

Design and optimization of wind turbine blade

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ABSTRACT: The overall efficiency of a windmill is the amount of electricity that can be generated over time on a cost basis. Two important factors that determine overall windmill efficiency are the ability to use low velocity wind and the ability of the windmill to convert the kinetic energy of the wind into electrical energy (or conversion efficiency. Currently, the most popular windmill design utilizes a large, single, three-blade rotor. It is obvious that "unused" wind passes between the blades of these three-blade systems. Rotors with more blades, such as those used on farms for irrigation, will turn at lower wind speeds, and have high conversion efficiency. However, these multiple blade rotor systems are subject to higher loads and unable to withstand extreme winds. The rotor blade is an important device that converts kinetic energy of wind into mechanical energy. It affects power performance, efficiency of energy conversion, load and dynamic stability of a wind power generation system. This paper presents an aerodynamic design of blade using CFD analysis. the objective of this project is to increase the efficiency of wind turbine by reducing the drag and lift. This present work is done in designing a wind turbine blade by using CREO-ELEMENT/PRO 5.0 Software. and optimizing the blade aerodynamically by using CFD analysis in ANSYS 11.0 Software.

Keywords: Wind energy, Airfoils, CFD, blade geometry

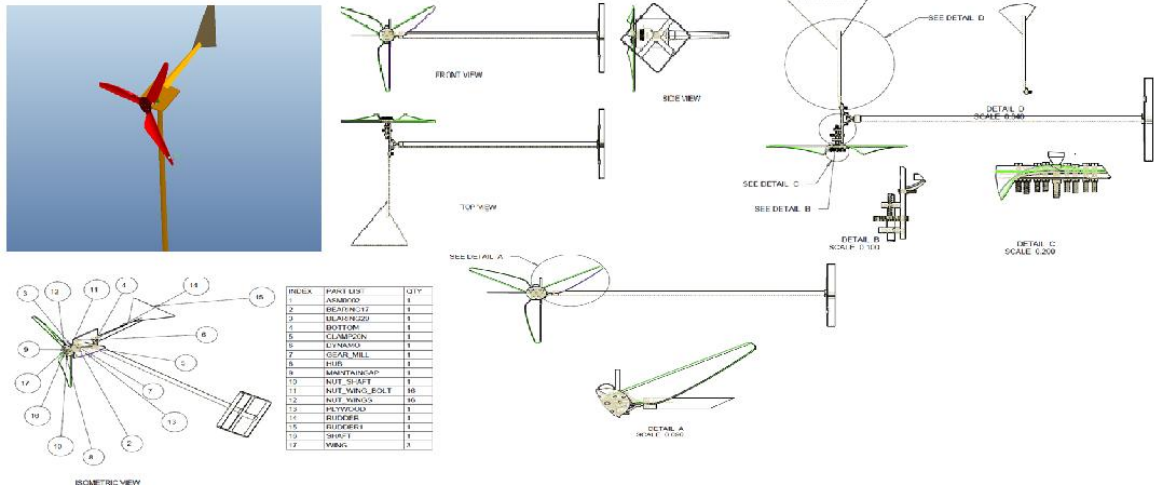
I. INTRODUCTION

Wind is air in motion. It is produced by the uneven heating of the earth's surface by the sun. Since the earth's surface is made of various land and water formations, it absorbs the sun's radiation unevenly. When the sun is shining during the day, the air over landmasses heats more quickly than the air over water. The warm air over the land expands and rises, and the heavier, cooler air over water moves in to take its place, creating local winds. At night, the winds are reversed because the air cools more rapidly over land than over water. Similarly, the large atmospheric winds that circle the earth are created because the surface air near the equator is warmed more by the sun than the air over the North and South Poles. Wind is called a renewable energy source because wind will continually be produced as long as the sun shines on the earth.

In the 1970s, oil shortages pushed the development of alternative energy sources. In the 1990s, the push came from a renewed concern for the environment in response to scientific studies indicating potential changes to the global climate if the use of fossil fuels continues to increase. Wind energy offers a viable, economical alternative to conventional power plants in many areas of the country. Wind is a clean fuel; wind farms produce no air or water pollution because no fuel is burned

The main interesting we have about wind energy at present, is the electricity production in order to substitute the expensive fossil fuels. To produce electric energy using the wind it is required an Aeolian-Generator, which is supported with the same principles of windmills. It is consisted by a wind turbine basically composed by blades, a cube or base and the electric generator.

