NEIL D. KELLEY, APPLIED RESEARCH METEOROLOGIST
IEA ANNEX 27 PROPOSED PRESENTATION OUTLINE

VIENNA, AUSTRIA

October 2017

OVERVIEW

1. Presentation Subject Matter Background and Description

The purpose of this presentation is to discuss the characteristics of atmospheric turbulence in the inflow and its impact on wind turbines whose rated generating capacity is 1 MW or less. The presentation will be based on research conducted over a period of 25+ years at the NREL. National Wind Technology Center and its predecessor organizations. The objective of this lecture will be to present a comprehensive look at the impact of atmospheric turbulence on the aerodynamic and aeroelastic dynamic responses of wind turbine structural components. In particular, it will be discussed how the role of specific atmospheric processes are responsible for the creation of important 3-dimensional turbulent structures in turbine inflows that are responsible determining the mechanical lifetime of turbine designs. Finally the role NREL *TurbSim* stochastic turbulence simulator will be discussed in the numerical simulation of wind turbine dynamics for a range of atmospheric inflow conditions as well as current limitations of the computational codes currently available.

2. Presentation Outline

The presentation will be presented in two sessions, one in the morning and one in the afternoon.

a) Morning Session 1

The morning session will concentrate on discussing field measurement experience of the structural dynamic response to turbulent inflows for a range of HAWT turbines whose characteristics are summarized in Figure 1.

Table 1. Turbines in which detailed inflow and coupled structural response will be discussed.

Turbine	Rotor Diameter	Rated Power	Rotor	Hub	Power regulation	Yaw control
Bergey Excel 10	7 m	10 kW	3-bladed, upwind	rigid	furling	passive (tail)
Micon 65▲	21 m	65 kW	3-bladed, upwind	rigid	stall	active
Lynnette Assoc. AWT-26	26.2 m	275 kW	2-bladed, downwind	teetered	stall	passive
Cannon Wind Eagle CWE300	29 m	300 kW	2-bladed, downwind	teetered	stall	passive (> 50 kW)
Westinghouse WWG600▲	42 m	600 kW	2-bladed, upwind	teetered	full span, active collective pitch	active

▲turbines that will be primarily discussed

The purpose of this session will be to discuss the correlations between a range of inflow turbulence properties and corresponding structural loading expressed in terms of the Damage Equivalent Load or *DEL* and, when available, fatigue damage accumulation. Data from the Micon 65 and the Westinghouse WWG600 turbines that have be used to establish the most efficient turbulent parameter predictors that scale the *DEL*. The role of the diurnal solar cycle in the variation of periods of high loading events will be discussed. The role of the ingestion of coherent turbulent structures present in the turbine inflow in creating significant loading events will be covered. Examples of such events observed on the remaining turbine designs in Figure 1 will be presented.

b) Morning Session 2

The second morning session will be devoted to discussing the atmospheric processes and turbulence dynamics that are responsible for inducing large load excursions and period of significant vibratory responses in turbine blades, drivetrains, and support towers. The atmospheric variables needed to scale these flow processes and the resulting turbulence characteristics are established particularly the fundamental "independent" variables that will be used in defining individual simulations by the *TurbSim* stochastic turbulence simulator. Of particular importance is the role of the diurnal variation of vertical stability in the atmospheric layer in which a specific turbine will occupy and operate in. The stochastic nature of many of the important turbulent properties that are important to turbine lifetime simulations will be examined.

c) Afternoon Session 1

The first session of the afternoon will be devoted to discussing the implementation of the TurbSim simulator code. The code provides simulations based on the IEC Kaimal and von Karman turbulence spectral models. However, its most important functionality is its implementation of five empirically-derived specific turbulence spectral models based on actual field measurements. These models provide the user with turbulent inflow environments that SWT turbines may encounter. While a realistic simulation of a wide range of turbulent inflow conditions is very important, the aerodynamic and aeroelastic simulator codes that provide the dynamic responses to the simulated turbulent inflow are as equally important. TurbSim is optimized for use with the NREL *Aerodyn* and *FLAP* (specified mode shapes) codes but also can be used to drive the *MSC-ADAMS*© commercial multi-body structural simulator. The presenter's opinion on the limitations of these codes to faithfully reproduce the turbine dynamic responses under a wide range of inflow conditions will be discussed.

d) Afternoon Session 2

The final session will be devoted to the actual implementation of the *TurbSim* simulator. The objective will be the discussing the process of establishing the desired inflow boundary conditions through the *TurbSim* input file. No particular aerodynamic/aeroelastic simulator combination will be assumed though any generated simulations should execute using the latest available releases of the NREL *Aerodyn/FLAP* or *MSC-ADAMS*© codes. The *TurbSim* User's Guide provides information that can be used to interface its output to other aerodynamic/aeroelastic simulators. The choice of turbulent spectral models will be discussed for specific applications. When measurements of high resolution turbulence and the vertical stability are available, it is possible to provide a closer match to observed inflow conditions by using actual scaling values for some of the turbulence properties available in the *Turbsim* input file. This will be discussed.

3. Recommended Reading and References

The following NREL reports are recommended for reading and can be obtained from NREL through the following links:

- N.D. Kelley, (2011), Turbulence-Turbine Interaction: The Basis for the Development of the TurbSim Stochastic Simulator, NREL/TP-5000-52353, 332 pp., http://www.nrel.gov/docs/fy12osti/52353.pdf

- N. D. Kelley, B. J. Jonkman, (2007), Overview of the TurbSim Stochastic Simulator: Version 1.21 (Revised February 1, 2001), NREL/TP-5000-41137, 13 pp., http://www.nrel.gov/docs/fy07osti/41137.pdf
- B. J. Jonkman, (2009), TurbSim User's Guide: Version 1.50, NREL/TP-5000-46198, 85 pp., http://www.nrel.gov/docs/fy09osti/46198.pdf