Numerical Investigation of Solidity Effect Based on Variable Diameter on Power Performance of H-type Darrieus Vertical Axis Wind Turbine (VAWT)

ABSTRACT

Renewable energy resources especially wind energy, have seen significant growth in the worldwide energy market as clean energy sources. This has brought attention to areas with low and moderate wind speeds. Small-scale Darrieus vertical axis wind turbine (VAWT) with omnidirectional capability captures potential energy in these areas at a cost-effective scale. Numerous studies have been conducted to optimise their design, hence improving the performance of these turbines. Turbine solidity, σ, representing the ratio of the overall area of the blades over the swept area of the turbine, is one of the influential geometrical factors that significantly affect wind turbine performance. Previous studies on solidity focused on the number of blades and blade length variations, while the study on turbine diameter is limited. Hence, this paper intends to numerically investigate the effect of solidity that corresponds to different turbine diameters. Power performance and flow characteristics are investigated closely according to different solidity, σ and tip speed ratios, λ using high-fidelity computational fluid dynamic (CFD) method, which solves the unsteady Reynolds-Averaged Navier-Stokes (RANS) equations. Solidity and tip speed ratios vary within a wide range of 0.3 – 0.7 and 0.5 – 4.5, respectively. The results show that decreasing the turbine solidity from 0.7 to 0.3 could significantly increase the maximum power coefficient, Cp, by 30%. However, turbine with high solidity (σ = 0.7) generate much higher instantaneous moment coefficient, Cm than the low solidity turbine (σ = 0.3), but at lower λ and a narrower range of λ. The difference in turbine's performance between high and low solidity turbine is attributed to stall experienced by the blade at low λ and the blockage effect experienced by the turbine at moderate to high λ that significantly influence the energy generation at downstream region.