Ain Shams University
Faculty of Engineering
Mechanical Power Department

Performance Assessment of an Interactive Three-Rotor Savonius Wind Turbine

A Thesis Submitted in Partial Fulfilment for the Requirements of the Degree of Master of Science in Mechanical Engineering

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LIST of PUBLICATIONS

[1] A. El-Baz, K. Youssef, and M. Mohamed, "Innovative improvement of a drag wind turbine performance," Renewable Energy, vol. 86, pp. 89–98, 2016.

[2] A. El-Baz, N. Mahmoud, A. Hamed and K.Youssef, "Optimization of two and three rotor Savonius wind turbine," Proceedings of ASME Turbo Expo, 2015.

[3] A. El-Baz, K.Youssef, and M. Abdel-Maksoud, "Improving the performance of Savonius wind turbine using three-rotors design," Proceedings of ICFD11, 2013.

STATEMENT

This thesis is submitted in partial fulfillment for the degree of Master of Science in Mechanical Power engineering, to the Faculty of Engineering, Ain Shams University.

The work included in this thesis was carried out by the author, primarily at the laboratories of the Mechanical Power Engineering Department, Faculty of Engineering, Ain Shams University.

No Part of this thesis has been submitted for degree or qualification at any other university.

Signature

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Date: / / 2015

Board of Supervisors

The undersigned certify that they have read and recommended to the Faculty of Engineering, Ain Shams University, for acceptance a thesis entitled **"Performance Assessment of an Interactive Three-Rotor Savonius Wind Turbine"**, submitted by **Khaled Youssef Mohamed Youssef**, in Partial Fulfillment for the Requirements of the Degree of Master of Science in Mechanical Engineering.

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ABSTRACT

Vertical axis type wind turbines have strong potential in small and medium power applications due to their simple design. However, a major disadvantage of this design is the noticeable low conversion efficiency. Therefore, more research is required to improve the efficiency of this design. The present work introduces a novel design of a two and three rotor Savonius turbine with rotors arranged in a parallel pattern. The performance of the new design is assessed by computational modeling of the flow around the turbine. A 2D computational model is firstly applied to investigate the performance of a single rotor design to validate the model by comparison with experimental measurements available in the literature. The model introduced an acceptable accuracy compared to the experimental measurements. The performance of the new design is then investigated using the same model. In addition, numerical optimization of the design parameters of two and three rotors Savonius turbine have been performed using the commercial finite volume solver ANSYS FLUENT [14.5] coupled with optimization code ModeFRONTIER®. The new turbine design was found to have higher power coefficient compared with single rotor design. The peak average power coefficient of the two rotors design was computed to be 60 % greater than that of the single rotor design while the three rotors was computed to be 70 % greater than that of the single rotor design. Furthermore, the torque coefficient was also higher than that of the single rotor turbine at high tip speed ratio. This improved performance is attributed to the favorable aerodynamic interaction between the rotors which accelerates the air flow around the rotors and generates higher turning torque in the direction of rotation for each rotor. The optimized arrangement for two-rotor turbine showed that the upper and lower rotor should have an opposite rotation direction. The optimized arrangement of three-rotor turbine showed that the upstream rotor and one downstream rotor should have a similar direction of rotation while the second downstream rotor is rotating in opposite direction. The obtained results encourage developing new applications of the Savonius wind turbine.

Nomenclature

Roman Symbols

$A_r = H/D$	Aspect ratio	[-]
C_m	Turbine torque coefficient	[-]
C_p	Turbine power coefficient	[-]
D_o	End plate diameter	[m]
d_s	Turbine shaft diameter	[m]
R_d	Down rotor rotation direction	[-]
R_l	Left rotor rotation direction	[-]
R_u	Upper rotor rotation direction	[-]
S_d	Down rotor spacing	[m]
S_l	Left rotor spacing	m]
S_u	Upper rotor spacing	[m]
U^+	Dimensionless velocity	[-]
u_τ	frictional velocity	$[m/s]$