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REVIEW ON: ANALYSIS OF NREL S807 BLADES AEROFOIL SHAPE UNDER VARYING WIND SPEED

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***Abstract*—Energy of wind can be economically used to generate electrical energy Wind can also be used to provide mechanical power such as for water pumping. In India generally wind speeds obtainable are in the lower ranges. Therefore, attempts are on the development of low cost, low speed mills for irrigation of small and marginal farms for providing drinking water in rural area. This paper deals with the analysis and power performance of horizontal axis wind turbine on NREL S807 blade rotor and new method based on analytical approach. The installation of wind turbine and its power production, a NREL S807 blade used in this work. The main purpose of this paper is to do the testing & performance analysis and experimental work. Here we setup the vertical axis wind turbine. In which we use NREL S807 type wind turbine. Since we know that any electrical generator has two main parameters one is voltage and other is current. Speed of the generator rotor affects the voltage of electrical machine and when it is connected to load then current started to flow which required more torque. Therefore high torque required to for the connected load .In our model we used the turbine in which torque quality is low but it gives very good speed at the time of rotation. So here we get all the mechanical characteristics for any generator.**

***Keywords*—Renewable energy, wind rotor, Horizontal axis wind turbines (HAWT), Wind Energy**

I. INTRODUCTION

For the last two or three years, the global small wind turbine (SWT) market has been on the upswing. The main reason for the growth of small wind turbine are increasing fossil fuel prices, new tech enabled small wind turbine and the different type which it can be put to both ‘grid-tied’ and ‘stand-alone’ system. The market for SWT (small wind turbine) technology is encouraging in India.Adoption of micro generation technologies, reduced costs etc.to reach a significant level. NREL S807airfoil used in wind turbine is generally categorized in a ‘small’ type HAWT, specifically which is a Omni-directional for accepting the drag force of wind with good starting characteristics and operates on lower wind speeds which generally produces the power from a few watt to 20 kW. Therefore on domestic level these can be widely used to charge the batteries. The efficiency is as low as compared to horizontal axis wind turbines and darrieus type vertical axis wind turbine. The reason for lower efficiency is the nature of fluid flow over the rotor blades which produce positive and negative torque on leading and trailing rotor blades respectively. As smaller size NREL S807 wind rotors reduces in the use of material and manufacturing cost. The location of NREL S807 wind rotor is at lower altitudes provides easier installation and maintenance. Also the use of long electric cables can be avoided for the supply of power due to lower altitude of the rotor blades. Location at higher altitudes is also possible which leads to higher wind speed, lower turbulence and higher generation of power. No need to use larger land area like wind farms since the location for the use of NREL S807 wind rotor is Multi storey building and roof mounting. The major advantage of NREL S807 type wind rotor is that it works within well balanced turbulence of air, transmits minimum vibrations and bending stresses to the walls or roofs [1]. India is now the eleventh largest economy in the world, fourth in terms of purchasing power. It is poised to make tremendous economic strides over the next ten years, with significant development already in the planning stages. In recent years, India has emerged as one of the leading destinations for investors from developed countries. This attraction is partially due to the lower cost of manpower and good quality production. The expansion of investments has brought benefits of employment, development, and growth in the quality of life, but only to the major cities. This sector only represents a small portion of the total population. The remaining population still lives in very poor conditions [2].

Another form of solar energy or converted form is wind energy. Earth gets heated up at different rates during day and night by the radiations of sun heats, but also when different surface of the earth absorb or reflect at the different rates, the sun affect the earth by an irregularly of heat energy, the state of the air discriminated between different regions. The wind forms due to the hot air expand and rise up while cold air condenses and sinks. Generally horizontal motion of air flow is known as wind. Wind is nothing more than just moving air. It was created by the uneven heating of the Earth's surface by the sun. Because of the irregular shape of the land affected by the thermal energy from the sun, so the situation is different in the air. Time of day, the air above the land heats up more quickly than the air over water. Warm air over the land expands and rises, and the heavy air, colder rushes to her place, creating winds. At night, the winds are prominent, because the air cools more rapidly over land, over water [3]. The exponential growth in the rate of energy consumption is the main causes of energy shortage as well as energy resources depletion worldwide. Power shortage is very common in countries like India, where most of the population (over 40 percent) have no access to modern energy services. On average, it is expected that electricity demand will grow by 7.4 percent annually for the next 25 years [4].

