Energy Harnessing By Various Non-Conventional Wind-Turbine Designs And Augmentation Of Its Aerodynamic Efficiency.

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Abstract

In continuous search of clean, safe and renewable energy sources, wind power is certainly one of the most attractive solutions. Wind power was used earlier for several centuries for propelling ships, driving wind mills, pumping water, irrigating field and numerous other purposes.

By 1990's wind-energy to electrical energy has become economically competitive .It is in areas of favorable wind and wind-electric energy systems are now on the forefront of renewable energy utilization projects sponsored by the Department of Nonconventional Renewable Energy (DNRE). Several wind turbine generators have been installed throughout the world.

Various new innovation, design of windmills used throughout the world are discussed with relative merits and demerits, their power generation etc. Also, aerodynamics and various other terms concerned with the windmills are briefly discussed in the paper.

Keyword: *Renewable energy, Electrical energy, Wind farms, Wind speed, Aerodynamics, Wind Turbine Generator etc.*

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1. Introduction

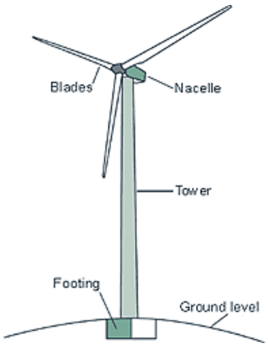

Figure1

In continuous search of clean, safe and renewable energy sources, wind power is certainly one of the most attractive solutions

Wind is the air-in-motion. Wind Energy is converted in rotary mechanical energy by the wind turbine.

Wind farms are located in geographical areas which have continuous, steady, favorable wind in the speed range between 10km/hr to 47 km/hr. Annual average wind speed of 17km/hr is considered to be very suitable.

In India, wind farms are operating in Tamil Nadu, Karnataka and Gujarat since 1989. Several new projects totaling 500MW are at various stages of execution

The aerodynamics is a very important aspect of wind turbines. Overall the details of the aerodynamics depend very much on the topology. Every topology has a maximum power for a given flow, and some topologies are better than others. In general all turbines can be grouped as being lift based, or drag based with the former being more efficient.

2. Types of Windmills

A). On basis of shaft mounting:

I. Horizontal shaft Wind turbine: Horizontal shaft Wind turbine generators units are more popular. The generator-turbine unit is mounted on tall tower.
II. Vertical shaft Wind turbine: Vertical shaft Wind turbine units are mounted on ground level .They are generally in very large range (4MW and above) and are also commercially successfully in some countries.

B). The electrical generators with wind-turbine-generator units

I. 50 Hz A.C. synchronous generators with constant speed connected to the grid. Power control and gear are necessary.
II. Variable frequency A.C. Induction generators with variable speed. An electronics frequency
III. Charger converts variable frequency (0-20 Hz) output to commercial frequency supply.

C). Options available for wind-electrical energy conversion plant

i. As standalone generators with battery storage supports.
ii. In parallel with the electrical grid as energy displacement plants. Battery storage is not necessary.
iii. Wind–Diesel hybrid for remote stand alone system.

India's potential for useful wind energy plant is about 25,000MW. This may constitute about 10 ٪ of the national installed capacity. Wind farms with unit rating of 15 kW-200 KW have been installed in Gujarat and Tamil Nadu.

2.2 Wind's Kinetic Energy Consumption

The aerodynamics of a horizontal-axis wind turbine is not straightforward. The air flow at the blades is not the same as the airflow far away from the turbine. The very nature of the way in which energy is extracted from the air also causes air to be deflected by the turbine. In addition the aerodynamics of a wind turbine at the rotor surface exhibit phenomena that are rarely seen in other aerodynamic fields. for a hypothetical ideal wind-energy extraction machine, the fundamental laws of conservation of mass and energy allowed no more than 16/27 (59.3%) of the kinetic energy of the wind to be captured. This Betz' law limit can be approached by modern turbine designs which may reach 70 to 80% of this theoretical limit.

2.3 Power Control

A wind turbine is designed to produce a maximum of power at wide spectrum of wind speeds. All wind turbines are designed for a maximum wind speed, called the survival speed, above which they do not survive. The survival speed of commercial wind turbines is in the range of 40 Km/s to 72 Km/s. The most common survival speed is 60 Km/s.

If the rated wind speed is exceeded the power has to be limited. There are various ways to achieve this. A control system involves three basic elements: sensors to measure process variables, actuators to manipulate energy capture and component loading, and control algorithms to coordinate the actuators based on information gathered by the sensors.

3. Design Specifications

Stall: Stalling works by increasing the angle at which the relative wind strikes the blades (angle of attack), and it reduces the induced drag.

Pitch control: Major challenge in designing blades is to ensure quick stalling so that sudden acceleration moves the blades. Loads can be reduced by making a structural system softer or more flexible. This could be accomplished with downwind rotors or with curved blades that twist naturally to reduce angle of attack at higher wind speeds.

