The Relationship between the Variable Values of Wind Turbines

Zaki Haddad

Damascus University, Syria.

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Abstract There is widespread recognition that renewable fuels offer at least a partial solution to global warming. Thus, much of the research on wind generation focuses on designing and engineering wind turbines and their components, as well as sitting on and offshore wind farms for maximum output [1]. This paper examines the relationship between the variables values of wind turbines, such as blade rotational speed, wake rotational speed, wind velocity and blade tip radius, theoretically depending on the blade element momentum, or BEM, in order to identify the most suitable turbines based upon the locale being considered.

Keywords Air speed, blade rotational speed, wake rotational speed, wind farm, rotor wind turbine

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1 Introduction

Globally, wind energy is becoming a prominent source of renewable energy, and nowadays is exerting much effort to improve its generational effectiveness. This research examines the relationship between the variables values of wind turbines ($\Omega^*\omega, v_1, R$) operating under ideal conditions. The theoretical objective is to find the turbines' highest efficiency [2].

Corresponding author: hcfre@engineer.com

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2 Literature Review

Blade element momentum (BEM) is a method that explains how the aerodynamics forces affect the rotor wind turbine [2], [3], [4]. Reference [2] presents the axial forces

$$df_x = \frac{1}{2}\rho\upsilon_1^2[4\alpha(1-\alpha)]\,2\pi rdr \quad (1)$$

The axial torque [2] presents

$$dT = \rho 2\pi rdr\upsilon_2\omega r^2 = \rho\upsilon_1(1-\alpha)\,\omega r^2\,2\pi rdr \quad (2)$$

The max power theoretically [2, 3, 4] presents

$$P = \frac{16}{27}\frac{1}{2}\rho\pi R^2\upsilon_1^3 \quad (3)$$

The wake of wind turbine has been studied several ways [1], [4]. Thus, [4] gives turbulence intensity, $I_{T,total}$, as:

$$I_{T,total} = \sqrt[m]{(1-N.P_w)\,I_T^m + P_w\sum_{i=1}^{N} I_{T,w}^m . S_i} \quad (4)$$

2.1 *The Relationship between Variables Values of a Wind Turbine*

The max torque T_{max} is calculated at α= 1/3. The theoretical result can be written as:

$$T_{max} = \frac{\pi}{2}\rho\omega\upsilon_1(1-\frac{1}{3})\,R^4 \quad (5)$$

$$T_{max} = \frac{2}{3}\frac{\pi}{2}\rho\omega\upsilon_1 R^4 \quad (6)$$

The torque can be extracted from equation (3):

$$T = \frac{p}{\Omega} = \frac{\frac{16}{27}\frac{1}{2}\rho\pi R^2\upsilon_1^3}{\Omega} \quad (7)$$

From equations (6,7) we have:

$$T = \frac{\pi}{2}\frac{2}{3}\rho\omega\upsilon_1 R^4 = \frac{\frac{16}{27}\frac{1}{2}\rho\pi R^2\upsilon_1^3}{\Omega} \quad (8)$$

$$\Omega\omega = \frac{8}{9}\frac{\upsilon_1^2}{R^2} \quad (9)$$

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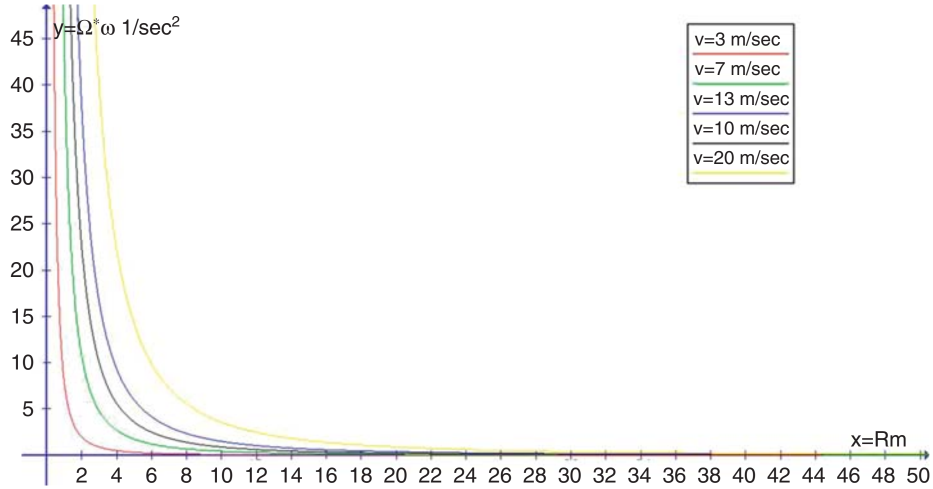

Figure 1 Relationship between Ω*ω and v_1,R.

Equation (9), which shows the relationship between variables values Ω*ω and v_1,R, allows us to choose the best values when designing the wind turbine and wind farm.

Figure (1) shows the relationship between Ω*ω rotation rotor wind turbine * rotation wake rotor wind turbine, v_1 air speed (3m/sec start velocity, 7m/sec operation velocity for a small wind turbine, 10m/sec operation velocity for a medium wind turbine, 13m/sec operation velocity for a large wind turbine, 20 m/sec out services velocity for wind turbines) and R radius rotor wind turbine. We note that the wake decreases when the radius of a wind turbine increases. That is, the wake will be very low when the radius is up to 20 m and the rotation wake will be very high when the radius is less than 4 m. Figure (1) also shows that when wind velocity is low, 3 m/sec (red line) the weak is very low and when it is high, the weak is also high, 20 m/sec (yellow line). The rotor wind turbine can be chosen at the minimum value of wake, so the diagram of the turbine's generator (supplied by the manufacturer) determines the rotation of the generator and the production power from it, which helps to find the rotation of wake so the values of β (the relative flow angle). The wind farm can be designed when the value of the wake is known [4].

3 Conclusion

This research has explained how the rotors of wind turbines can be chosen theoretically based on the variables values Ω*ω,v_1,R, in order to design the most suitable turbines for a particular operational site.

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Nomenclature

α	Axial induction factor
A	Area
c	Aerofoil chord length
C_P	Power coefficient
D	Rotor diameter
E	Kinetic energy
F	Force
$I_{T,total}$	Maximum turbulence intensity at hub height in the centre of the wake
m	Wohler curve exponent corresponding to the material of the considered structural component
N	Number of closest neighboring wind turbines
p	Pressure
P	Power
p_w	Probability of wake condition
r	Radiuses and radial direction
R	Blade tip radius
T	Torque
V	Velocity
x_i	Distance to the i'th wind turbine
β	Relative flow angle onto blades
λ	Tip speed ratio
ρ	Density
Ω	Blade rotational speed
ω	Wake rotational speed
γ	Aerofoil inlet angle

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