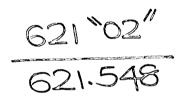
LB/DON/106/02/DeprofME-US:

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

By

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This Thesis was Submitted to the Department of Mechanical Engineering of the University of Moratuwa, Sri Lanka in Fulfilment of the Requirements for the Degree of Master of Philosophy



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August 2002

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.

UOM Verified Signature

..... Mahinsasa Narayana

I certified that the above statement is correct alway. Sri Lanka

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Supervisor

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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.



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NOMENCLATURE

- 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
- C₁ 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
- 1 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
- P₀ Energy content in the undisturbed wind
- P_u Rotor power
- R Radius of the rotor
- r₀ Hub radius
- Re Reynolds No
- T Torque
- V₁ 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



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