Generator torque: Modern large wind turbines are variable-speed machines. When the wind speed is below rated, generator torque is used to control the rotor speed in order to capture as much power as possible

Yawing: Modern large wind turbines are typically actively controlled to face the wind direction measured by a wind van**e.** By minimizing the yaw angle (the misalignment between wind and turbine pointing direction), the power output is maximized and non-symmetrical loads minimized. However, since the wind direction varies quickly the turbine will not strictly follow the direction and will have a small yaw angle on average. The power output losses can simply be approximated to fall with $(\cos(\text{yaw angle}))^3$**.**

Blades and its material: The ratio between the speed of the blade tips and the speed of the wind is called tip speed ratio. High efficiency 3-blade-turbines have tip speed/wind speed ratios of 6 to 7. Modern wind turbines are designed to spin at varying speeds. Use of aluminum and composite materials in their blades has contributed to low rotational inertia, which mean that newer wind turbines can accelerate quickly if the winds pick up, keeping the tip speed ratio more nearly constant.

Blade count: Aerodynamic efficiency increases with number of blades but with diminishing return. Increasing the number of blades from one to two yields a six percent increase in aerodynamic efficiency, whereas increasing the blade count from two to three yields only an additional three percent in efficiency. Further increasing the blade count yields minimal improvements in aerodynamic efficiency and sacrifices too much in blade stiffness as the blades become thinner.

Tower Height: Wind velocities increase at higher altitudes due to surface aerodynamic drag and the viscosity of the air. The variation in velocity with altitude, called wind shear, is most dramatic near the surface. Typically, in daytime the variation follows the wind profile power law, which predicts that wind speed rises proportionally to the seventh root of altitude.

4. Innovation in Windmill Designs

Altering the windmill designs has shown surprisingly good results. Also, the scope of its usage has increased as they are available in variety of forms as per requirement. Here are a few new windmill designs along with its details.

A. Whale Power

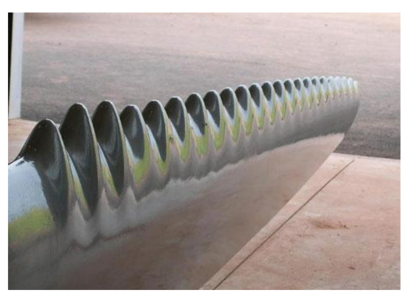

Figure 2

It has redesigned the typically smooth blades on a New blade design could increase annual electrical production for existing wind farms by 20 percent. Whale Power's tubercle-like structures on the turbine blades allow the blades to have steeper angles--without causing stalling or creating too much drag. During low wind, blades with steeper angles can theoretically generate significantly more power.

B. Quiet Revolution

Figure 3

The wind turbine is designed for an urban environment with low wind speeds and changing wind directions. Its helical design allows the turbine to collect wind from all directions equally.

C. Wind spire

Figure 4

Wind spire is a vertical wind turbine, similar to the Quiet Revolution. This 10 m tall, 1.3 m wide turbine generates 2000 turbine, adding a series of ridges, based on kilowatts per hour given 20 kmph winds, and it can survive winds up to 170 kmph.

D. Honeywell Wind Turbine

Figure 5

Honeywell is a rooftop wind turbine that works in wind speeds as low as 4 kmph. The Honeywell turbine does not have gears like traditional wind turbines. Instead, it creates power from magnets in its blade. It results in lower resistance, which can mean higher energy output.

E. We Power

Figure 6

We power is a vertical-axis wind turbine that operates quietly and performs well in low-speed winds. Unlike many turbines, which either rely solely on lift (in the case of traditional three-blade turbines) or drag (used in wind-speed gauge anemometers), We POWER uses a combination of both. Its unique airfoil lets it produce power at low wind speeds.

F. Spiral Drag Wind Turbine

Figure 7

This vertical axis turbine uses drag propulsion to push the blade that is designed as an involutes spiral. The turbine uses aluminum vanes formed into an involutes spiral--giving the blade extremely high surface area--to capture wind and rotate.

G. Architectural Wind Turbine

Figure 8

Architectural Wind turbine is a small wind turbine that can be mounted on the top edge of a building. When wind hits a building, the resistance creates an area of accelerated air flow--straight up the side of the building. It is situated at Logan International Airport in Boston.

H. Sky Serpent

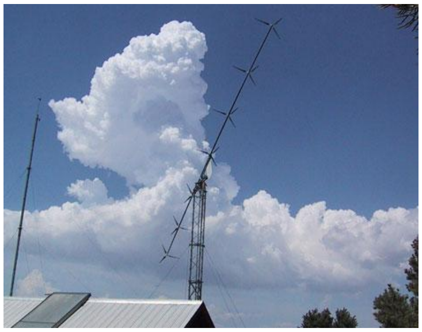

Figure 9

The Sky Serpent makes use of multiple rotors attached to a single generator. Past multi rotor turbines have run into trouble because their rotors just catch the wind generated by the spin of neighboring rotors. The Sky Serpent's rotors are spaced and angled to ensure that each one is catching fresh wind.

