Development of Wind Energy Conversion System to Meet Future Energy Needs

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Abstract
Increase in cost of energy is one of the major causes of inflation. Increase in cost of fuels, combined with non-availability of fuels has invoked interest in usage of renewable source of energy viz., wind energy as the future source of power. The study includes a description of the design and fabrication of wind mill with emphasize on the conversion system, different type of rotors and their functioning and generation of electric power. Analysis is based on geographical terrain conducive for its installation.

Keywords
Design, Fabrication, Energy Production, Sitting, Wind Energy, Conversion System, Solidity

I. Introduction

The primary method proposed for using wind energy is to convert the kinetic energy of the wind into mechanical energy and then into electrical energy. Wind turbines are used to transform the air flow into rotary power. Basically wind turbines extract power from the wind when their rotors are pushed around by moving air. In recent years there has been a tremendous interest in wind energy. Wind power can play a vital role for water supply (wind pumps) and electric power generation (wind generators). This article gives a general overview of wind machine design, basic elements of WECS (wind energy conversion system) sitting of wind energy conversion system, methods to control rotor over speed and electric power generation. The schematic diagram of wind mill is given in fig. 1.

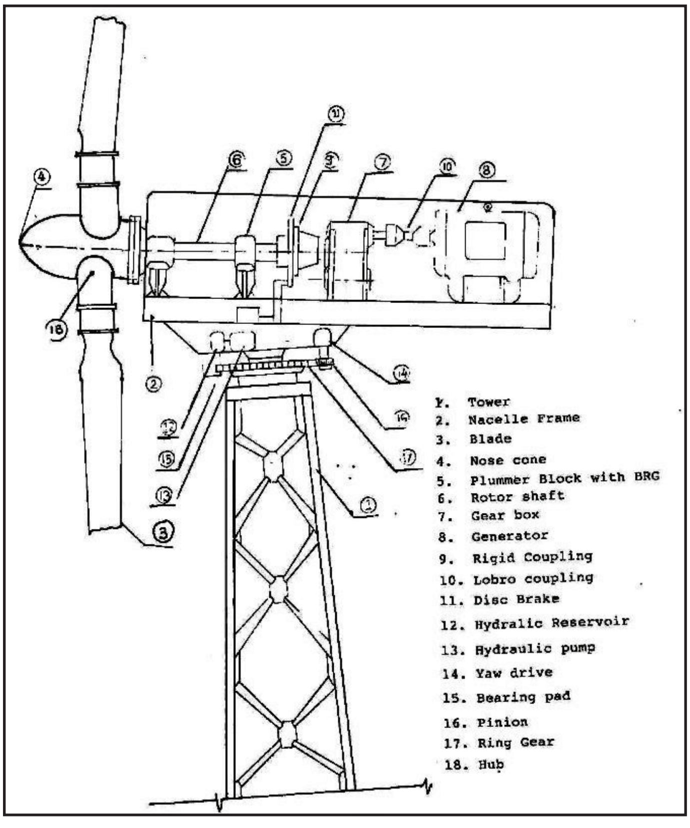

Fig. 1: Diagram of Wind Mill

II. Wind Energy

The kinetic energy in the wind is proportional to the square of its velocity. Since wind forces are proportional to the square of the velocity, wind power is proportional to wind speed cubed. If wind speed doubles wind power goes up by a factor of eight. This is an important concept of wind power generation.
The power that wind turbine blades can extract from the wind is given by the expression

Power $= e\, k\, A\, \rho\, \upsilon^3$
e = efficiency of the blades
k = conversion factor for units
A = Area swept out by blades
υ = Wind velocity
ρ = density of air

III. Wind Machine Design

In order to design blade, aerodynamic analysis for optimum CP (coefficient of performance) at design wind speed should be considered. Chord and blade angles are calculated based on aerodynamic analysis.

Mechanical design of gears, shafts and brakes should be done based on minimum power required to start the machine, cut-in-speed, capacity to absorb variation in rotor torque by storing in the form of strain energy, shaft rigidity for non-useful loads and flexibility for useful loads.

