Analytical and numerical investigation of unsteady wind for enhanced energy capture in a fluctuating free-stream

David Wafula Wekesa[a] CongWang[b] Yingjie Wei[b]Louis Angelo M.Danao[c]

Abstract

Unsteady wind is characterized by low energy content and large fluctuations. A Computational Fluid Dynamics (CFD)-based method for capturing wind energy in a fluctuating free-stream, supported by analytical formulations, is investigated in this paper. We implemented unsteady Reynolds-Averaged Navier-Stokes (RANS) solver to control the dynamic mesh motion. Using an urban wind resource, characteristic fluctuation frequencies at 0.5 Hz, 1.0 Hz, and 2.0 Hz have been selected to demonstrate the enhanced wind energy capture. The numerical energy coefficient marginally changed from 0.36 at 0.5 Hz to 0.37 at both 1 Hz and 2 Hz cases. The results reveal that the highest frequency of fluctuation with meaningful energy content in unsteady wind condition is ≈1 Hz. The study findings promote our understanding about the energy associated with short-period fluctuations reflecting realistic unsteady wind environment. Additionally, the present study approach to analyze wind energy capture on a H-Darrieus wind rotor in a fluctuating free-stream can be extrapolated to other slightly complex VAWT configurations.