II. METHODOLOGY



III. NOMENCLATURE

V_0 = Inlet wind velocity; α = Angle of attack; ω = Blade angular velocity ; r = Blade radius ; V_r = Resultant wind velocity; ρ = Air density; FL = Lift Force ; FD = Drag Force; N = Speed of wind turbine; CL and CD are coefficient of lift and coefficient of drag respectively; CP = Coefficient of performance; PN = Numerical Power; PA = Analytical Power.

IV. CFD ANALYSIS BY USING ANSYS 11.0 SOFTWARE

Computational grid and calculation conditions Computational grid domain is divided into rotational part and stationary part. Rotational part is configured with domain which surrounds the blade and the rest. To generate numerical grid, ANSYS ICEMCFD V11.0 is used and hexagonal grid is applied for the purpose of improving the accuracy and convergence of the solution. About 5.0 million nodes are generated for a single blade domain that rotates, and 1.5 million nodes are used for stationary domain. A numerical grid on the blade surface and surroundings are shown in Fig.

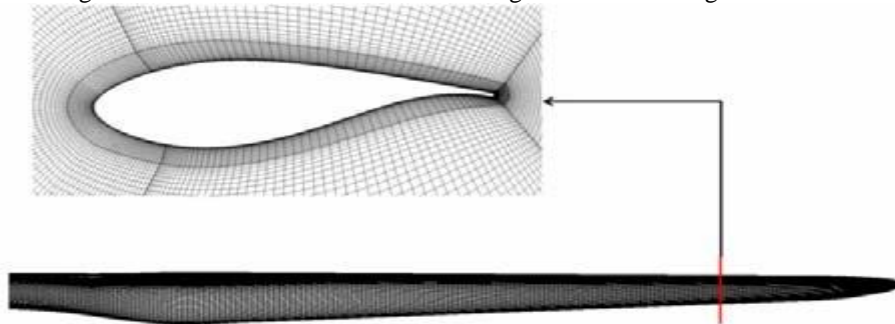


Fig. Computational grids.

Calculations:

$$\alpha = 9^\circ ; V_0 = 3 \text{ m/s} ; N = 6 \text{ rpm} ; r = 53 \text{ m} ; \rho = 1.225 \text{ Kg/m}^3$$

$$V_r = r \cdot \omega = r \cdot 2 \cdot \pi \cdot N / 60 = 53 \times 2 \times \pi \times 6 / 60$$

$$V_r = 33.284 \text{ m/s}$$

$$V_r = \sqrt{V^2 + V_0^2} = \sqrt{(33.284^2 + 9)}$$

$$V_r = 33.41 \text{ m/s}$$

From Fluent software we get values of

$$CL = 0.173 ; CD = 0.345$$

The lift and drag force are given by the expression,

$$L = \frac{1}{2} C_l \rho c V^2$$

$$D = \frac{1}{2} C_d \rho c V^2$$

Where c - Chord length

V - Velocity of free stream air

C_l and C_d are the coefficients of lift and drag.

$$L = 0.5 \times 0.173 \times 1.225 \times 7.31 \times (33.41)^2$$
$$= 864.61$$

$$D = 0.5 \times 0.345 \times 1.225 \times 7.31 \times (33.41)^2$$
$$= 1724.228$$

$$\text{Resultant Force} = F_R = \sqrt{D^2 + L^2} = \sqrt{(864.61^2 + (1724.228^2))}$$
$$F_R = 1928.85\text{N}$$

Power = P N

= Torque $\times \omega$ ----- Numerical Value

$$= (F_R \times r \times \omega)$$

$$= (F_R \times V)$$

$$= (1928.85 \times 33.41)$$

$$P_N = 64199.73 \text{ Watts}$$

Power = $P_A = 0.5 \times \rho \times A \times V_o^3 \times CP$ -----Analytical Value

$$= 0.5 \times 1.225 \times 8820.26 \times (3)^3 \times CP$$

$$= 145865.05 \times CP$$

$$\text{Therefore, } CP = \frac{64199.73}{145865.05}$$
$$= 0.44$$

V. CONCLUSION

In this project a wind turbine blade is design by using CREO-ELEMENT/PRO 5.0 Software. and optimize the blade aerodynamically by using CFD analysis in ANSYS 11.0 Software. The maximum value of coefficient of performance (CPmax = 0.44) was observed at velocity of air 3 m/s. and 6 rpm. This blade can generate maximum power of 64199.73 Watts at maximum CP. From analysis we concluded that ANSYS-Fluent shows a good performance in calculating the lift, drag and moment coefficients of aerofoils. the wind turbine blade designed by this method has good aerodynamic performance in low wind speed conditions.

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