Structural design for blades, root, hub, support structure, tower and foundation is based on static, dynamic and fatigue loading. Blade root is subjected to loads as well as moments in all three directions. In addition, they vary throughout the life of the machine even if it is in a shutd own condition. Soft designing techniques like coining and teetering of rotor may be used in rotor design.

Selection of tower is also important in wind machine design as it slows down the wind and also imparts excitation loads on the machine. Natural frequencies of different wind machine components need to be carefully designed considering the frequency of these excitation loads.

IV. Significance of Solidity in WECS

Solidity of a wind mill is the ratio of blade or rotor surface area to rotor swept area.

To get 2 KW out of a generator that runs at 200 rpm, the large magnet and coils that weigh as much as 135 kg is required. The same 2 KW can be generated by a smaller generator which weighs about 22.5 kg by spinning that generator at about 2000 rpm.

From this we can see that a light weight low cost wind turbine requires a fast
– turning rotor with much lower solidity as shown in fig. 2.

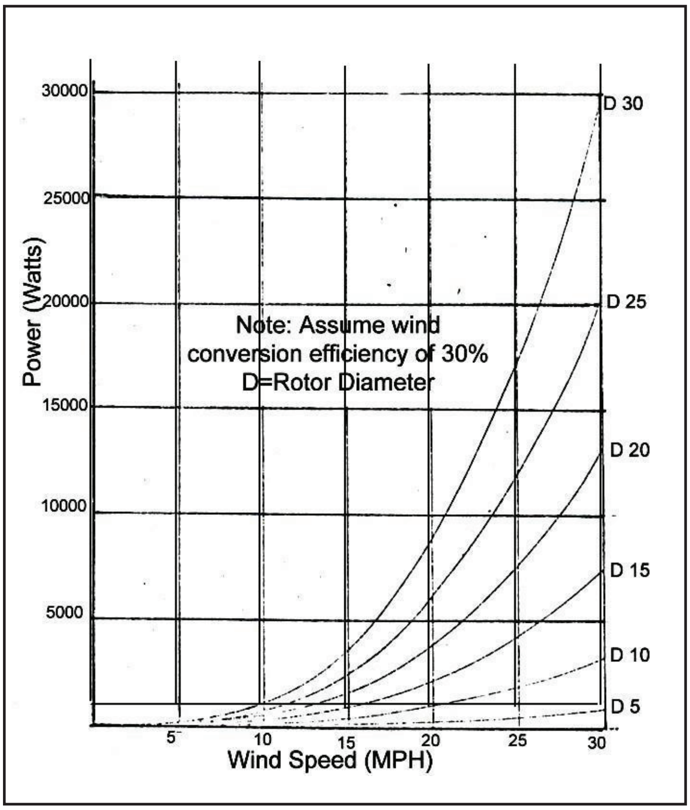

Fig. 2: Can be Used to Estimate the Power Output of any Wind Turbine in any Wind

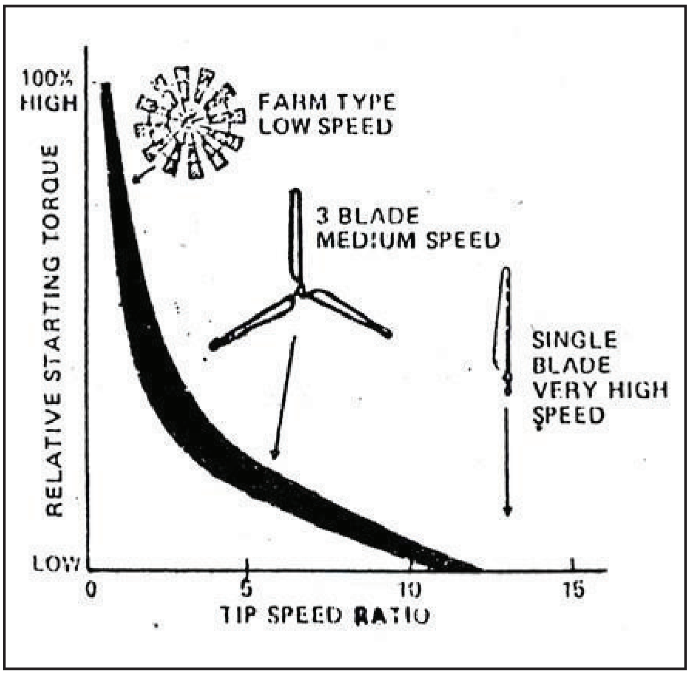

Fig. 3: How the Relative Torque of Various WECS Decreases With Increasing Tip Speed Ratio?