According to the International Energy Agency, more than 28 percent share of total world energy consumption in India and China in 2030 at the same time a significant amount of energy should come from renewable sources. National Action Plan on Climate Change (NAPCC) was created in 2008 to fight against climate change, has also examined the role of renewable energy in total energy India production [5]. The NREL S807 wind rotor is fluid-mechanical device with S-type cross sectional blades in which wind power acts perpendicular on the blades and converts into the rotating motion of the central shaft [6]. The different geometries of NREL S807 wind turbine in order to determine the most effective operation parameters. It was found that, the two blades rotor is more efficient than three and four blades rotors. The rotor with end plates gives higher efficiency than those without end plates. Double stages rotor have higher performance than single stage rotor [7]. A blade with a given airfoil section and length can be fastened to spokes in several ways giving rise to many configurations. Two models are used in the analysis of Darrieus turbines: the single stream tube momentum model and the free wake vortex model. The former is more suitable to carry out an extensive study because of its short CPU time, the latter, which guarantees the best accuracy, can be used to verify the most significant results. The diagrams of the average coefficient of power and of the power for a given speed of the attacking wind are shown. The work-exchange between the wind flow and the machine is investigated by defining an internal efficiency of the wind turbine. [8]. The high wind speeds required by economically feasible horizontal axis wind turbines and presents a solution in the form of an ultra-low cost vertical axis wind turbine optimized for lower average wind speeds increasing the feasible wind farming land area within the United States. The feasibility, design, and optimization of localized vertical axis wind turbine farms in regions where wind speeds are lower and less predictable in direction is presented. [9]. Vertical axis wind turbine when compared to horizontal axis wind turbine, they have higher potential to meet the energy needs of domestic purpose, because of less speed of blade, and have complex operation .In this work for investigation of various technologies for construction and operations and to optimize the value of such turbines to be used as a market device tested is made used. [10].

In the comparative analysis of straight blade and curved bladed of HAWT, they have varied no of blades .They have analyzed the complete wind turbine in a low speed tunnel at different velocities and angle of attack. It has been found that magnitude of the drag coefficient increases as the angle of attack increased and the magnitude of lift coefficient decreases as the wind velocity increase. For the curved bladed as the angle of attack is increased lift coefficient of the curved bladed increases and became less influence by the wind velocity .For the complete wind turbine the straight blade HAWT has a relatively low cut in velocity as compare to curved bladed HAWT irrespective the no. of blades .They have also shown that three bladed HAWT produced higher rotation and speed as compare to the HAWT have two blades [11]. S Mathew et.al, have expressed windmills' to modern electricity generating 'wind turbines', the wind energy conversion technology has undergone significant changes. Turbines of various shapes and sizes, working on different design principles, were introduced by researchers and inventors during the course of this development. In this chapter, we will briefly describe this evolution of the modern wind energy conversion technology. This is followed by discussions on the basic principles governing the wind energy conversion process and classifications of wind turbines [12]. SruthiMuluk has done the analysis on the Horizontal axis wind turbine .She has taken two parameters for calculation of rotation rates of the blade and voltage output ,firstly she has compared three un waited blades and six un waited blades and found that three un waited blades gives higher rotation rate and higher voltage output .She has also Increase the weight of the blades 5 gm to each and found that highest rotation rate and voltage were observed with the weighted three blade configuration where as the lowest rate and voltage were observed with the UN waited 6 blade configuration .These results may be useful in wind turbine designs [13]. Small-scale HAWTs are attractive due to their ability to capture wind from different directions without using yaw; this simplifies the design and gives the turbine tolerance to turbulence in urban areas. One difficulty with HAWTs is to prevent over speeding and component overloading at excessive wind velocities. This paper suggests that necessary control can be achieved by controlling the electric power in order to operate the turbine in the stall region [14]. In the HAWT, the hardware realization of the wind energy conversion system consists of a 1.5kW HAWT-driven permanent magnet synchronous generator (PMSG), a PWM rectifier and a grid-tied PWM inverter. The PWM inverter is mandatory to maintain the dc capacitor voltage mainly adapted for operating in parallel with the power grid. The PWM rectifier, serving as a speed governor, is employed to modulate the revolution speed of the HAWT according to the desired power-speed curve so as to extract maximum power from the wind. To guarantee the aerodynamic performance of the HAWT, a simple method, based on the long-term recorded energy efficiency, can determine the optimum power-speed curve for the HAWT. The effectiveness of the proposed strategy is assessed experimentally by examining the closed-loop system response to various wind speeds [15].

