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Analysis of NACA 4415 Blade Profile for Horizontal Axis Wind Turbine Using Various Aerodynamic Characteristics

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Abstract— **In this Era of fast growing demand of Energy New type of Energy Conversion systems are must to be developed. Due to Increased Carbon Footprints We are moving towards use of Renewable Energy resources. Out of All renewable Energy resources Wind Energy is almost consistent for a period of time at a particular time so it can be taken as major source of Energy.**

Wind flow Characteristics can be easily obtained at a Particular place by Anemometric data to know the type of Wind Turbine blades which can be employed at a particular Site. Different types of Wind Turbines can be used to extract Energy At a particular place for a specific purpose like electricity or powder grounding purposes.

Index Terms—**Demand of Energy, Energy Resources, Renewable Energy Resources, Wind Turbine Blade.**

I. INTRODUCTION

Wind power was first used long time ago by many civilizations during mankind history to produce mechanical energy or for navigation. Only with the use of coal and oil in the last two centuries its importance decreased, but during the last decades the interest on this topic grew as much as the possible business around it. Since the beginning, two types of windmills and turbines have been built to use this renewable source: some machines with horizontal axis of rotation (HAWT) and some other with vertical axis (VAWT). The firs type is the most common today, but growing market asks for machines with different proprieties to fit different requests. VAWT design have been always mistreated by literature and market, but with some new or improved technologies and decreasing prices for valuable materials such as permanent magnet, together with the peculiarity of VAWT turbines to operate were other types have problems, this turbine can have a very important advantage in the actual market.

Wind energy is the kinetic energy associated with the movement of atmospheric air due to uneven heating and cooling of the earth's surface. This is a renewable energy resource and a popular form for extracting power for humankind. Wind energy is a potential clean energy resource which is currently used to produce energy and will without doubt remain constant in the future. Wind energy contrasts with other forms of energy such as biomass or fossil fuel which have limitations namely, massive carbon dioxide emissions, threat to the atmosphere, and so on which results in a loss of their acceptability for use in energy production [1]. Wind energy which comes from air current flowing across the earth's surface is a source of renewable power. Wind turbines harvest this kinetic energy and convert it into electricity power for homes, farms, schools, or business applications on small or large scales. People around the world are now aware of wind energy which enables the fastest growth of wind market. This wind energy is a supply of renewable energy which provides a beneficial and stable investment in the energy economy field. In addition, this wind energy is used by the wind turbine to produce clean energy which does not contribute to the greenhouse effect or environmental (air or water) pollution. Technological advancements offer low costs for electricity generation using wind energy harnessed by wind turbines and contribute to a remarkable monetary savings. People from urban areas in different locations fully depend on wind turbines installed in their local areas which enable them to reduce their reliance on electricity produced from other resources. From the market point of view, this energy sector is stable and does not involve international politics because there is no use of tangible fuels. However, this wind energy use for electricity production includes some disadvantages. From a visual or aesthetic point of view, some people are not comfortable with onshore and offshore wind turbine installations. Sometimes it is claimed that wind turbine operation and installation poses a threat for migratory birds. For particular cases this issue can be solved by proper turbine installation. Another important point arises when site analysis is done for wind turbine installation, namely the noise emission and shadow flicker; however, certified design improvement solves the issue of noise emission, and large scale turbines are usually installed away from populous communities. Wind power is the extraction of this wind energy by wind turbines. Wind energy has the potential to contribute power generation with a reported capacity to generate 20% of world electricity. Different wind turbines with various capacities are used to extract power from the wind. Horizontal Axis Wind turbine (HAWT) and Vertical Axis Wind turbine (VAWT) are the most common types of wind turbines currently being used for energy production from wind. This study is concerned with a small scale Helical twist Vertical Axis Wind Turbine (VAWT);. To solve this problem Computational Fluid Dynamics (CFD) which is a branch of fluid mechanics has been found to be a powerful tool, and furthermore, for fluid flow problems CFD offers numerical simulation. CFD techniques have been used in this study. Wake is an important variable which plays a significant role for performance investigation of individual turbines and in an array of turbines sited on shore or off shore. Wake is generally defined as the reduced velocity region at the downstream side of the turbine. Wake generated from the turbine operation in the downstream flow field cause power loss for the arrayed

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turbines. Wake characteristics are difficult to describe in the real world operation. Knowledge of turbine wake characteristics is very important for two main purposes. First, optimizing the wind turbine design for aerodynamic performance prediction and second, for turbine array configuration including turbine interspacing. Array staggering decisions are being made based on the wake generation.