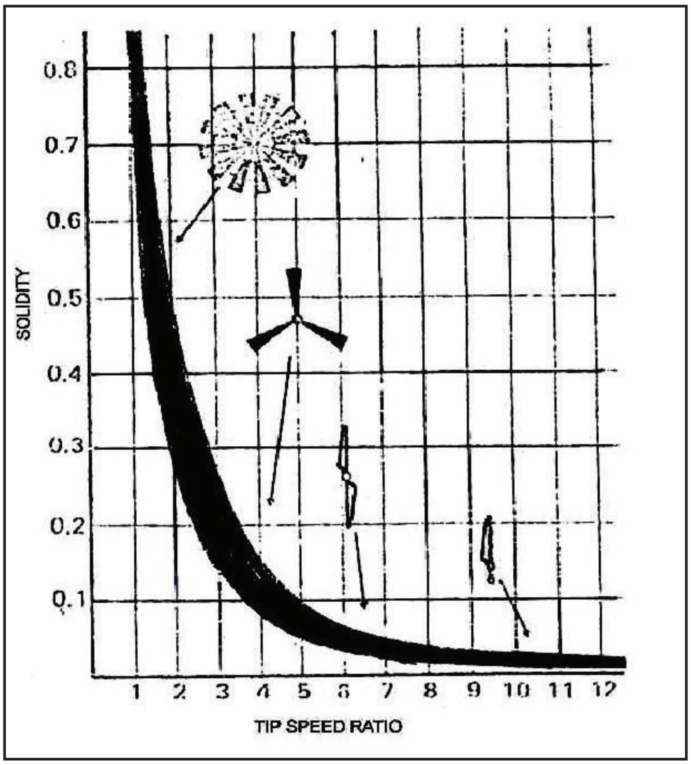

Fig. 4: How the Tip Speed Ratio Changes With Solidity

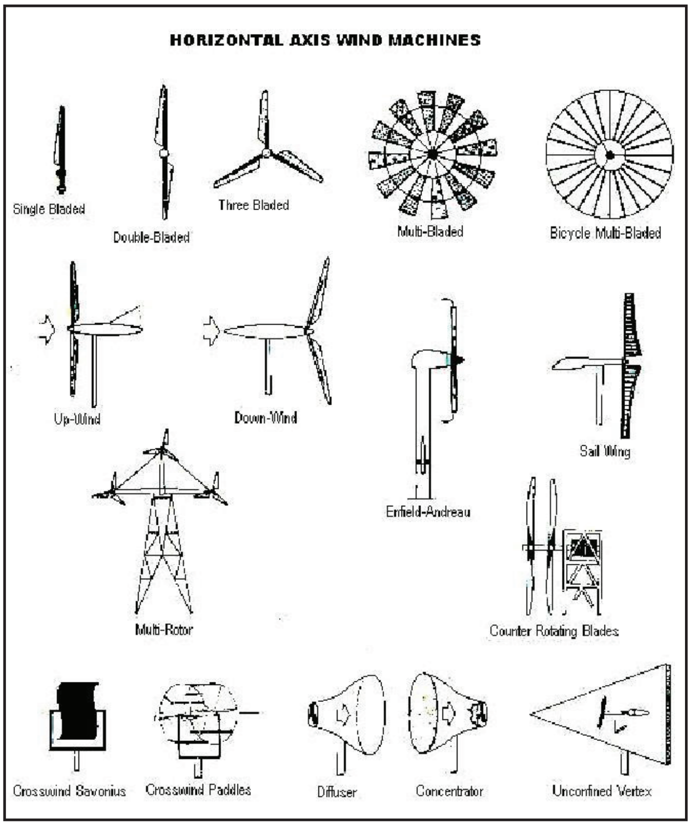

Fig. 5: Horizontal Axis Wind Machines

High solidity rotors spins slowly compared to low solidity rotors. Fig. 3 shows how the relative torque of various WECS decreases with increasing tip speed ratio. High torque requires a high solidity and that type of WECS works best at low tip speed ratios. Fig. 4 shows how the tip speed ratio changes with solidity. Solidity affects design appearance in its relation to the number of blades. High solidity wind turbines have many blades; low solidity machines have few, usually four or less. A wide variety WECS are sketched in fig. 5 and fig. 6.

