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Modeling and Simulation of Wing Turbine at Different Wind Speed

Dharmesh M. Savsani[1], Nitika Agarwal[2]

[1]School of Engineering, R.K. University, Rajkot, Gujrat, INDIA

[2]Assistant Professor, Electrical Department, School of Engineering, R.K. University, Rajkot, Gujrat, INDIA

ABSTRACT

This paper presents the modeling and simulation of wind turbine model using MATLAB/Simulink software package. The proposed model is design with a user-friendly icon using Simpower of Simulink block libraries. Taking the effect of wind speed into consideration, the output mechanical torque and mechanical power of wind turbine model are simulated using the proposed model.

Keywords— Wind turbine; power co-efficient (Cp) model; mechanical torque model; mechanical power model.

I. INTRODUCTION

Wind power growth with a 20% annual rate has experienced the fastest growth among all renewable energy sources since five years ago. It is predicted that by 2020 up to 12% of the world's electricity will have been supplied by wind power. [1]

Wind is stochastic in nature; speed and direction of wind at a location vary randomly with time. Apart from the seasonal and daily variations, the wind pattern may change from year to year even to the extent of 10 to 30 per cent. Hence, the behaviour of the wind at a prospective site should be properly analyzed. The wind, for example the shoreline breeze, is the result of uneven heating of the earth by the sun. Sea breezes, result of the seas ability to maintain temperature. Daytime land heats sea is cool & night time land cools faster than sea[1]. This concept is as shown in Fig.1. Principle of wind turbine also deals with the two types of force Drag and Lift. Generally drag forces termed as a loss for WT so it should be minimized but it is always present.

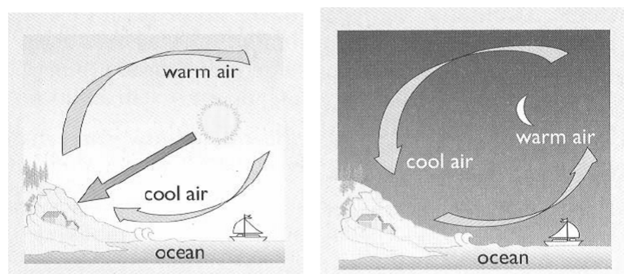

Fig.1 Basics of Wind energy- Wind generation

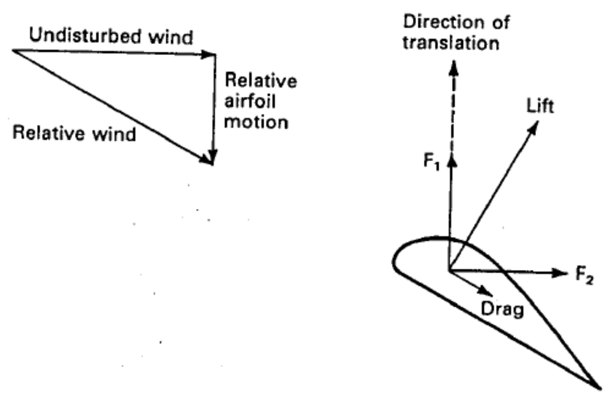

Fig.2 Lift and drag on a stationary airfoil and Lift and drag on a translating airfoil

II. MODELING OF WIND TURBINE

To maximize the energy production not only wind conditions and geometrical parameters of a wind turbine are significant, but the control strategy is very important, too. In order to develop and simulate the control system a proper model of the wind turbine has to be built. The model should be able to represent the nonlinear behaviour of wind turbines. Some simplifications can be assumed, which shorten the simulation time significantly while the simulation accuracy remains at a comparable level. This is important especially with respect to the simultaneous simulation of several units, i.e. wind farm simulation. One basic supposition is the one-dimensional wind flow, so the wind speed at the whole swept rotor area is assumed to be the same. Additionally, variations of the horizontal direction of wind speed are not considered, thus the wind is assumed to have a yaw angle of zero. In practice the horizontal variation causes an energy loss of 1-2% which can be neglected for the purpose of simulation [2].