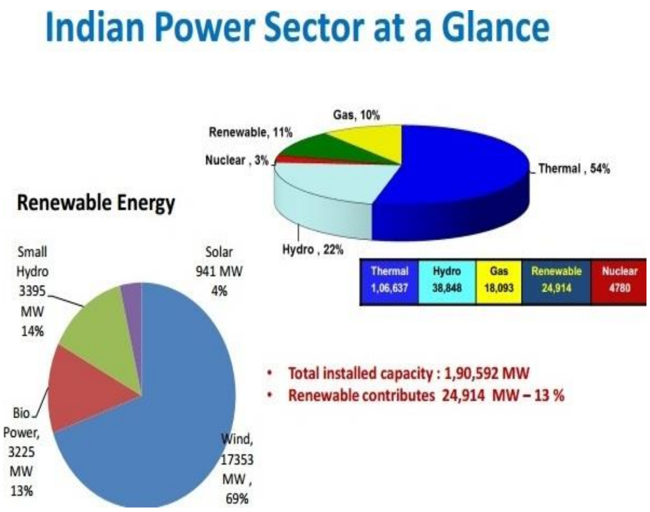

Fig.1 Indian Power Sector at a Glance (Source- National Energy Report, NIC, India)

A. Horizontal Axis Wind Turbine

Horizontal-Axis Wind Turbines (HAWT) have the main rotor shaft and electrical generator at the top of a tower, and may be pointed into or out of the wind. Small turbines are pointed by a simple wind vane, while large turbines generally use a **wind** sensor coupled with a servo motor. Most have a gearbox, which turns the slow rotation of the blades into a quicker rotation that is more suitable to drive an electrical generator

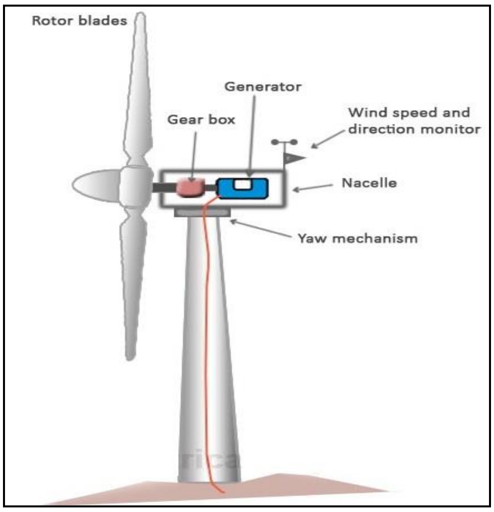

Fig.2 Horizontal Axis Wind Turbine

The rotor of HAWT designed aerodynamically (Fig.2) to capture the maximum surface area of wind in order to spin the most ergonomically. The blades are lightweight, durable and corrosion-resistant material.[2] The best materials are composites of fibreglass and reinforced plastic. the blades of HAWT are of two types, the first one is of lifting style , These are the most efficiently designed, especially for capturing energy of strong, fast winds. Some European companies actually manufacture a single blade turbine, and the second one is of drag style wind turbine blade, The drag style wind turbine blade, most popularly used for water mills, as seen in the old Dutch windmills. The blades are flattened plates which catch the wind. These are poorly designed for capturing the energy of heightened winds. In this paper we are going to focus the designing and simulation of a horizontal axis wind turbine blade by the use of QBlade software.[4]

B. QBLADE

The software project QBlade was started in 2010 at the chair of fluid mechanics of the TU Berlin. The motivation was to create a single tool that comprises all the functionality needed for aerodynamic wind turbine design and simulation without the need to import, convert or process data from other sources in order to encourage the research on wind turbine worldwide this software is made available and distributed freely under GPL licence[5].

Functions of QBlade software:

- Airfoil design and analysis
- Lift and drag polar extrapolation
- Blade design and optimization
- Turbine definition and simulation

C. The Role of Aerodynamics in Wind Turbine Design

A wind turbine is a complex system which consists of several components, including a rotor, a transmission system, a generator, a nacelle, a tower and other electro-mechanical subsystems. The rotor blades are the most important components. In order to transfer wind energy into mechanical power, the blade is designed as an aerodynamic geometry with nonlinear chord and twist angle distributions. The section view of a wind turbine blade is of an airfoil shape (one or more airfoils), which is expected to generate high lift and low drag forces. The shape of the blade is vital as it determines the energy captured, and the loads experienced[3]

LITERATURE REVIEW

N. Karthikeyanet.al.

Discussion over Various Wind Turbine Blade Parameters associated with blade geometry on unfavorable wind power sites.Wind energy is innately renewable, abundant in the earth and can possibly reduce the dependency on fossil fuels. Wind is an incarnation of sun and is always nourished by the latter. Approximately 10 million MW of energy can be continuously generated from the wind sources. In contrast to the large horizontal axis wind turbines (HAWT), which are established in the area with optimum wind conditions, small wind turbines are being installed to produce power irrespective of favorable wind conditions. Parameters associated with blade geometry optimization are important, because once optimized, shorter rotor blades could produce power comparable to larger and less optimized blades.