Many of the wind machines are designed with three or more blades, two blades are occasionally used. A small two bladed turbines usually need a larger tail fin than an equivalent three bladed machines or special weights to make the wind wheel behave as a four bladed unit.

Small two bladed WECS have governor control mechanism weights in a position where another set of blades would otherwise be installed. For small machines this approach is practical. For large two bladed machines yaw controls are more appropriate.

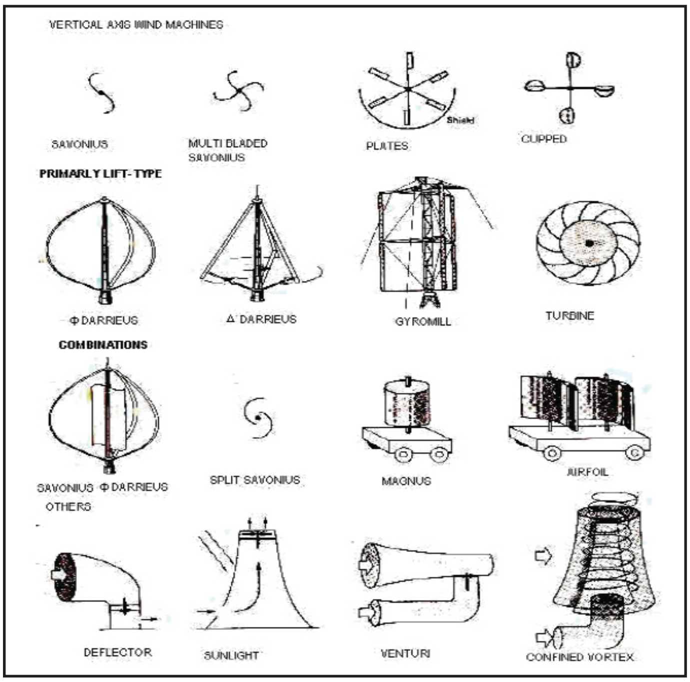

Fig. 6: Vertical Axis Wind Machines

The major construction variations we find when selecting a WECS generally will involve the blades. Different blade construction methods are shown in fig. 7. On popular blade material is wood either laminated or solid with or without fiber glass coatings. Uncoated wooden blades usually have a copper or other metal, leading edge cover for protection.