I. Helix-Wind

Figure 10

Helix Wind offers a well-designed system that creates electricity to power any home or small business. This design catches wind from all directions, creating smooth powerful torque to spin the electric generator. It’s mounted up to 12 m high, in winds as low as 16 kmph, thus allowing the Helix system to fulfill electricity needs.

5. Aerodynamics of Wind Turbines

5.1 lift, Drag and Coefficient of Power

The primary focus of wind turbine aerodynamics is the magnitude and distribution of the force generated by wind interacting with the blade.

Drag is the same force that is felt pushing against you on a windy day. The direction of the drag force is parallel to the relative wind

Lift is the same force that allows most aircraft to fly. The direction of lift force is perpendicular to the relative wind.

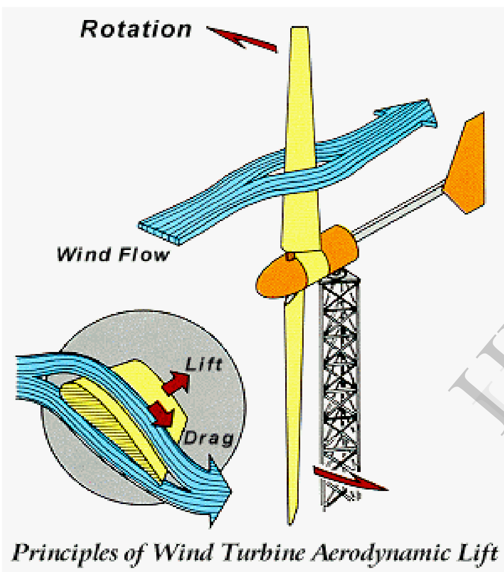

figure 11

The coefficient of power is the most important variable in wind turbine aerodynamics. This equation is similar to efficiency, so values between 0 and less than one are typical.

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

C_P Is the coefficient of power ρ is the air density, A is the area of the wind turbine, and finally V is the wind speeds.

5.2 AEROFOIL

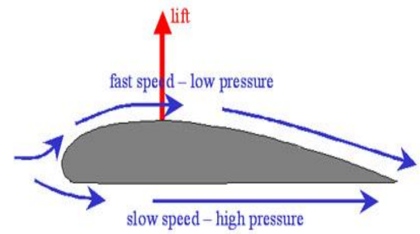

Figure 12

The airfoil sections are of utmost importance for the performance of a windmill. Here maximum L/D ratios are desired to maximize efficiency. To avoid over speed conditions, the maximum power of the windmill has to be strictly limited, which can be achieved by a specially designed family of airfoils.

In an airfoil, one surface of the blade is somewhat rounded, while the other is relatively flat. When wind travels over the rounded, downwind face of the blade, it has to move faster to reach the end of the blade in time to meet the wind travelling over the flat, upwind face of the blade. Since faster moving air tends to rise in the atmosphere, the downwind, curved surface ends up with a low-pressure pocket just above it. The low-pressure area sucks the blade in the downwind direction, an effect known as "lift." On the upwind side of the blade, the wind is moving slower and creating an area of higher pressure that pushes on the blade, trying to slow it down.

6 CASE-STUDIES:

Wind Turbine Generation Plant details that we visited in Maharashtra (India).

1). Total number. Of WTG: 96 machines

Plant consists of WTG of capacity:

a) 1200 KW or 1.2 MW
b) 600 KW or 0.6 MW

c) 1250 KW or 1.250 MW

Stretch: 35 to 40 km

2).600 KW WTG configurations:

a) Length of blade : 26m
b) Height of blade : 65m
c) Cost: 3.5 Crore approx.
d) Tower shape : Lactic

3).1200 KW WTG configurations:

a) Length of blade: 35m
b) Height of blade: 75m
c) Cost: 6 Crore approx.
d) Tower shape: turbine

4). Type of Gear box: Asynchronous
5). Gearbox speed ratio: 1:75
6). Maximum speed: 42 km/hr
7). Threshold speed: 7 km/hr

7. MERITS-DEMERITS:

MERITS:

I. Wind Energy is an inexhaustible source of energy and is virtually a limitless resource.
II. Windmill generators don't emit any emissions that can lead to acid rain or greenhouse effect.
III. Energy is generated without polluting environment.
IV. The area occupied by wind-mill units is very less although the height is more. Thus the land around it can be utilized for other purposes like agriculture.
V. Increase in aerodynamic efficiency has saved the material requirement to a large extent. Also, it has reduced the unit size considerably.
VI. Vi Recently, wind-mills using waste materials have also been devised challenging the traditional WTG units and largely increasing the scope for innovation in design, materials, WTG capacity etc.

DEMERITS

i. It is unreliable energy source as winds are uncertain and unpredictable.
ii. Windmills can be set up only in those areas where strong wind is available for maximum period of time.
iii. Generally, the places where electricity is required are far from where it is generated. Thus transmission costs are added up to the price of electricity.
iv. Maintenance cost of wind turbines is high as they have mechanical parts which undergo wear and tear over the time.

8. CONCLUSION

- Thus various non-conventional methods of wind power harnessing result in energy production
- wind power contributes to about 2000.00MW of total energy.

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