II. Wind Energy Scenario In India

Wind power program began in India at the end of five-sixths of the annual plans for 1983-1984 and in recent years has increased dramatically. The main objective of the program was to commercialize the production of wind energy, support for research and development, provide assistance to wind projects and awareness. Under this program, the Ministry of Non-Renewable Energy (MNRE) has made several changes regarding incentives, plans and policies for wind power. Twenty years have passed since the shape of the world's first offshore wind power Vindeby (5 MW), was built in Denmark. Today, 4,620 MW of offshore wind power was installed worldwide, accounting for approximately 2% of the total installed capacity of wind power. Over 90% of it is installed outside Northern Europe, in the North, Baltic and Irish Seas and the English Channel. Most of the rest is in two demonstration projects on the east coast of China. However, there are also high for greater deployment expectations elsewhere, governments and businesses in Japan, Korea, USA, Canada, Taiwan and even India have shown enthusiasm for offshore development in its waters. According to the projections of several ambitions, a total of 80 GW offshore winds could be installed in 2020 in the world, three quarters of this Europe. India is a newcomer to the wind industry compared with Denmark or the USA. But the policy support of the Indian wind energy has led India and ranks fifth capacity5 most installed wind power. The total installed capacity of 19,565 MW was 30 June 20136 and now India is just behind the United States, China, Spain and Germany. The total installed capacity of wind power shows a better performance of India in the field of wind energy (Table 1). The top five countries of wind energy are China, USA, Germany, Spain and India, which together represent 73 percent of the global wind capacity.

According to MNRE, wind energy for most renewable percent installed capacity ie70 (2012) compared to other renewable energy sources. The total installed wind power capacity in India reached 17.9 GW in August 2012 the total capacity added in 2012 was around 1700 total installed capacity MW7 2013 in India and 2011 is illustrated in Figure 2 Rapid growth of installation of wind power was measured in the southern and western India. One needs about 350-360 GW of total capacity of power generation has been reported by the Central Electricity Authority in its national plan for electricity (2012), for the year 20228W. Wind potential onshore only has hitherto been used by India. Despite the fact that India has a coastline 7,500 km, we have not yet taken advantage of our offshore wind resources for electricity generation. The capacity utilization factor (CUF) offshore wind is much higher compared to onshore turbines because of strong offshore SPEED. Director Wind offshore Committee was established in August 2012 by MNRE, which published a draft national policy Energy Offshore Wind in May 2013 [16].

UCC has also set a target of increasing the share of renewable energy in total energy production to 15 percent by 2020, which clearly demonstrates the commitment of India for sustainable development. The huge gap between demand and supply requires more energy resources. The main challenge is to meet energy needs in a sustainable way and one of the best options available in the current scenario is renewable energy, it is necessary to strengthen the renewable energy and efficiency program Towards renewable energy, to be indigenous in nature and should have a low production cost, the condition can improve energy security, reduce our dependence on imports, to solve the problem of instability in fuel prices etc. [17]. The dioxide carbon emissions can be reduced by an average of 3.3 million tons per year by adding 1 GW of energy from renewable sources so it will help minimize the adverse effects of climate change on India.

Wind energy can emerge as a solution to most problems because it is cost effective in nature, clean source of energy, reduce the demand for fossil and could be a tool in the fight against climate change fuels. Wind energy has been used since ancient times for various purposes. Before the development of the steam engine, wind power is conventionally used mainly for various applications such as sailing, etc [18]. In consideration of unique concept, Govt. Madhya Pradesh has sanctioned another 15 MW project in Madhya Pradesh MPWL Wind Farms Ltd., Bhopal, Nagda hills near Dewas on the Consolidated Energy Consultants Ltd. comfort CECL Bhopal. All 25 Wegs were commissioned on 31/03/2008 and under successful operation [19].

TABLE 1: TOTAL GLOBAL INSTALLED CAPACITY (JUNE 2017)

Country	Installed Capacity (MW)
China	188232
USA	89077
Germany	56132
Span	23170
India	32848
UK	18872
Italy	9479
France	13759
Canada	12239
Denmark	5476
Portugal	5316
Sweden	6691
Australia	4557
Brazil	12763
Japan	3400
Rest of the World	10230
Total	296,065

III. WORKING PRINCIPAL OF NREL S807 TYPE WIND TURBINE

The NREL S807 rotor is the simple type of rotor of the modern types of wind energy conversion system. S.J. NREL S807 was invented the NREL S807 rotor in 1920. It requires relatively low velocity wind for operation so it has become more popular. S. J. NREL S807 gives the basic concept in 1922; he had used the two half of the cylinders or drum. The open side of these two half cylinders opens each other and these arraignments fixed to a vertical axis. In recent years, this principle has been an important development in particular two finishers, Oyo Shield and limit side of wind generation of these two companies produce small engine or propeller blades where fluted drums NREL S807 rotor blades have evolved spirally formed. These machines are ideal for use on buoys, offshore platforms, buildings, signals and messages, where small amounts of energy are required .These devices have to be extremely strong, pretty, and omnidirectional. They are more efficient than conventional machines NREL S807 and less pressure on their support structures [20].