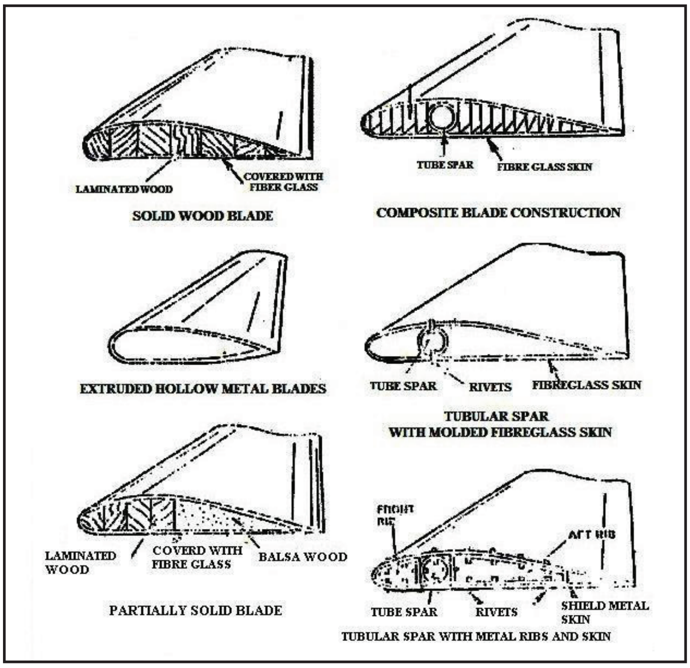

Fig. 7: Different Blade Construction Methods

The extruded hollow aluminum blade can also be used. Built up fiber glass blades with honey comb or foam cores or hollow cores are also being used.

V. Power From the Wind

To find a WECS site with the most available wind power it is essential to understand the variation of power with wind speed.

Available power $= 0.5 \times D \times A \times S^3$

Where

D = Air density

A = Area of the rotor disc

S = the wind speed.

Since the air density (D) at a site normally varies only 10 percent or less during the year the amount of power available depends primarily on the area. (A) of the rotor disc and the wind speed (S). Increasing the diameter of the rotor disc by increasing the blade length will allow the WECS to intercept more of the wind and there by harness more power.

VI. Siting of Wind Energy Conversion System

A. Siting in Flat Terrain

The only way to increase the available power in uniform terrain is to raise the machine higher above the ground. A measurement of average wind speed at one level can be used to estimate wind speed at other levels.

Fig. 7 shows how a sharp change in roughness affects the wind profile

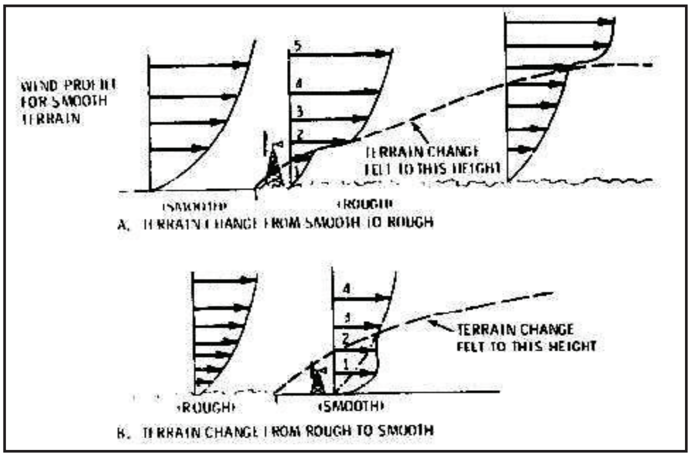

Fig. 8:

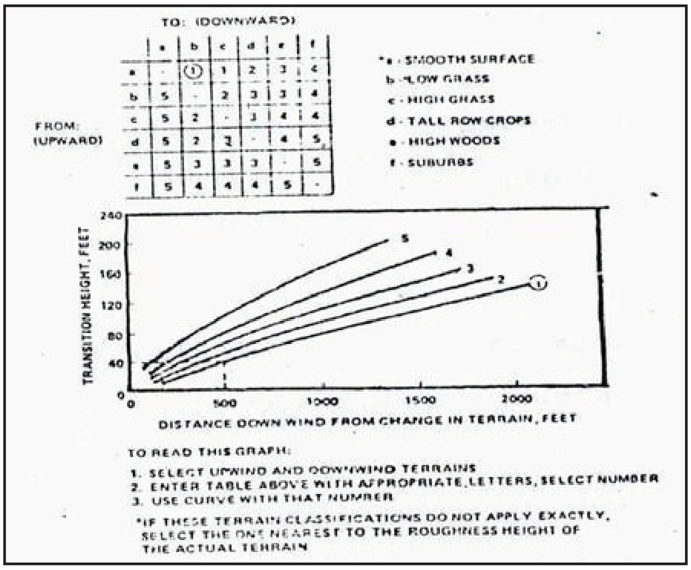

Fig. 9:

If a WECS were sited at the first level in part A of the figure the user would be greatly under – utilizing wind energy since roughness changes cause a sharp increase in wind speed slightly above the first level.

