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# Wind Power Turbine

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***Abstract: In the recent years, Wind Turbines are acceptable as an alternative source of electrical energy instead of fossil or nuclear power plants, because of the environmental and economic benefits. Wind energy plays an important role in the supply of energy. Wind Energy, like solar energy, is a free power energy resource energy from the wind can be tapped using the turbines. Wind Turbine is a machine used for converting the kinetic energy in the wind into mechanical energy.If the mechanical energy is used directly by machinery, such as a pump or grinding stones, the machine is called Wind Mill. If the mechanical energy is then converted into electricity, the machine is called Wind generator. The goal this paper is to develop the Mathematical Model to generate the electricity from a Wind Turbine.***
***Keywords: Mathematical Model of Wind Energy, Wind Turbine.***

## INTRODUCTION

Like Solar energy, Wind energy is a free power energy resource from the wind. Wind Turbines are used to convert the kinetic energy in the wind into the mechanical energy. There are two types of wind energy devices; those which use mainly **aerodynamic lift** and those which use **aerodynamic drag.** High-speed turbines rely on lift forces to move the blades. To generate electricity from a wind turbine, it is usually desirable that driving shaft of the generator operates at considerable speed (1500 revolutions per minute). This, together with the higher aerodynamic efficiency of lift devices, means that turbines which rely on aerodynamic drag are not generally used. There are two types of turbines, one with the **Horizontal axis** and another with **Vertical axis**.Vertical axis turbines were developed and commercially produced in 1970 until the end of 1980.Vertical axis wind turbines have the advantage as that no tower is needed but the disadvantage is that they are not self-starting.

**Vertical Axis wind turbines**

**Horizontal axis wind turbines wind farm Horizontal axis wind Turbines consists of three major parts**

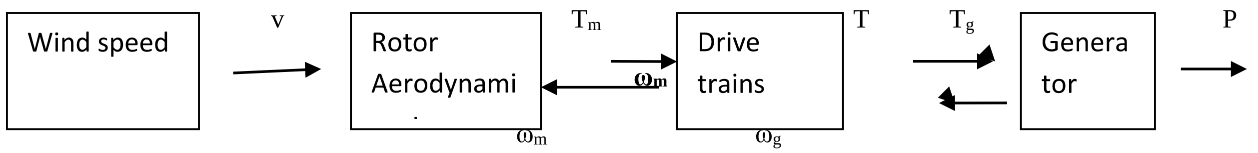
 

1) **The rotor blades** which extracts the kinetic energy present in the wind and transform into the mechanical power.
2) The **nacelle**, with a power control system that limits and conditions the extracted power, a gearbox that transfers the load and increases the rotational speed to drive the generator and an electrical system which converts the mechanical energy into electrical energy.
3) A **tower** supports the nacelle.

**Wind Farm** - A Wind farm is a collection of wind turbines in the same locations and used for the generation of wind power electricity. Installing several turbines in groups at a site leads to large scale utilization of wind energy.
**Onshore wind farms** are constructed inland usually in hills or mountainous regions to favor windy conditions.
**Offshore wind farms** are installed in the sea, at least 10 km away from the land. This is attractive because of higher speed

**Modeling in Wind Turbine:**
Modeling is a basic tool for analysis, such as optimization, project, design and control.Models utilized for steady state analysis are simple but dynamic models for energy conversion systems are not **Modern wind turbine** generator systems consists of a **horizontal axis of rotation**, a wind wheel consisting of 3 blades, a high-speed induction generator, and a gearbox. Induction generators are used because of their advantages, such as simplicity of construction, possibilities of operating at various operational levels.

A wind energy conversion system is




**The** tip speed ratio $\lambda = V_{tip} / V_{wind} = \omega R / v$ **, where**

**ω is the** angular velocity ( rad / sec ) **, R** is the rotor radius , **v** is the wind speed

$C_p$ is the coefficient of performance = Power extracted / Power of wind

Kinetic energy $E = 1/2 (mv2)$ ------ (1)

Power in the moving air = $dE / dt = 1/2\ m \times v^2$ ------ (2)

Air = Mass / sec = velocity × Area × Density ---------- (3)

Power **P = 1/2 × swept area × Air Density × Velocity**

$= 1/2 \times (\pi r^2) \times \rho v^2 \times v$

$= 1/2 (\pi r^2 \rho v^3)$ -------- **(4)**

Power in the wind $P = (\rho A v) . v^2 / 2 = 1/2 (\rho A v^3)$

**ρ** is the air density ( $kg / m^3$ )

**A** is the area ( $m^2$ )

**V**is the wind speed ( m / s)

**P** is the power of the wind ( watts or J/s )

**Power of blade** $P = C_p\ 1/2\ A \rho v^3$ ------- **(5)**

$\rho = \rho_0 - 1.94 \times 10^{-4} H$ , $\rho_0 = 1.225 kg / m^3$ is the air density at the sea level at temperature T = 298K

$C_p$ **= Power extract / Power of wind**

$\Delta E = \frac{1}{2} m V_e^2 - \frac{1}{2} m V_0^2$ **where** $V_e$ is incoming speed & $V_0$ is the outgoing speed

The flow rate mass of the stream air $m = \rho_a A_a V = \rho A_a V_e (1 - a)$

Output Velocity $V_0 = V_e (1 - b) = V_e (1 - 2a)$ where $b = 2a$ according to Betz theory.

$$\Delta E = \frac{1}{2}\ \rho_a A_a V_e(1 - a)\{V_e^2 - V_e^2(1 - 2a)^2\}$$

Changing KE due to moving air from upstream to downstream has a maximum value w.r.t. a and can be found by dE / da = 0

We found that **E is maximum at a = 1/3**

$$V_0 = V_e(1 - a) = 2/3\ V_e$$

This means that the approaching (striking) to the actuator (blades) wind speed is decreased by 1/3 of its stream value (coming value )

**Maximum Power** $\Delta E = \frac{8}{27}\rho_a\ A_a V_e^3$ **at** $a = 1/3$

**Maximum Power Coefficient** $C_p = P_{extract\ maximum} / P_{available}$

$$= \frac{8}{27}\rho_a\ A_a V_e^3 / \frac{1}{2}\rho_a\ A_a V_e^3$$

$$= 16/27$$

$$= 0.5926$$

Thus all wind power cannot be captured by the rotor. Rotor efficiency is 59% (theoretical)

## CONCLUSION

It is essential that clean energy is produced in large amounts at reasonably less cost. One way of doing this is to use nonconventional energy sources such as wind energy. A wind energy conversion system consists of the blades, mechanical parts, and inductor generator. In wind turbine model inputs are the wind velocity v and blade pitch angle $\beta$ . The wind velocity is a disturbance variable, it changes constantly and cannot be controlled. On the other hand, the blade pitch angle $\beta$ is a manipulated variable. It can be adjusted in order to reduce the unwanted power when the wind speed becomes too high. All wind power can not be captured by rotor, only 59% wind energy is captured by rotor.

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