IMPROVED ROTOR DESIGN FOR A SMALL SCALE HORIZONTAL AXIS WIND TURBINE SUITABLE FOR LOW WIND POTENTIAL

By

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Declaration

I hereby declare that this submission is my own work and that, to the best of my knowledge and behalf, it contains no material previously published or written by another person nor material, which to substantial extent, has been accepted for the award of any other academic qualification of a university or other institution of higher learning except where acknowledgment is made in the text.

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CONTENTS

Page

Abstract VI

List of figures VII

List of tables IX

Nomenclature XI

1. Introduction 1

1.1. Current global status of energy generation 1

1.2. Wind as a source of energy 4

1.3. Wind Energy application in Sri Lanka 6

1.3.1. Wind energy for water pumping in Sri Lanka 6

1.3.2. Rural electrification 7

1.3.3. Grid connected wind turbines in Sri Lanka 9

1.4. 100W NERDC wind turbine for off-grid power generation in Sri Lanka 9

1.5. Objectives 11

1.6. Outline of thesis 11

2. Performances analysis of wind rotors 13

2.1. Introduction 13

2.2. Aerodynamic behaviour of a wind rotor 14

2.2.1. Ideal performance of a wind rotor 14

2.2.2. Performance of a wind rotor with wake rotation effect 16

2.2.3. Performance of a wind rotor with effect of wake rotation and blade resistance 21

2.2.4. Vortex system of the rotor 25

2.3. Performances of the wind rotor developed by NERD Centre 27

3. Electrical generators used for wind turbines 32

3.1. Generators used for the grid connected applications 32

3.1.1 Introduction 32

3.1.2 Wind turbine with asynchronous (induction) generators 32

3.1.3 Wind turbine with multi-pole permanent magnet generators. 33

Page

3.1.4 Wind turbine with synchronous generators 34

3.2. Generators used for small scale off - grid wind turbines 35

3.3. Performances of the permanent magnet generator developed by NERDC 36

3.3.1 Development of a suitable electrical generator for micro scale power generation 36

3.3.2 Design parameters of PMG 37

3.3.3 Characteristics of the permanent magnet generator 41

4. System performance of the battery-charging wind turbine of the NERD centre 44

4.1. Introduction 44

4.2. Combined characteristics of NERDC wind rotor and generator 44

4.3. Performance of the system at different sites 48

4.3.1 Design wind speed 48

4.3.2 Energy indices of the wind turbine 49

4.3.3 Performance of the wind turbine at a low wind potential site 49

4.3.4 Performance of the wind turbine at a high wind potential site 52

4.3.5 Comparison of performance of the wind turbine at two different sites 54

4.4. Energy requirement of a rural community 55

5. Design of a wind rotor suitable for low wind potential 56

5.1 Selection of operation parameters 56

5.2 Modification on increasing diameter together with same solidity of the existing wind rotor 56

5.3 Initial torque of the wind rotor and the permanent magnet generator 60

5.4 Design of a high solidity wind rotor 61

5.5 Perform of the high solidity wind rotor in low wind potential site 66

6 Validation by model testing 74

6.1 Introduction 74

6.2 Dimensional analysis and physical modelling 74

6.1.1 Governing parameters 74

Page

6.1.2 Scale down models of wind rotors 76

6.3 Experimental set up 77

6.4 Comparison of the performance of the models of existing rotor and high solidity rotor 81

6.4.1 Experimental investigation 81

7 Discussion and Conclusions 88

7.1 Wind rotor performance 88

7.2 Energy options 89

7.3 Concluding remarks: cost of energy production 90

7.3.1 Cost of energy at Makewita low wind potential site 90

7.3.2 Cost of energy at Mirijivila good wind potential site 91

7.3.3 Cost of energy from 100W solar panel 91

7.3.4 Comparison of cost of energy production and amount of energy generation by solar and wind power systems 92

References 94

Appendix I 96

Appendix II 98

Appendix III 101

Appendix IV 102

Appendix V 104

Appendix VI 107

ABSTRACT

The design wind speeds of most of the existing wind turbine rotors are in the range of 6 to 15 m/s with cut-in wind speed of 3.5 m/s. The performance of such a wind turbine in Sri Lanka is not satisfactory, where the wind velocities are relatively low. This is due to low initial torque, which leads to difficulty in starting, as well as due to poor running efficiencies. This makes wind turbines less attractive for areas with low wind speeds.

The main objectives of this study were to predict the performance of the existing NERDC wind turbine system and identify the main causes for its poor running performance at low wind speed and thereby design a rotor with improved performance. When improve the performance of the rotor to extract more energy from low wind-speeds, cut-in wind speed and design wind speed of wind turbine should be reduced. Low starting torque of wind rotors was identified as a main restriction against the reduction of cut-in wind speed of wind turbines. This study intends to analyse the aerodynamics of wind rotors theoretically and thereby introduces appropriate changes to the geometrical parameters of the blades. Especially, possibility of increase of solidity of the rotor, without effecting adversely on its aerodynamic efficiency was analysed.