In order to investigate the effectiveness of the energy conversion in wind energy conversion systems, first the available energy stored in the wind needs to be determined. Actually, the energy in the wind can be treated as the kinetic energy of a large amount of air particles with a total mass, m, moving at a wind velocity v[3]. Assuming that all the air particles are moving at the same speed and direction before impacting the rotor blades of the wind turbine, the potential available kinetic energy stored in the wind can be expressed according to the following expression[4]:

$$Ec = \frac{1}{2} m v^2$$

where, *Ec*, is the kinetic energy of the moving air particles, and is the total mass of the air particles, while ,v , is the velocity of the air particles (wind speed). Since the air particles are moving at a speed, v, the total mass, m can be rewritten as follows:

$$Pw = \frac{d}{dt} Ec$$
$$= \frac{1}{2} p s v^3$$

The actual wind power at any instant of time can be represented as:

$$p_{wind} = \frac{1}{2} p \pi R^3 v^3$$

Where, Pwind , is the potentially available power in the wind. We can observe that the wind power is proportional to the cube of the wind speed, which means that a small increase of the wind speed will result in a large increase of the wind power.

However, the power can only stand for the maximum potential power which is available when the wind with velocity, v, passes through the swept area of the wind turbine with radius, R. According to Betz's idea, after impacting the rotor blades of the wind turbine, the velocity of the wind decreases form v to v_2 which means that when the wind passes through the wind turbine blades, there is still some kinetic power left in the wind. The relationship between the power that is captured by the wind turbine and the potential maximum power in the wind can be expressed as follows:

$$Cp = \frac{Pm}{Pw}$$

where, Pm is the mechanical power captured by the wind turbine, and Cp is the power coefficient of the wind turbine which can be expressed as follows:

$$Cp(\lambda, \beta) = C1\left(\frac{C_2}{\gamma} - C_3\beta - C_4\beta - C_5\right) e^{-C_6 \frac{1}{\gamma}}$$

Where,

$$\frac{1}{\gamma} = \frac{1}{\lambda + 0.08\beta} - \frac{0.035}{1 + \beta^3}$$

And,

$$\lambda = \frac{R\omega}{v}$$

where, β, is the blade angle and λ is the tip speed ratio of the wind turbine, while, w, is the angular speed of the wind turbine generator. The values of the coefficients (c_1-c_6) depend on the type of the wind turbine.

Accordingly, the power captured by the wind turbine can be rewritten as:

$$Pm = \frac{1}{2} p \pi R^2 v^3 Cp$$

The wind turbine torque on the shaft is:

$$Tm = \frac{1}{2} p \pi R^2 v^3 \frac{Cp}{\omega}$$

III .SIMULATION AND RESULTS

The following simulations for the variable speed operation of wind energy conversion system, is used in MATLAB.

