Wind Energy Conversion System Design for Clean Power Generation Using CAD Modeling and Simulation

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***Abstract*—In the recent years wind power is broadly considered and utilized as one of the most promising renewable energy sources. In the recent research study, aerodynamic analysis of horizontal axis turbine is accomplished by using CFD. Blades which are mostly feasible for commercial grade wind turbines embody a straight span-wise profile along with airfoil shaped cross sections. Wind tunnel test is implemented in order to test aerodynamic efficiency wind turbine blade. The objective of this study is to design a wind turbine. The design process includes the selection of the solar system for maximum efficiency and wind turbine type and the determination of the blade airfoil, pitch angle distribution along the radius, and chord length distribution along the radius. The pitch angle and chord length distributions are optimized based on conservation of angular momentum and theory of aerodynamic forces on an airfoil. Blade Element Momentum (BEM) theory is first derived then used to conduct a parametric study that will determine if the optimized values of blade pitch and chord length create the most efficient blade geometry. This work includes a discussion of the most important parameters in wind turbine blade design to maximize efficiency.**

***Index Terms*—Wind Turbine.**

- **HAWT.**
- **BEM Theory.**
- **Parametric Study.**
- **Maximization of efficiency.**

I. INTRODUCTION

In the recent years wind power is broadly considered and utilized as one of the most promising renewable energy sources. In the recent research study, aerodynamic analysis of horizontal axis turbine is accomplished by using CFD. Blades which are mostly feasible for commercial grade wind turbines embody a straight span-wise profile along with airfoil shaped cross sections. Wind tunnel test is implemented in order to test aerodynamic efficiency wind turbine blade. In this project, the researchers' choice is NACA 4421 airfoil for analysis. CFD Analysis of HAWT Blade is executed at various blade angles with the aid of ANSYS CFX and also by correlating that result with experimental results. HAWT efficiency remarkably rely upon the blade profile and its orientation. The researchers are able to identify the optimum angle at which HAWT provides constant output.

Wind turbine technology is one of the effective means to implement this renewable resource in order to produce environmentally friendly electrical energy. As it is an intricate system it depends upon the is unification of multiple engineering disciplines, which comprises of structures, aerodynamics, controls and electrical engineering. The main objective of the wind turbines is to capture maximum energy from the wind energy. Best design parameters have to be selected for each and every constituent of the wind turbine. It leads to increase in efficiency and life cycle. The two stages of a wind turbine blade design process are aerodynamic design and structural design.

Nowadays, wind turbines are one of the rapidly growing renewable energy source in the world. Sustainability of the modern grid is the main aim for harnessing wind energy. There are many types and categories of wind turbines. They can be mainly classified into vertical axis wind turbine (VAWT) and horizontal axis wind turbine (HAWT) [1]. Our concentration is on modeling and designing of HAWT as this device can be used to harness the vast natural resource.in the form of wind energy. It can extract the wind energy from the higher heights as it is mounted on a tower and thus increases the efficiency.

This device can extract wind power in the rural and urban areas where space is a constraint [2]. This device may further reduce the noise generation compared to

other turbines due to minimization of pulsation of initial torque behaviour.

II. PROBLEM IDENTIFICATIONS

To advance turbine blade design in order to maximize the lift force on the blade and reduce drag so that the force on the blade that acts in the tangential direction is maximized, air turbine design it is crucial to reduce the trust on the turbine blades because it wastes energy and it requires a stronger blade to withstand its loading this helps to maximize annual energy production.

Wind energy conversion systems are very different in nature from conventional generators, and therefore dynamic studies must be addressed in order to integrate wind power into the power system. Wind turbines are machines that remove energy from the wind by leveraging the aerodynamic principles of lift and drag. Lift and drag forces move the turbine blades which convert kinetic wind energy to rotational energy by optimizing lift and drag principles. For this study the simulation is based on modern wind turbine design procedure; selection for best airfoil, optimum pitch angle, blade geometry in order to increase rated wind power.

III. METHODOLOGY

- Wind turbine

A wind turbine uses the aerodynamic force of the lift to rotate a shaft which in turn helps in the conversion of mechanical power to electricity by means of a generator.

Wind turbine generator which converts the kinetic energy of the wind into mechanical shaft power to drive a generator that in turn produces electrical energy. A wind turbine (WT) is composed of five main elements:

1. Rotor made up of rotor blades that use aerodynamic lift to convert wind energy into mechanical energy.
2. A rotor bearing fixed on a structure that causes ade fined rotation of the rotor and leads to conversion of the aerodynamic wind energy into a rotational shaft torque. A yaw system maintains the horizontal rotor axis pointing upstream into the wind.
3. A power conversion system that converts the low-speed rotational energy into suitable shaft power to drive an electrical generator.
4. A tower and foundation structure to support the rotor and generator system at a height that harvests the most amount of energy for an acceptable capital cost.
5. An electrical power distribution system that supplies the energy to the consumer in compliance with local grid code and system requirements.

For this purpose, there are mainly two types of wind turbine and these are: 1) Horizontal axis wind turbine (HAWT)

2) Vertical axis wind turbine (VAWT).CAD Modeling

- MATLAB 2018R & Solid Work 2019R Simulations

Having the above calculated values we come up to 2018 and 2019 as follows, 2018 tip speed, turbine power and torque output

Comparison of each value in the above different situation based on blade numbers except blade number two others give the same value but from design point of view the increase of blade number we can see the following consequences turbine torque and turbine power comparisons

Blade number	Turbine power(KW)	Turbine torque(KNm)
2	1600.3	685.8
3	2154.6	923.4
4	2154.6	923.4
5	2154.6	923.4

Finite Element Analysis (FEA)

- Import CAD model into ANSYS or similar simulation software.
- Define:
- Material properties
- Creep study.
- Fatigue Analysis.
- Dynamic Study.
- Objectives of a dynamic analysis. Tools & Software Used
- CAD Software: Creo / SolidWorks FEA Software: ANSYS Workbench

IV. CONCLUSION

An optimal aerodynamic blade design has been proposed for analyzing starting torque behavior of a small HAWT. An approach is given for smooth starting torque which is believed to reduce mechanical vibration of the coupling between the turbine shaft and the generator shaft respectively. From the ADAMS simulation results, it has been observed that the pulsation of the torque is diminished by this design approach, which has been done in Pro/ENGINEER with the help of the MATLAB generated parameters. This, in turn, may reduce the stress on the electric generator and the coupling. The application of BEM theory helped in analyzing the aerodynamic behavior of the wind turbine. It would be extremely difficult, complex and expensive to test and analyze an actual machine in a wind tunnel. The simulation results are quite encouraging and it may be possible to apply this model to design a practical machine. It is being planned to build and test a wooden or a composite model meant for practical applications.

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