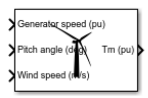
Wind Turbine

Implement model of variable pitch wind turbine



Libraries:
Simscape / Electrical / Specialized Power Systems / Electrical Machines

Description

The Wind Turbine block models the steady-state power characteristics of a wind turbine. The stiffness of the drive train is infinite and the friction factor and the inertia of the turbine must be combined with those of the generator coupled to the turbine. The output power of the turbine is given by the following equation.

$$P_m = c_p(\lambda, \beta)\frac{\rho A}{2}v_{\text{wind}}^3, \quad (1)$$

where:

P_m	Mechanical output power of the turbine (W)
c_p	Performance coefficient of the turbine
ρ	Air density (kg/m^3)
A	Turbine swept area (m^2)
v_{wind}	Wind speed (m/s)
λ	Tip speed ratio of the rotor blade tip speed to wind speed
β	Blade pitch angle (deg)

Equation 1 can be normalized. In the per unit (pu) system we have:

$$P_{m\_\text{pu}} = k_p c_{p\_\text{pu}} v_{\text{wind\_pu}}^3,$$

where:

P_{m_pu}	Power in pu of nominal power for particular values of ρ and A
c_{p_pu}	Performance coefficient in pu of the maximum value of c_p
v_{wind_pu}	Wind speed in pu of the base wind speed. The base wind speed is the mean value of the expected wind speed in m/s.
k_p	Power gain for c_{p_pu}=1 pu and v_{wind_pu}=1 pu, k_p is less than or equal to 1

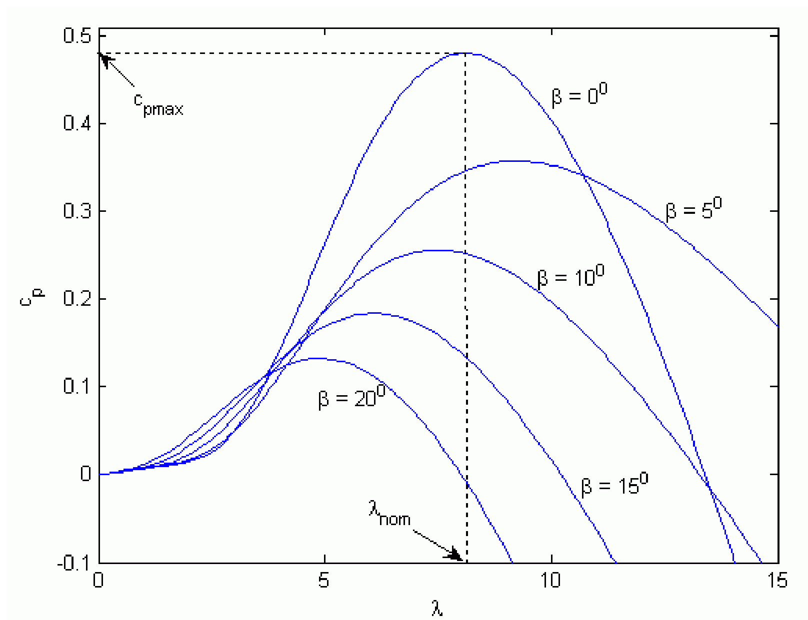
A generic equation is used to model c_p(λ,β). This equation, based on the modeling turbine characteristics of [1], is:

$$c_p(\lambda, \beta) = c_1(c_2/\lambda_i - c_3\beta - c_4)e^{-c_5/\lambda_i} + c_6\lambda,$$

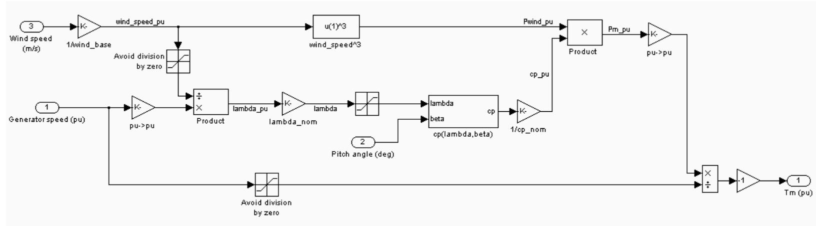
with:

