NUMERICAL SIMULATION OF VAWT STOCHASTIC AERODYNAMIC LOADS PRODUCED BY ATMOSPHERIC TURBULENCE: VAWT-SAL CODE

Gregory F. Homicz
Sandia National Laboratories; Albuquerque, NM 87185

ABSTRACT

Blade fatigue life is an important element in determining the economic viability of the Vertical-Axis Wind Turbine (VAWT). A principal source of blade fatigue is thought to be the stochastic (i.e., random) aerodynamic loads created by atmospheric turbulence. This report describes the theoretical background of the VAWT Stochastic Aerodynamic Loads (VAWT-SAL) computer code, whose purpose is to numerically simulate these random loads, given the rotor geometry, operating conditions, and assumed turbulence properties. A Double-Multiple-StreamTube (DMST) analysis is employed to model the rotor's aerodynamic response. The analysis includes the effects of Reynolds number variations, different airfoil sections and chord lengths along the blade span, and an empirical model for dynamic stall effects. The mean ambient wind is assumed to have a shear profile which is described by either a power law or a logarithmic variation with height above ground. Superimposed on this is a full 3-D field of turbulence: i.e., in addition to random fluctuations in time, the turbulence is allowed to vary randomly in planes perpendicular to the mean wind. The influence of flow retardation on the convection of turbulence through the turbine is also modeled. Calculations are presented for the VAWT 34-m Test Bed currently in operation at Bushland, Texas. Predicted time histories of the loads, as well as their Fourier spectra, are presented and discussed. Particular emphasis is placed on the differences between so-called "steady-state" (mean wind only) predictions, and those produced with turbulence present. Somewhat surprisingly, turbulence is found to be capable of either increasing or decreasing the average output power, depending on the turbine's tip-speed ratio. A heuristic explanation for such behavior is postulated, and a simple formula is derived for predicting the magnitude of this effect without the need for a full stochastic simulation.