The setup used in our research work is vertical axis wind turbine. NREL S807 type wind turbine is used as a vertical axis wind machine .Two main parameters which affect electrical generator is voltage and current .Speed of the generator rotor affects the voltage of electrical machine and when it is connected to load then current started to flow which required more torque. Therefore high torque required to for the connected load .In our model we used the NREL S807 turbine in which torque quality is low but it gives very good speed at the time of rotation. So here we get all the mechanical characteristics for any generator.

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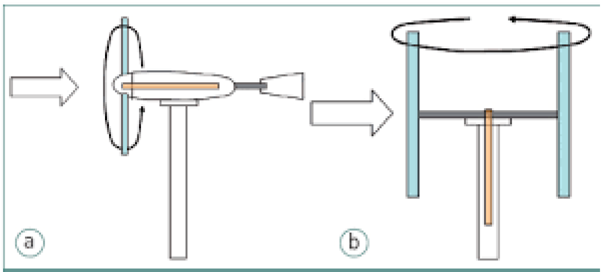

Fig.1: a) Horizontal-axis wind turbine (HAWT - propeller model)
b) Vertical-axis wind turbine (VAWT - H-Darrieus model)

Fig.1HWAT and VWAT

IV. Design Parameters Of HAWT

The various parameter of a vertical axis wind turbine include swept area (A), power of the wind (P), Reynolds number (Re) and Tip Speed Ratio (TSR), Drag Force (F_D), Torque (T), Mechanical power (Pm) and Power coefficient (Cp).

Swept Area (A): The swept area is the section of air that encloses the turbine in its movement, the shape of the swept area depends on the rotor configuration, this way the swept area of an HAWT is circular shaped while for a straight-bladed vertical axis wind turbine the swept area has a rectangular shape and is calculated using: [21].

A = 2RL

Where, A = Swept Area of rotor (m^2)
R = the rotor radius (m)
L= length of the blade (m)

Power of the wind (Pa): The power of the wind is proportional to air density, area of the segment of wind being considered, and the natural wind speed. The relationships between the above variables are provided in equation below

$$P_a = \frac{1}{2}\rho A V^3$$

Reynolds number (Re) and Tip Speed Ratio (TSR): Reynolds number (Re) is defined as the ratio of inertia force to the viscous force. Reynolds number signifies the relative predominance of the inertia to the viscous forces occurring in the flow system. The higher the value of Re. greater will be the relative contribution of inertia effect. Reynolds number as given by equation,

$$R_e = \frac{\rho L V}{\mu}$$

Where, V = velocity of the flow of the fluid (air)
L= length of the blade
ρ = mass density of fluid (air)
μ = viscosity of fluid (air)
ω = is the angular speed [rad/s],
N = Turbine Speed (rpm)

$$\omega = \frac{2\pi N}{60}$$

The power coefficient is strongly dependent on tip speed ratio, defined as the ratio between the tangential speed at blade tip and the actual wind speed. [21]

$$TSR = \frac{\text{Tangential Speed at the Blade tip}}{\text{Actual Wind Speed}} = \frac{R\omega}{V}$$

Drag Force (F_D): There are two ways of extracting the energy from the wind depending on the main aerodynamic forces used:

The drag type takes less energy from the wind but has a higher torque and is used for mechanical applications as pumping water. The most representative model of drag-type HAWTs is the NREL S807.

The lift type uses an aerodynamic airfoil to create a lift force, they can move quicker than the wind flow. This kind of windmills is used for the generation of electricity. The most representative model of a lift-type HAWT is the Darrieus turbine; its blades have a troposkien shape which is appropriate for standing high centrifugal forces. [21]

$$F_D = \frac{C_D C_l\, L\, \rho V^2}{2}$$

Where, CD = drag coefficient
C_l = Chord length (m)

Torque (T): We know torque is equal to the multiplication of force and perpendicular distance of application of force,

T = FD x Int of dl=FD x L

Mechanical power (Pm): The power generated by the mechanical device is called mechanical power. It is usually less than ideal power i.e. air power (Pa). It is calculated by the relation

$$P_m = \omega T$$

The wind velocity is measured by the anemometer and the rpm of the shaft is measured by tachometer.