The blade elementary theory and the momentum theory were used to analyse the aerodynamic performance of rotors theoretically and these results were validated by wind tunnel model testing.

The results of this study indicate that the permanent magnet generator and rotor of the NERDC system were not matched properly, which resulted in low overall system efficiency. In addition, the design parameters of the rotor were not appropriate for sites with low wind potential. Other finding of this study was suitable wind rotor for extract more energy from low wind potential, should be with higher diameter and higher solidity.

LIST OF FIGURES

			Page
1	Figure 1.1	Global primary energy requirements, 1850 - 2100	3
2	Figure 1.2	Global carbon emissions from fossil fuel use, 1850 – 2100	3
3	Figure 1.3	Development of the wind energy use wordwide	5
4	Figure 1.4	Wind energy use by continents in percentage at the end of 2000	6
5	Figure 1.5	Basic configuration of NERDC wind turbine	10
6	Figure 2.1	Control volume used for a wind turbine	15
7	Figure 2.2	Flow behind the rotor with "Wake Rotation" effect	17
8	Figure 2.3	Velocity diagram of a blade element	17
9	Figure 2.4	Maximum power coefficient of ideal wind rotor with wake effect	20
10	Figure 2.5	Forces diagram of a blade element	21
11	Figure 2.6	Power coefficient Vs tip speed ratio (λ_0), for different C_l/C_d	24
12	Figure 2.7	Vortices due to tip of the blade	25
13	Figure 2.8	Simplified vortex system of a wind rotor	26
14	Figure 2.9	Existing 2-bladed wind rotor of the NERDC	28
15	Figure 2.10	Power coefficient curve of the existing NERDC wind rotor	29
16	Figure 2.11	Power performance of the existing NERDC wind rotor with different wind speeds	30
17	Figure 2.12	Torque performance of the existing NERDC wind rotor with different wind speeds	31
18	Figure 3.1	Combine characteristics of wind rotor and induction generator at different wind speed	33
19	Figure 3.2	Combine characteristics of wind rotor and multi-pole PMG at different wind speed	34
20	Figure 3.3	Combine characteristics of wind rotor and synchronous generator	35
21	Figure 3.4	Section of rotor showing magnetic circuit	39
22	Figure 3.5	Rotor of the permanent magnet generator (PMG)	40
23	Figure 3.6	NERDC permanent magnet generator	40
24	Figure 3.7	Experimental set-up to find out the performance of permanent magnet generator	41
25	Figure 3.8	Characteristic performance of permanent magnet generator (PMG) with 24V battery bank	42
26	Figure 4.1	Generator and rotor performance curves of NERDC wind-turbine	45
27	Figure 4.2	Combine performance of the generator and the rotor	46

			Page
28	Figure 4.3	100W NERDC wind turbine	47
29	Figure 4.4	Output power characteristics of NERDC wind turbine	48
30	Figure 4.5	Wind speed and energy distribution at Makewita, Ja-Ela, height 20m	50
31	Figure 4.6	Wind speed and Energy, frequency distribution at Mirijivila, height 20 m	52
32	Figure 5.1	Generator and rotor performance curves of the modified NERDC wind turbine (with 1:3 gear box)	57
33	Figure 5.2	Performance of modified wind turbine	58
34	Figure 5.3	Initial torque of modified wind rotor with different wind speeds	61
35	Figure 5.4	Optimum incidence angle at the section r=0.9R=1980 mm	61
36	Figure 5.5	Optimum incidence angle at the section r=0.4R=880 mm	64
37	Figure 5.6	Linearized blade angles of high solidity rotor	65
38	Figure 5.7	High-solidity 4-bladed wind rotor	66
39	Figure 5.8	Power coefficient curve of 4-bladed high solidity wind rotor model	67
40	Figure 5.9	Combine performance of 4-bladed rotor and PMG (with 1:5 gear box)	67
41	Figure 5.10	Initial torque of high solidity wind rotor with different wind speeds	68
42	Figure 5.11	Performance of high-solidity 4-bladed wind turbine	69
43	Figure 5.12	Overall efficiency of wind turbines	72
44	Figure 6.1	Configuration of the set-up and air velocity data points	78
45	Figure 6.2	Friction pulley arrangement of break dynamometer	79
46	Figure 6.3	Wind tunnel and experimental set-up	80
47	Figure 6.4	Power characteristics of the manufactured 2- bladed model	82
48	Figure 6.5	Torque characteristics of the manufactured 2-bladed model	83
49	Figure 6.6	Power characteristics of the manufactured 4-bladed model	85
50	Figure 6.7	Torque characteristics of the manufactured 4-bladed model	85
51	Figure 6.8	Typical rotor curves and load curves of friction pulley	86