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Part (B) of the figure shows that in smooth terrain, little or anything would be gained by increase in tower height from the first level to even as high as the third.

To estimate the level at which a dramatic change in wind speed might be expected the user must estimate the height to which upwind surface roughness affect the wind profile. Fig. 9 provides this estimate called transition heights.

B. Siting in Non-Flat Terrain

To select candidate sites in such terrain the potential user should indentify the terrain features (i.e. hill, ridges, cliffs, valleys) located in 'or near' the siting area.

In complex terrain land forms affect the air flow to some height above the ground in many of the same ways as surface roughness does.

However to topographical features affect air flow on a much larger scale over shadowing the effects of roughness. When weighing various sighing factors by their effects on wind power, topographical features should be considered first barriers second and roughness third.

VII. Methods to Control Rotor Over Speed

It is important to understand the various methods of rotor speed control. Blades are designed to with stand certain centrifugal force and a certain wind load. The centrifugal force tends to exert a pull on the blades whereas wind loads tend to bend the blades as shown in fig. 9.

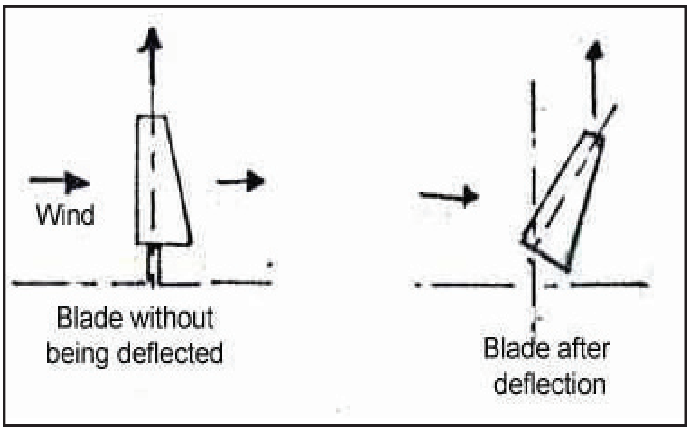

Fig. 10:

A control is needed to prevent over stressing the WECS in high winds. Obviously one could design a wind turbine strong enough to withstand the highest possible wind. But this is more expensive compared to a more fragile unit having a good control system.

Two primary methods exist for controlling a wind turbine is

- Tilting the wind wheel out of excessive winds and
- Changing the blade angles to lower their loads

