWEA STS and secure acceptance by IBC for AWEA STS
  - Amend TIA-222-G-4 to include options for methods of loads, strength, and fatigue analysis more consistent with IEC 61400-2

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