شبكة المعلومات الجامعية
التوثيق الإلكتروني والميكروفيلم

بسم الله الرحمن الرحيم

HANAA ALY

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جامعة عين شمس

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قسم

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HANAA ALY

Ain Shams University

Faculty of Engineering

A Research Study on the Design Parameters of Dual Rotor Wind Turbine

Thesis Submitted to the Faculty of Engineering Ain Shams University

For Partial Fulfillment of the Degree of Master of Science in Mechanical Power Engineering

By:

Hazem Ali Mohamed Ali Abdelkarim

Bachelor of Science in Mechanical Engineering
The British University in Egypt – 2014

Supervised By:

Prof. Dr. Nabil Abdel-Aziz Mahmoud

Professor of Mechanical Power Engineering Department,
Faculty of Engineering, Ain Shams University.

Prof. Dr. Ahmed Mohamed Reda El-Baz

Professor of Mechanical Power Engineering Department,
Faculty of Engineering, Ain Shams University.

Dr. Ashraf Mostafa Hamed

Doctor of Mechanical Power Engineering Department,
Faculty of Engineering, Ain Shams University.

Cairo - 2020

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EXAMINERS COMMITTEE

Name	**signature**
Prof. Ahmed Farouk Abdel Gawad **Mechanical Power Engineering Department** **Faculty of Engineering – zagazig University**	…………………………
Prof. Ashraf A. E. Ghorab **Mechanical Power Engineering Department** **Faculty of Engineering – Ain Shams University**	…………………………
Prof. Nabil Abdel Aziz Mahmoud **Mechanical Power Engineering Department** **Faculty of Engineering – Ain Shams University**	…………………………
Prof. Ahmed Mohamed Reda El Baz **Mechanical Power Engineering Department** **Faculty of Engineering – Ain Shams University**	…………………………

Date : …/…/….

List of Publications

1- **H. A. Abdelkarim, N. A. A. Mahmoud, A. R. El-Baz and A. M. Hamed, "Numerical Analysis on the Performance of Dual Rotor Wind Turbine," International Journal of Scientific Research and Management (IJSRM), vol. 08, no. 03, pp. 352-368, 2020.**

STATEMENT

This thesis is submitted to Ain Shams University in partial fulfillment of the requirement for the M.Sc. Degree in Mechanical Power Engineering, Ain Shams University.

The work included in this thesis has been carried out by the author in Mechanical Power Engineering Department, Ain Shams University.

No part of the thesis has been submitted for a degree or a qualification at other university or institute.

Signature:

Name: Hazem Ali Mohamed Ali Abdelkarim

Date:

Researcher Details

Name of Researcher	Hazem Ali Mohamed Ali Abdelkarim
Date of Birth	Jan, 10th 1993
Place of Birth	Cairo - Egypt
Nationality	Egyptian
University degree	B.Sc. Mechanical Engineering
Department	Mechanical Department
University	The British University in Egypt
Date of Degree	July 2014
Current Job	Equipment Engineer at TRANE Co.

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ABSTRACT

This study investigates the aerodynamic performance of a special modification on the horizontal axis wind turbines aiming to maximize the power extracted from the wind. The study focuses on the effect of introducing a second rotor to the main rotor of the wind turbine in what is called a dual-rotor wind-turbine (DRWT). The numerical study was investigated on the performance of small-scale model of a wind turbine of 0.9 m diameter using S826 airfoil.

Both the Co-rotating and Counter-rotating configurations were investigated at different tip speed-ratios (TSR) and compared with the performance of the single rotor wind turbine (SRWT). Many parameters were studied in the dual-rotor turbines. These include the spacing between the two rotors, the pitch angle of the rear rotor, changing the rotation speed ratio between the rear and front rotor and the effect of the diameter ratio (D_{ratio}) between the front and rear rotor. Three-dimensional simulations were performed using Multi-Reference Frame (MRF) technique.

The Co-Rotating Wind Turbine (CWT) and Counter-Rotating Wind Turbine (CRWT) were found to have better performance compared to that of the SRWT with an increase of 12 to 14% in peak power coefficients. Moreover, the effect of changing the pitch angle of the rear rotor on the overall performance was found to be of a negligible effect between angles 0^{o} and 2^{o} tilting toward the front rotor. On the other hand, the ratio of rotational speed of the rear rotor to the front rotor was found to cause a further increase to the peak performance of the CWT and CRWT of about 3 to 5%. The study ends up with investigating the effect of changing the diameter ratio between the two rotors, separating distance, and the rotation speed ratio as well as study the effect on the overall performance compared to the SRWT.

KEY WORDS:

Dual-rotor wind-turbines, Counter-rotating wind turbines, Co-rotating wind turbines, Computational fluid dynamics, Power coefficient.

NOMENCLATURE

Roman Symbols

A	Wind Turbine Rotor Swept Area	[m^2]
C_d	Drag Coefficient	[-]
C_L	Lift Coefficient	[-]
Cp	Power Coefficient	Cp
C_T	Moment Coefficient	[-]
D	Single Rotor wind turbine Diameter	[m]
D_F	Front Rotor Diameter	[m]
D_r	Rear Rotor Diameter	[m]
D_{ratio}	Diameter Ratio between rear and front rotor	[-]
F_x	Axial Force	[N]
K	Turbulent Kinetic Energy	[J]
N	Rotational Speed for Single rotor wind turbine	[rpm]
N_f	Front Rotor Rotational Speed	[rpm]
N_r	Rear Rotor Rotational Speed	[rpm]
N_{ratio}	Rotational Speed Ratio rear to front rotor	[-]
P	Power extracted from wind stream	[Watt]
R	Wind Turbine Rotor Radius	[m]
R_f	Front Rotor Radius	[m]
R_r	Rear Rotor Radius	[m]

T	Torque	[N . m]
u	Velocity in X-direction	[m/s]
$\bar{u}$	Mean velocity in X-direction	[m/s]
u'	Fluctuating velocity in X-direction	[m/s]
V_e	Velocity at exit of wind turbine	[m/s]
V_i	Velocity at inlet of wind turbine	[m/s]
V_r	Wind velocity at reference height	[m/s]
V_{wind}	Velocity of the Upcoming wind stream	[m/s]

Greek Symbols

ρ_{air}	Air density	[kg/m^3]
μ	Dynamic viscosity	[Pa.s]
$U*$	Friction Velocity	[m/s]
α	Hellmann exponent	[-]
ν	Kinematic viscosity	[m^2/s]
Θ	Pitch angle rear to front rotor	[Degree]
λ	Tip speed ratio	[-]
ω	Turbine angular speed	[rad/s]
Y^+	Y Plus	[-]

Abbreviations

BEM	Blade Element Momentum Theory
CFD	Computational Fluid Dynamics
CRWT	Counter-Rotating Wind Turbine
CWT	Co-Rotating Wind Turbine
DRWT	Dual-Rotor Wind Turbine
HAWT	Horizontal-Axis Wind Turbine
MRF	Multi-Reference Frame
OPT	Optimal Twist and Tapered
SRWT	Single-Rotor Wind Turbine
SST	Shear Stress Transport Turbulence Theory
TSR	Tip Speed-Ratio
TUT	Tapered and Un-Twisted
UOT	Untapered and Optimum Twist
UUT	Untapered and Untwisted
VAWT	Vertical-Axis Wind Turbine

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