HAWT for Power Generation

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ABSTRACT

A wind turbine is a device that converts kinetic energy from the wind into mechanical energy. If the mechanical energy is used to produce electricity, the device may be called a wind generator or windcharger. Today’s wind turbines are manufactured in a range of vertical and horizontal axis types. Wind turbines are basically used for various applications. It is considered to be the most efficient and clean energy in this present scenario. In this paper a novel model of wind turbine has been proposed for auxiliary power generation in ship. This turbine remains as a good extra source of power in the ships. Basically, a design of Horizontal axis wind turbine has been given in this paper.

Keywords: Vertical, Horizontal axis wind turbine, Power generation

I. INTRODUCTION

Wind turbines are designed to exploit the wind energy that exists at a location. Aerodynamic modelling is used to determine the optimum tower height, control systems, number of blades and blade shape. Wind turbines convert wind energy to electricity for distribution. Conventional horizontal axis turbines can be divided into three components. The rotor component, which is approximately 20\% of the wind turbine cost, includes the blades for converting wind energy to low speed rotational energy. The generator component, which is approximately 34\% of the wind turbine cost, includes the electrical generator, the control electronics, and most likely a gearbox (e.g. planetary gearbox, adjustable-speed drive or continuously variable transmission) component for converting the low speed incoming rotation to high speed rotation. Horizontal-axis wind turbines (HAWT) have the main rotor shaft and electrical generator at the top of a tower, and must be pointed into 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. The blades are placed a considerable distance in front of the tower and are sometimes tilted forward into the wind to a small extent. Some models operate at constant speed, but more energy can be collected by variable-speed turbines which use a solid-state power converter to interface to the transmission system.

Picture Depicting Upwind and Downwind turbine

All turbines are equipped with protective features to avoid damage at high wind speeds, by feathering the blades into the wind which ceases their rotation, supplemented by brakes. Downwind machines have been built, despite the problem of turbulence (mast wake), because they don’t need an additional mechanism for keeping them in line with the wind, and because in high winds the blades can be allowed to bend which reduces their swept area and thus their wind resistance. Since cyclical (that is repetitive) turbulence may lead to fatigue failures, most HAWTs are of upwind design. In this paper a design of upwind Horizontal Axis Wind Turbine has been provided. A cost effective model has been given here.
II. BLOCK DIAGRAM OF THE TURBINE MODEL PROPOSED

A block diagram has been given here for better understanding of the model proposed. The proposed model has been designed with two rotors, each rotor possessing 3 blades. Each rotor has separate brake discs, in order to safeguard the rotors during turbulence. Both the rotors are connected to the same Gearbox and Generator.

Low speed shaft and High speed shaft are connected to the Gearbox and Generator respectively. Finally the total Nacelle is placed on the tower. A yaw drive and a yaw motor are also set up, which is located inside the tower. Then the power generated is stored in the storage unit.

III. MODEL DESCRIPTION

The three bladed rotors is the most important and most visible part of the wind turbine. It is through the rotor that the energy of the wind is transformed into mechanical energy that turns the main shaft of the wind turbine. Lift is primary due to the physical phenomena known as Bernoulli’s Law. This physical law states that when the speed of an air flow over a surface is increased the pressure will then drop. The wind turbine will start to rotate very slowly at first, but as it gathers speed it begins to accelerate faster and faster. The change from slow to fast acceleration is a sign that the blade’s aerodynamic shape comes into play, and that the lift greatly increases when the blade meets the head wind of its own movement. The fast acceleration, near the wind turbine’s operational rotational speed places great demands on the electrical cut-in system that must capture and engage the wind turbine without releasing excessive peak electrical loads to the grid.

The proposed model is designed in such a way that it could be used in any oceanic conditions. In this model Horizontal Axis Wind Turbine has been designed especially an upwind turbine is given. Two rotors have been used here, each rotor is fitted with 3 blades. Totally 6 blades. In this design the rotors are kept opposite to each other, facing in different directions.

IV. INTERNAL STRUCTURE

The following diagram depicts the internal structure of the model proposed. This diagram also depicts the basic idea behind the project.
Here in this diagram Double rotor mechanism is clearly depicted. Here both the rotor shaft is attached to separate Gearboxes, Which in turn is connected to the Generator. This whole setup is set inside the Nacelle mounted on the tower.

