AIN SHAMS UNIVERSITY
FACULTY OF ENGINEERING
MECHANICAL POWER DEPARTMENT

STUDY OF THE PERFORMANCE OF THREE INTERACTING STRAIGHT BLADED DARRIEUS VERTICAL AXIS WIND TURBINES

A thesis submitted for the partial fulfillment of Ph. D. degree in mechanical engineering

By

Eng. Mohamed Abdelrahman Elmetwally Elbeltagy
M. Sc. In Mechanical Power Engineering 2011

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STATEMENT

This thesis submitted as partial fulfillment of Ph. D. degree in mechanical engineering, Faculty of Engineering, Ain Shams University.

The author carried out the work included in this thesis, and no part of it has been submitted for a degree or qualification at any other scientific entity.

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THESIS SUMMARY

The current study experimentally and numerically investigates the effect of the wake interaction among multi turbines of straight bladed Darrieus vertical axis wind turbines. The experimental study was conducted using a wind tunnel with an open test section. The uniformity of the wind tunnel was studied and enhanced to give a better face velocity distribution. The numerical study was conducted using a commercial ANSYS CFD software. The experimental results of two test cases, from the literature and from the current experimental study, were used to validate the CFD software. The simulation results, obtained by the CFD software, were found to be in good agreement with the experimental results. Three typical five bladed turbines were used in this study. Various two turbine and three turbine configurations were examined experimentally and numerically to reach the optimum configuration in terms of power coefficient. The results showed that in two turbine arrangement, the co-rotation configuration was better than any of the counter-rotation configurations in terms of power coefficient and the closer the gap between turbines, the better the performance in terms of power coefficient, while the aligned configuration appeared to be the best

in terms of power coefficient, rather than any of the staggered configurations. In three turbine arrangement, it was found that the co-rotation configuration was better than the counter-rotation configuration in terms of power coefficient, while the aligned configuration was better than any of the triangle shaped configurations in terms of power coefficient.

Key Words:

Vertical axis wind turbine, Darrieus straight bladed wind turbine, wind energy, wind tunnel, efficiency, power coefficient, tip speed ratio, CFD simulation, turbulence model

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Mohamed Al Beltagy

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TABLE OF CONTENTS

NOMENCLATURE

A	Turbine Swept Area (m^2)
c	Blade Chord Length (m)
C_d	Drag Coefficient
C_l	Lift Coefficient
C_m	Moment Coefficient
C_p	Power Coefficient
D	Drag Force (N)
d	Turbine Diameter (m)
F_N	Normal Force (N)
F_T	Tangential Force (N)
g	Gravitational Acceleration (m/s^2)
H	Blade Height (m)
h	Deflector Height (m)
I	Turbulent Intensity (%) - Electrical Current (A)
k	Turbulent Kinetic Energy (m^2/s^2)
L	Lift Force (N)
l	Normal Distance (m)
M	Moment (N.m)
n	Number of Blades
P	Power (W)
p	Pressure (Pa)
$P_{elec.}$	Electrical Power (W)
Pe	Peclet Number, Pe = Re Pr
Pr	Prandtl Number, Pr = $c_p \mu$ / k
R	Turbine Radius (m)

Re	Reynolds Number, $Re = V\ d\ /\ \nu$
$R_{elec.}$	Electrical Resistance (Ω)
S	Strain Rate (1/s)
Sc	Schmidt Number
t	Time (s)
U	Turbulent Velocity (m/s)
V	Air Velocity (m/s)
$V_{elec.}$	Voltage (V)
W	Relative Velocity (m/s)
w	Width (m)