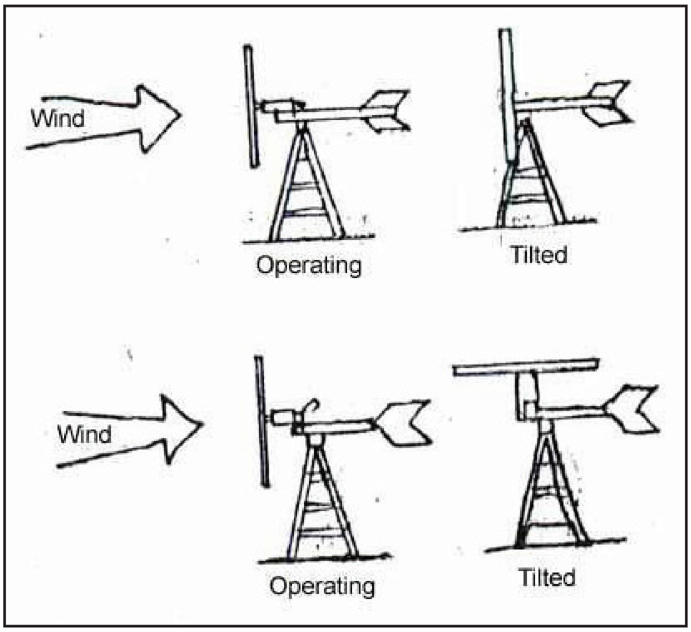

Fig. 11: Illustrates Two Methods Commonly Used for Shut - off Control

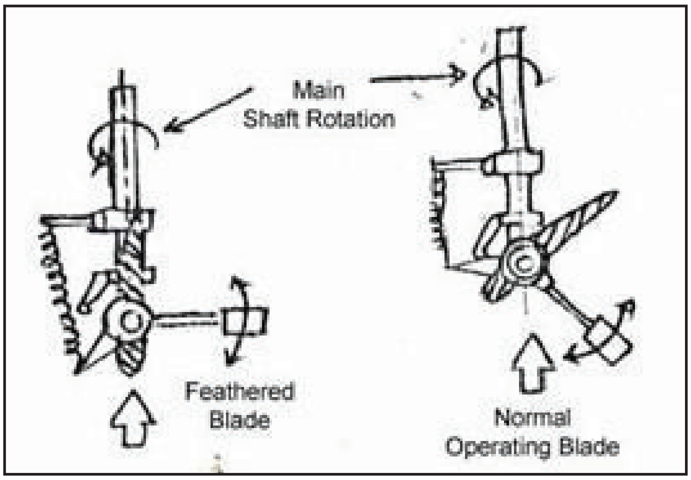

Fig. 12: Illustrates a Simple Mechanical Mechanism Used to Control Blade Angle for Feathering the Blades

Here the leading edge of the blade is in its normal positions at an angle suitable to cause blade motion in the direction indicated. As blade rpm increases centrifugal force on fly weight cause the weight which is connected to the blade to move around the blade center pivot shift and cause the blade to pitch towards the feathered position. The feathered position pulls the leading edge of the blade in to the wind to reduce or eliminate its driving force.

Over speed control or shut off or re- set function can be combined with any of the design types to provide manual shut down of the WECS. Other methods of blade control. Such as automatic drag spoilers and hydro line brakes can also be used.

Another WECS characteristic is its furling speed at which the WECS is automatically or manually shut off. WECS that must be furled will do so by automatic mechanical or electronic control or to operate a ground shut off control. When high winds are anticipated the tail vane may be locked side ways to turn the machine out of the wind a brake is locked or blades are locked in the feathered position.

VIII. Electric Power Generation

Alternating current is generated in an ac generator by passing coils near alternate poles of magnets. The ac current generated is fed directly to the wires outside the unit. The faster the coils of wire pass the magnetic poles the higher the frequency. To establish a fixed or constant frequency the rotor rpm must be kept constant regardless of wind speed. For small WECS the blade control device required to hold a constant rpm can be an expensive mechanism.

Special generators are being developed that produce a constant frequency but allow for variable rpm by electronic compensation. Another method for generating fixed frequency ac is to generate dc, and change the dc into ac by means of an inverter.

Generation of dc usually involves generation of ac inside the generator then conversion of the ac to dc by means of brushes and a commutator. Another method is to rectify the ac out put of the alternator to dc.

Suppose that the WECS supplies more kWh than needed. The batteries would be over charged and energy would be wasted. To preclude this situation, a load monitor is used. The load monitor senses the situation when the WECS creates more power than the electric system needs and reacts by switching on load. Load might be a resistance electric heater immersed in a water heater tank. It may be another battery bank or any other load that will use the excess power.

IX. Conclusion

The need for a renewable, non polluting source of energy in the present scenario is of at most importance considering the cost of fuels, their scarcity and the pollution caused by the fossil fuels. This study, attempt to provide an insight into production of wind energy, which is a renewable source of energy. It emphasizes mainly on the design and fabrication of wind energy system. The study concludes that design and fabrication of wind energy system, has desired performance and characteristics in experimental situation

Refereences

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