Due to double rotor mechanism power generated will increase. This model was generated specially for the turbine that could be installed in ships for power generation. A pitch system can be used to control the speed of at different conditions.

V. AIR FOIL

In the proposed model each Rotor diameter of 17m is chosen, so as per the requirements S-821 air foil is chosen.

VI. DESIGN SPECIFICATIONS

Few specifications of the proposed model have been specified here in this section.
Total Rotors = 2
Each Rotor Diameter = 17 metre.
Blade Length = 5-10 metre (Here 8 metre is chosen)
Hub Height $[9] = 2.7936 (D)^{0.7663}$
$= 2.7936(17)^{0.7663} = 25-30$ metres (approx.) = 30 metre can be taken here.
Generator = Geared Drive, High Speed, three stage, wound rotor reduction.
t/c = 0.240.
Clmax = 1.4.
Cdmin = 0.014.
Cmo = 0.15.

Rotor swept area $= \frac{\pi d^2}{4} = 226.865$ (Each Rotor)

Tip Speed Ratio = 5.
The following mass calculations are done according to the formulas [2] derived by National Renewable Energy Laboratory (NREL).

Mass of few components that are used in this model have been calculated and given here. All the mass calculations are in Kg’s and all the length calculations are in metres.

\[ \text{Blade Mass} = 0.1452 \times \text{Rotord Radius}^{2.9158} \text{ (per Blade)} \]
\[ = 0.1452 \times (8.5)^{2.9158} = 74.46. \]

\[ \text{Hub Mass} = 0.954 \times (\text{Blade mass per single blade}) + 5680.3 \]
\[ = (0.954 \times 74.46) + 5680.3 = 5751.33. \]

\[ \text{TotalPitchBearingMass (TPBM)} = 1295 \times \text{Total Blade mass (6 blades)} + 491.31 \]
\[ = (1295 \times 446.76) + 491.31 = 579045.51 \]

\[ \text{TotalPitchSystemMass} = (\text{TPBM} + 1.328) + 555 \]
\[ = (579,045.51 + 1.328) + 555 = 769527.43 \]

\[ \text{Spinner, Nosecone} = (18.5 \times \text{Rotor Diameter}) - 520.5 = (18.5 \times (17+17)) - 520.5 = 108.5 \]
\[ \text{LowSpeedShaftMass} = 0.0142 \times \text{(Rotor Diameter)}^{2.988} \]
\[ = 0.0142 \times ((17+17)^{2.888} = 376.0100 \]

\[ \text{Bearing Mass} = \frac{(\text{Rotor Diameter} \times 0.883)}{600 - 0.038} \times 0.0092 \times (\text{Rotor Diameter})^{2.5} \]
\[ = ((17+17) \times 0.0133 \times 0.0092 \times (34)^{2.5} = 28.0424 \]

\[ \text{TotalYawsystemMass} = 1.6 \times \text{(0.0009(Rotor Diameter)}^{3.314} \]
\[ = 1.6 \times (0.0009 \times (17+17)^{3.314}) \]
\[ = 171.2709 \]

\[ \text{Tower Mass} = (0.3973 \times \text{swept area} \times \text{hub height}) - 1414 \]
\[ = (0.3973 \times 226.865 \times 30) - 1414 = 1290.0039 \]

\[ \text{MainframeMass} = 2.233 \times (\text{Rotor diameter})^{1.953} \]
\[ = 2.233 \times (17+17)^{1.953} = 2187.09 \]

\[ \text{Power Generated by the turbine} [8] \]
\[ = C_p \times 0.5 \times \rho \times A \times V^2 \times \eta_g \times N_b \]
\[ = 21.249 \text{ Kwh} \]

All these values by these calculations tend to change owing to the variable wind speed prevailing in the Ocean.

VII. CONCLUSION

With rapid development of wind power technologies and significant growth of wind power capacity installed worldwide, various wind turbine concepts have been developed. Wind Energy is the major source of power for the upcoming generation where fossil fuels are fast depleting. Millions of ships waste tons offossil fuels per year. Hence the model proposed in this paper can be a wide replacement for it, and can act as a very good auxiliary power supply.

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REFERENCES