Power coefficient (Cp): The power coefficient C_p may be defined as how much power we get from the wind with a wind turbine. in other words it is the ratio of mechanical power generated to the available wind energy. The value of C_p is 0.2 up to 5m/s wind velocity,0.3 up to 10m/s and 0.4 for above 10m/s. but according to Betz coefficient the highest value of C_p is 0.593 [21]

$$C_p = P_m / P_a$$

V. Methodology

NREL S807 wind turbines are one of the simplest turbines. Aerodynamically, they are dreg-type devices, consisting of two or three blades (Vertical-half cylinder). A two blades NREL S807 wind turbine would look like an "S" letter shape in cross section.Experimental set-up consists of HAWT, charge controller, battery room, voltmeter and ammeter. Base: The base which we have used in our project is made of concrete and stands approximately feet high .The base should be of such strength that it can support the torque and moments produced from our wind turbine [23].

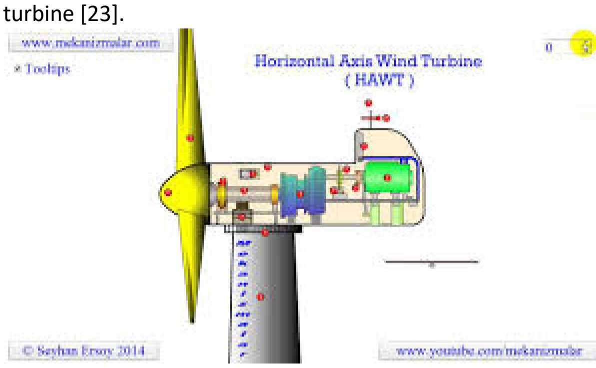

Fig. 2 Schematic drawing showing the drag forces on the NREL S807 blade [22]

Shaft: Blades are claimed and attached the shaft inflexibly. The shaft should be such that it should not bond or twist due to thrust generated by the rotation of blades [23].

Center Mounts: In order to connect turbine blades and radial arms to the centre shaft there should be strong connection needed get will with stand .The centrifugal and inertia forces caused by the wind turbine .The centre shaft mounts machine from aluminum will slide over the end of the shaft and will be secured with set screws enabling quick assembly and disassembly .All the arms are bolted in a centre with an angle of 720 (for five blades) [24].

Radial Connecting Arms:The blades are connected to the centre mount with the help of radial arms .The radial arms such that it should have minimum inertia movements and can with stand high centrifugal forces [24].

Blade Connecting Assembly:Blade connecting assembly will be used to connect the radial arm .The current design is to drill a hole. A washer will be located between a connecting arm and the side of the blade and a set screw cap will secure the blade to the radial arm.

Charge Controller:Wind charge controller is battery charger that can charge batteries by the power from the wind turbine. The charge controller is intelligent for charging batteries. This will prolong the life of batteries. The wind charge controller maintains the rotating speed of the wind turbine and keeps the voltage of charging batterieswhen the wind is too big. The controller will disconnect itself from the wind turbine, so it is very safe.There are three terminals on the left side of the controller; these three terminals will be connected to the three phase output from the wind turbine [25].

Battery: Electrical energy produced by wind turbine has many uses. Converting wind energy into electrical energy enables the user to store energy in a battery, transmit it over long distance, or convert the energy into many different forms. Battery charging is very popular because of its simplicity and versatility.

Fig. 3 Component of a NREL S807 wind turbine [26]

VI. Measurements And Instrumentation

The mechanical power for the tested NREL S807 rotor is can be determined by measuring the mechanical torque on the rotating shaft and rotational speed at different values of wind speed. The wind speed will measured by a propeller type digital anemometer. While the shaft's rotational speed measured using a digital DC tachometer. A voltmeter and ammeter are used for the calculation of voltage or current [27].

VII. Conclusion

In this paper, after broad literature review of some case study it can be concluded that various skill of these wind turbines can be constructed for different applications. They can be used to generate electricity to meet the power requirement for lighting in remote places or off-grid regions. They can be installed between the freeways where the wind shear from passing cars and trucks will rotate this turbine to generate enough power even at home as a bit skill fabricator to light under the over passes and between the freeways. The effect of different parameter on the NREL S807 wind turbine, Further the research can be extended for different variation in parameters such as overlap rations, number of blades in turbine, size of blades and different type blades. Research can move towards the development of small size vertical axis wind turbine for house hold purpose to fulfill the need of power at domestic level.

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