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

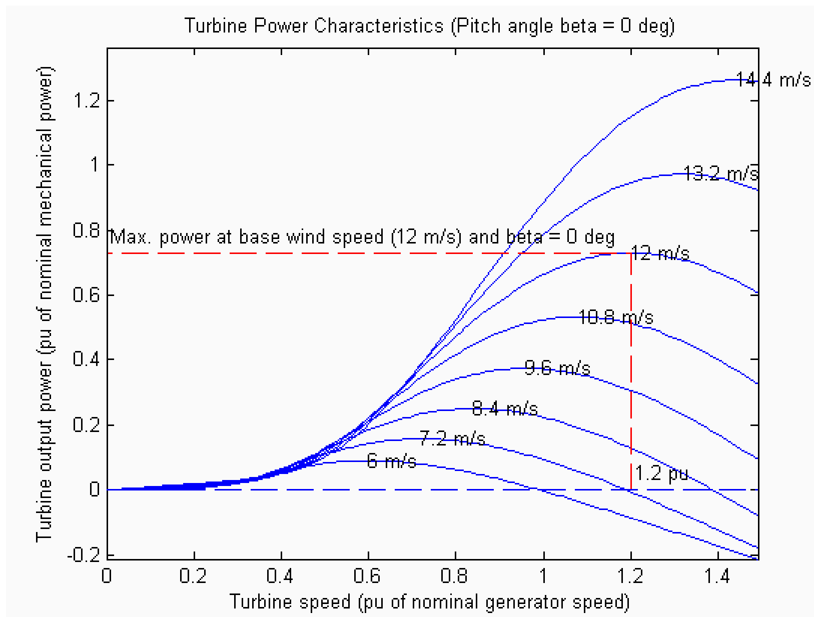
The coefficients c_1 to c_6 are: c_1 = 0.5176, c_2 = 116, c_3 = 0.4, c_4 = 5, c_5 = 21 and c_6 = 0.0068. The c_p-λ characteristics, for different values of the pitch angle β, are illustrated below. The maximum value of c_p(c_{pmax}= 0.48) is achieved for β = 0 degrees and for λ = 8.1. This particular value of λ is defined as the nominal value (λ$_{_nom}$).



This figure shows the Simulink® model of the turbine. The three inputs are the generator speed (ωr_pu) in pu of the nominal speed of the generator, the pitch angle in degrees, and the wind speed in m/s. The tip speed ratio λ in pu of λ$_{_nom}$ is obtained by the division of the rotational speed in pu of the base rotational speed (defined below) and the wind speed in pu of the base wind speed. The output is the torque applied to the generator shaft.



The illustration below shows the mechanical power P_m as a function of generator speed, for different wind speeds and for blade pitch angle β = 0 degrees. This figure is obtained with the default parameters (base wind speed = 12 m/s, maximum power at base wind speed = 0.73 pu (k_p = 0.73), and base rotational speed = 1.2 pu).



Ports

Input

collapse all

Generator speed (pu) — Generator speed, pu
scalar

Generator speed based on the nominal speed of the generator, specified as a scalar, in pu.

Pitch angle (deg) — Pitch angle, deg
scalar

Pitch angle, specified as a scalar

Wind speed (m/s) — Wind speed, m/s

nonnegative scalar

Wind speed, specified as a nonnegative scalar, in m/s.

Output

collapse all

Tm (pu) — Mechanical torque of wind turbine, pu
scalar

Mechanical torque of the wind turbine, returned as a scalar, in pu of the nominal generator torque. The nominal torque of the generator is based on the nominal generator power and speed.

Parameters

collapse all

Nominal mechanical output power — Nominal output power
`1.5e6` (default) | nonnegative scalar

The nominal output power in watts (W).

Base power of the electrical generator — Nominal power of electrical generator coupled to wind turbine
`1.5e6/0.9` (default) | positive scalar

The nominal power of the electrical generator coupled to the wind turbine, in VA. This parameter is used to compute the output torque in pu of the nominal torque of the generator.

Base wind speed (m/s) — Base value of wind speed
12 (default) | positive scalar

The base value of the wind speed, in m/s, used in the per-unit system. The base wind speed is the mean value of the expected wind speed. This base wind speed produces a mechanical power that is usually lower than the turbine nominal power.

Maximum power at base wind speed — Maximum power
`0.73` (default) | positive scalar

Power gain k_p at base wind speed in pu of the nominal mechanical power. k_p is less than or equal to 1.

Base rotational speed — Rotational speed at maximum power for base wind speed
`1.2` (default) | positive scalar

The rotational speed at maximum power for the base wind speed. The base rotational speed is in pu of the base generator speed. For a synchronous or asynchronous generator, the base speed is the synchronous speed. For a permanent-magnet generator, the base speed is defined as the speed producing nominal voltage at no load.

Pitch angle beta to display wind turbine power characteristics — Pitch angle beta
`0` (default) | nonnegative scalar

The pitch angle beta, in degrees, used to display the power characteristics. Beta must be greater than or equal to zero.

Display wind turbine power characteristics — Plot wind turbine power characteristics
button

Click to plot the turbine power characteristics for different wind speeds and for the specified pitch angle beta.

References

[1] Siegfried Heier, “Grid Integration of Wind Energy Conversion Systems,” John Wiley & Sons Ltd, 1998, ISBN 0-471-97143-X

Extended Capabilities

C/C++ Code Generation

Generate C and C++ code using Simulink® Coder™.

Version History

Introduced in R2006a

See Also

Wind Turbine Induction Generator (Phasor Type) | Wind Turbine Doubly-Fed Induction Generator (Phasor Type) mathworks.com

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