LIST OF TABLES

			Page
1	Table 1.1	World Energy Use by Source in 1900 and 1997	1
2	Table 1.2	CO_2-Emissions of commonly used fuels	2
3	Table 1.3	Forecast of renewable energy electricity generation capacity (MWe)	4
4	Table 1.4	Top five nations in wind energy usage at the end of year 2000	5
5	Table 2.1	Maximum C_p with λ_0 of an ideal wind rotor with wake effect	20
6	Table 2.2	Geometrical parameters of existing 2-bladed wind rotor at NERDC	28
7	Table 2.3	Theoretically calculated performance of the wind rotor	29
8	Table 3.1	Stator details	38
9	Table 3.2	Windings details	38
10	Table 3.3	Characteristic performance of permanent magnet generator (PMG) with 24V battery bank	42
11	Table 4.1	Performance of NERDC wind turbine	47
12	Table 4.2	The energy calculation indices of NERDC wind turbine at Makewita site	51
13	Table 4.3	Energy indices of high solidity wind turbine at Makewita site	51
14	Table 4.4	The energy calculation indices of NERDC wind turbine at Mirijivila site	53
15	Table 4.5	Energy indices of high solidity wind turbine at Mirijivila site	53
16	Table 4.6	Comparison of energy indexes of Makewita and Mirivila sites	54
17	Table 4.7	The daily energy demand for a typical rural house in Sri Lanka	55
18	Table 4.8	Efficiency of electrical equipment used in wind power generation	55
19	Table 5.1	Performance of modified wind turbine by increasing diameter of rotor together with same solidity of the existing wind rotor	58
20	Table 5.2	The energy calculation indices of NERDC modified wind turbine at Makewita site	59
21	Table 5.3	Performance comparison of existing and modified wind turbines	59
22	Table 5.4	Selected solidity of wind rotor to obtain the required higher torque coefficient (C_m)	62

			Page
23	Table 5.5	Optimum incidence angles, blade angles and chord lengths at the section r=0.4R and r=0.9R of the designed wind rotor	65
24	Table 5.6	Geometrical parameters of high solidity wind rotor	65
25	Table 5.7	Performance of high solidity wind turbine	69
26	Table 5.8	The energy calculation indexes of high solidity 4-bladed wind turbines at Makewita site	70
27	Table 5.9	Energy indices of high solidity wind turbine at Makewita site	70
30	Table 5.10	Comparison of performance existing, modified and designed wind turbines	71
31	Table 5.11	Overall efficiency η_{ove} % of wind turbines	71
32	Table 6.1	Parameters of existing wind rotor Model	77
33	Table 6.2	Parameters of high solidity wind rotor	77
34	Table 6.3	Geometrical parameters of the 2-bladed rotor model	81
35	Table 6.4	Geometrical parameters of the 4-bladed rotor model	81
36	Table 6.5	Experimental C_p & C_m values of 2-bladed low solidity wind rotor	82
37	Table 6.6	Experimental C_p & C_m values of 4-bladed high solidity wind rotor model	84
38	Table 7.1	Capital cost, cost of energy production and amount of energy generation by each wind turbines and 100W solar panel	92

NOMENCLATURE

$\dot{Q}$ - Flow rate of air

η_p - Tip loss of the wind rotor

α - Angle of attack

ω - Angular speed of the rotor

β - Blade angle

Γ - Circulation

ρ - Density of air

μ - Viscosity of air

Ω - Rotational speed of the air in the rotor wake

λ_0 - Tip speed ratio

ϕ_0 - Incidence flow angle

ϕ_g - Magnetic flux at the air gap of the generator

λ_r - Local speed ratio

A - Swept area of the wind rotor

b - No. of blades

C_d- Drag coefficient

C_l - Lift coefficient

C_m - Coefficient of moment

C_p - Coefficient of power

C_{Pmax}- Maximum power coefficient

C_{Pr} - Local power coefficient

D - Drag

F - Axial thrust

K_d - Distribution factor

K_f - Pitch factor

L - Lift

l - Chord of the blade

M - Moment

MTOE- Million tons of oil equivalent

N - Rotational speed of generator

n_b - Hub ratio of wind rotor

P - Number of poles

P_0 - Energy content in the undisturbed wind

P_u - Rotor power

R - Radius of the rotor

r_0 - Hub radius

Re - Reynolds No

T - Torque

V_1 - Undisturbed velocity of air

V_2 - Axial velocity of air at down stream wake

W - Velocity of wind relative to the rotor blade

Z_n - Number of conductors