(1) power co-efficient (Cp) model

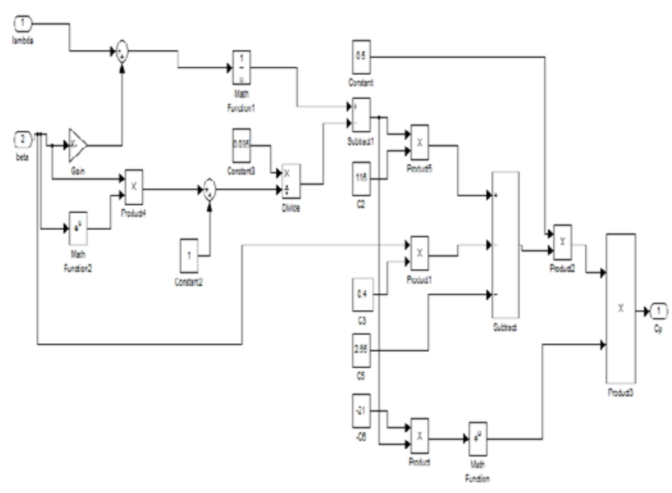

Fig.3 Simulation of power co-efficient model

(2) Mechanical torque (Tm) model

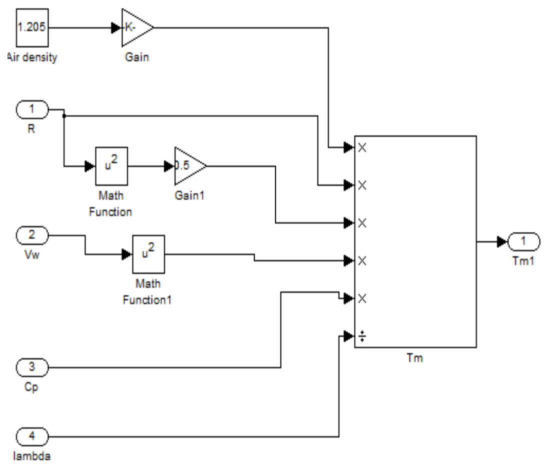

Fig.4 Simulation of mechanical torque model

(3) Wind turbine model

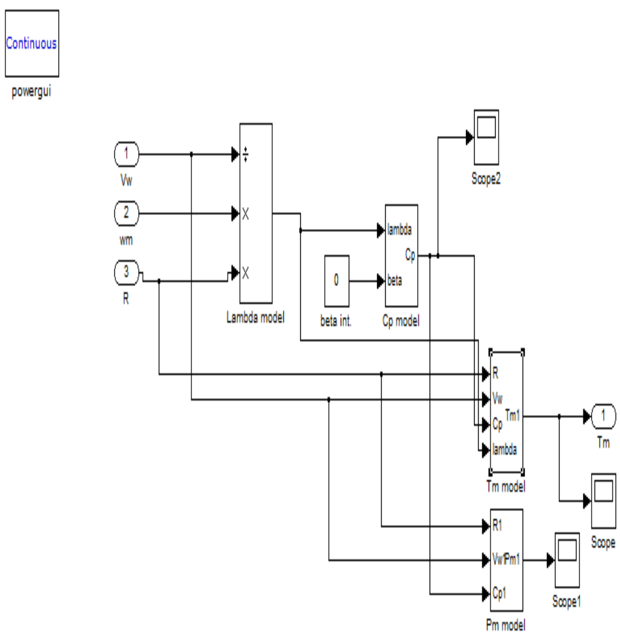

Fig.4 Simulation of wind turbine model

(4) Simulation result

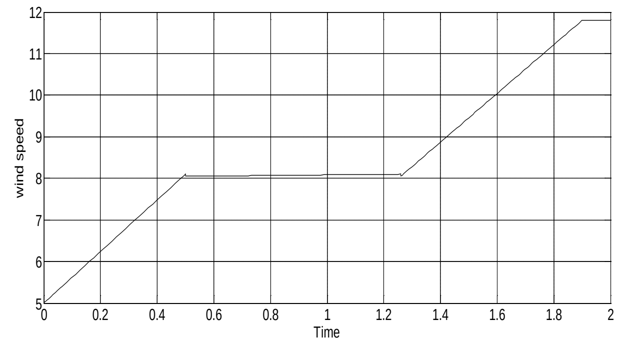

Fig.5 Wind speed input for the wind power generation system

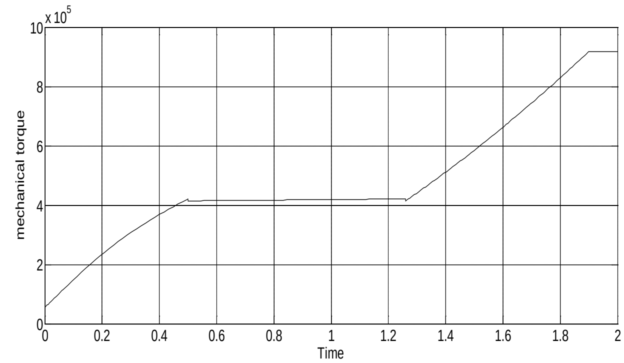

Fig.6 Mechanical torque of wind turbine

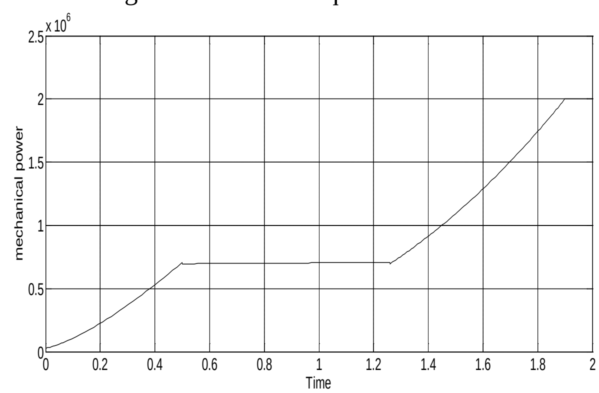

Fig.7 Mechanical power of wind turbine

IV. CONCLUSION

The modelling of a variable speed wind turbine has been treated. The model has been implemented in MATLAB/ Simulink in order to validate it mechanical torque and mechanical power have been obtained at different wind speed.

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