Simulating Turbulent Wind Fields for Offshore Turbines In Hurricane-Prone Regions

**Abstract**

Extreme wind load cases are one of the most important external conditions in the design of offshore wind turbines in hurricane-prone regions. Furthermore, in these areas, the increase in load with storm return-period is higher than in tropical regions. However, current standards have limited information on the appropriate models that can be used to simulate wind loads from hurricanes. This study investigates turbulent wind models for load analysis of offshore wind turbines subjected to hurricane conditions. Extreme wind models recommended in IEC 61400-3 and API/ABS (a widely-used standard in oil and gas industry) are investigated. The study further examines the wind turbine response subjected to hurricane wind loads. To include the API wind model, we modified TurbSim, a three-dimensional wind simulator. Finally, wind fields simulated using IEC and API wind models are used for an offshore wind turbine model established in FAST to calculate turbine loads and response.

**Modeling Approach**

- **API & IEC Wind Profile Models**
  - $v(z) = v_{hub}(z/hub)^{0.11}$, $v_{hub}$(10-min mean)
  - $C = 0.0573 + 0.15\, k / \phi$
  - Unit conversion: $v(z,t) = v(z,t)(1 - 0.41\, (z / t_c)^{0.75})$
  - $t_c = 3600, v_{hub}$(10-min mean at 10m above still water level)

- **API & IEC Wind Spectrum Models**
  - $f_s(f) = \frac{4k_r}{(1 + 6k_r)\, \omega_n}\, f^{0.41}$
  - $\omega_n = U_{10}/10$
  - $k_r$: index referring to the direction of wind speed component
  - $L_z$: integral parameter of turbulent wind speed component

- **API & IEC Wind Coherence Models**
  - $\text{Coh}(\theta) = \text{Coh}(\phi)$
  - $\text{Coh}(\theta), \text{Coh}(\phi)$

**Nondimensional Comparison of API & IEC Blade Loads**

- Different wind models result in different load magnitudes.
- API IEC blade load comparison

**Conclusions**

1. Different wind models result in different wind turbine extreme loads during hurricane conditions.
2. The API and IEC wind models result in different wind speed extrapolation along height, wind spectrum, coherence, return-period, and time-averaging intervals.
3. The API wind model has greater energy in the low-frequency range, which could excite some of the low structural modes and vibration of offshore turbines.
4. The API conditions tend to generate slightly smaller load maxima, but also larger minimum values of the loads.

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