Karam Y maalawiet.al.

Deriving variation of angle of Attack from rotor Size and blade Geometry without using iterative methods.This paper presents a direct approach for the determination of aerodynamic performance characteristics of horizontal axis wind turbines. Based on Glauert's solution of an ideal windmill along with an exact trigonometric function method, analytical closed form equations are derived and given for preliminary determination of the optimum chord and twist distributions. The variation of the angle of attack of the relative wind along blade span is then obtained directly from a unique equation for a known rotor size and refined blade geometry.

DanmeiHuet.al.
Effect of Rotation on Pressure Distribution on the surface of the foil, which will give rise to 3D stall delay in stalled HAWT. The study on the stall-delay phenomenon for horizontal axis wind turbine (HAWT) was carried out by employing the boundary layer analysis, the numerical simulation and the experimental measurement. The effects of rotation on blade boundary layers are investigated by solving the 3D integral boundary layer equations with assumed velocity profiles. It is shown that rotation has a generally beneficial effect in delaying separation compared with that under 2D stationary condition. Next, the detailed flow fields are simulated on the conditions of 2D stationary and 3D rotation by CFD code. The computation results show that rotation affects the pressure distribution on the surface of the foil, which can give rise to 3D stall-delay in stalled condition HAWT. Finally, the flow fields behind a model HAWT are measured with a hot-wire probe in the wind tunnel. The results show good agreement with those from 3D computation calculations, suggesting that the stall-delay should be taken into consideration, in order to accurately predict the loading and performance of a HAWT operating in stall.

Yang Sunet.al.
Computational fluid dynamic analysis of HAWT blade using sliding mesh controlled by user defined Functions.Horizontal axis wind turbine (hereafter HAWT) is the common equipment in wind turbine generator systems in recent years. The paper relates to the numerical simulation of the unsteady airflow around a HAWT of the type Phase VI with emphasis on the power output. The rotor diameter is 10-m and the rotating speed is 72rpm. The simulation was undertaken with the Computational Fluid Dynamics (CFD) software FLUENT 6.2 using the sliding meshes controlled by user-defined functions (UDF). Entire mesh node number is about 1.8 million and it is generated by GAMBIT 2.2 to achieve better mesh quality.

II. PROBLEM IDENTIFICATION

Comparative Study and optimization of Horizontal Axis Wind Turbine Performance via testing turbine aerofoil profile with Aerodynamic Parameters. Since the Turbine Blades are costly and very difficult to manufacture so it is necessary to have a simulative study before going to manufacture turbine Rotor blades.

III. METHODOLOGY

Procurement of aerodynamic performance data from previous work and selection of best profile amongst,Analysis of test data for newly better assumed blade profile using CFD Techniques. Iteration until better results are obtained.

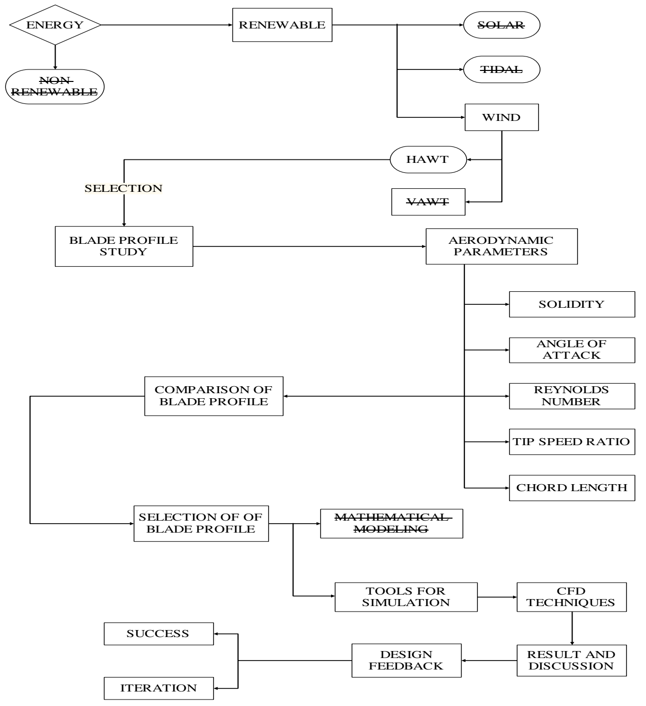

Fig3. Methodology

IV. COMPUTATIONAL ANALYSIS OF AERODYNAMIC PARAMETERS

A. Aerofoil Design

First of all two blade profiles under consideration were introduced in the software window in Fig.4

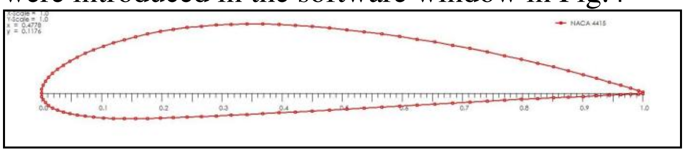

Fig. 4 Aerofoil Design in Software Window

B. Operational Point View

This view is used in analyzing the aerofoil blade with Pressure distribution and Power Coefficient - Distance graph.

