Summary of the Ph.D. Thesis

Performance Enhancement Methods of Vertical Axis Windmill (Savonius Rotor)

Supervised by

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Abstract of the Ph.D.

The increasing global demand for energy and environmental concerns have provoked a shift from exhaustible, fossil fuel based energy to renewable energy sources. It is clear that wind energy will play an important role in satisfying the future energy demands. Savonius rotors are low cost and simple type of vertical-axis wind turbines (VAWT). The theory of operation is based on the generated net drag. Savonius rotors may have two, three or four blades with low power coefficient.

In the present study, the performance of the Savonius rotor with different modifications aiming to improve the generated power is conducted numerically and experimentally. The numerical analysis is performed using the implementation of four different turbulence models in Reynolds-Averaged Navier-Stokes (RANS) equations. The employed turbulence models are Standard k-ε, RNG k-ε, Realizable k-ε, and SST k-ω. The numerical results are compared with published and present experimental data to select the suitable turbulence model. The study is performed on the conventional,

different modified blade shapes, deflector plate, twisted blades and a proposed design. The new proposed design is aimed to prevent impinging wind on the convex side of returning blade and direct it towards the concave sides of advancing and returning blades. Besides, the performance of conventional and modified rotors has been experimentally studied by measuring the generated torque and the pressure distribution on the blade surfaces at various tip-speed ratios and rotor angles.

The shear stress transport k-ω (SST k-ω) turbulence model shows more accurate results compared to others. A comparative study on the design parameters is conducted to improve the performance of the Savonius rotor. The studied parameters are the overlap ratio, wind speed, blade shape modification, deflector plate, blade twist and the new proposed design.

In the present study, different overlap ratios ranging from 0 to 0.5 are investigated. Results indicate that, the static torque coefficient is improved by increasing the overlap ratio. On the other hand, the power coefficient of the rotor reaches a maximum value at an overlap ratio of 0.15. Different modified polynomial blade shapes are studied and compared with the conventional one. Results also show that, one of the polynomial shapes can improve the torque and power coefficients compared with the other modified and conventional ones. This modified polynomial shape produces the lowest drag on the return blade. The presence of deflector plate with different lengths and inclination angles in front of the rotor has a considerable effect on the rotor performance. A deflector plate of 15^{o} inclination angle to the upstream wind flow produces a maximum power coefficient of 0.37 compared with 0.21 for conventional rotor at tip-speed ratio 0.9. The upstream wind flow is perpendicular to the rotor rotation axis. The twist of Savonius rotor blades can also improve its performance. Different blade twist angles ranging from 0^{o} to 55^{o} are studied. Results indicate that, Savonius rotor with the blade twist angle of 45^{o} gives a numerical maximum power coefficient. The new proposed design reaches a numerical maximum power coefficient of 0.48 at a tip-speed ratio of 1.1.