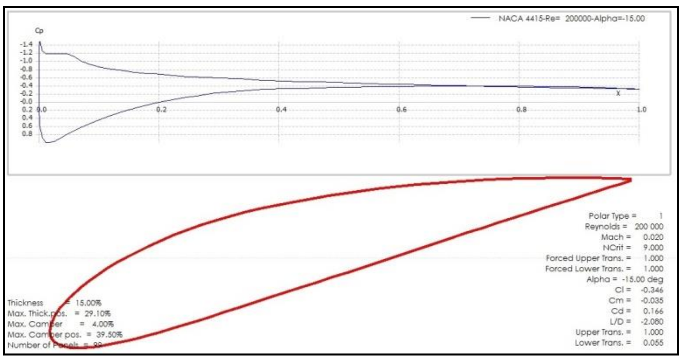

Fig.5 Pressure Distribution along Aerofoil (NACA4415)

C. Power Vs. velocity Plot

The Fig.6 represents the Power Vs. velocity Plot for the NACA 4415 blade Profile

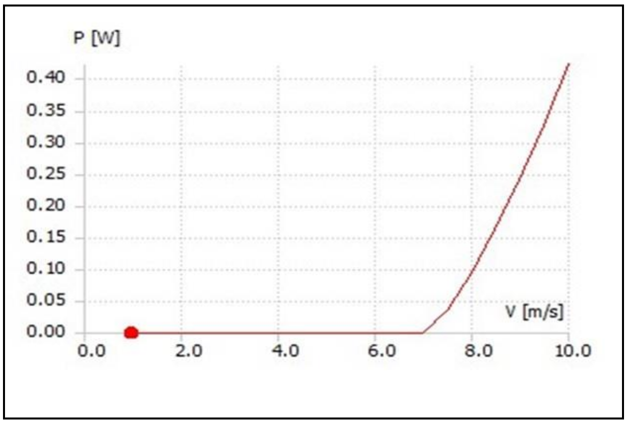

Fig.6. Power Vs. Velocity

D. Polar View

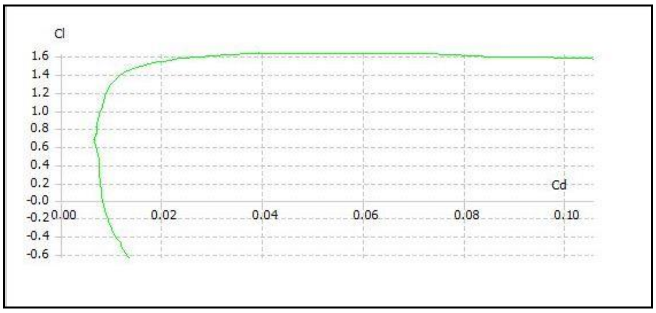

Fig.7 Graph between C_L and C_D

In this plot (Fig.7) for the values of C_D from 0.02 to 0.010 the value C_L gradually increases with positive slop and afterwards it increase linearly with positive slop

V. Conclusion

- Amongst all variants of wind turbines Horizontal Axis Wind Turbine have better power coefficient.
- For different types of blade profile a thicker profile has better performance than those relatively thinner profiles.
- Upon examination of 360 degrees polar extrapolation it was observed that value of lift forces for a particular turbine is good for a particular range of angle of attack.
- Upon examination of Turbine BEM Simulation it was observed that for the lesser values of wind velocity a small power was extracted by wind turbine afterwards power was gradually increases.
- For tip speed ratio of 0 to 7 power coefficient increases with tip speed ratio and afterwards it decreases and for value of tip speed ratio 12 and more power coefficient remains constant.

VI. FUTURE WORK

- Wind Turbines have bright future since soon we are going to end up our Natural Conventional Energy Resources due to hyper use of Energy Conversion devices
- Wind Energy Impact Assessment is to be done in Wind rich Area
- Wind Power should be manufactured in smaller units for deep reach up to every household
- Wind Power Testing laboratories are to be facilitated at much more sites.
- Wind Rose Diagrams and other Surveys are to be carried out to identify sites where Wind Power run Energy Conversion Systems can be installed.
- Results obtained from the Current study can be tested in Wind Tunnel Testing Facility for Validation of Results.

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