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Wind turbine – Varying blade length with wind speed

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Abstract: *The methodology for design of variable length blade is proposed in this project. The power produced at any given time is thus dependent on wind velocity and the rotor swept area of the turbine. Wind is variable in availability and consistency, thus to extract more power from the same variable velocity, it is required to vary the diameter of the rotor. In order to capture the maximum power the rotor diameter must be increased during low wind speed and decreased during high wind speeds. A variable length blade can adapt length variation to accommodate low wind velocities as well as high wind velocities during extreme conditions by extension and retraction mechanism, thereby increasing the operational time and power production of the turbine.*
Keywords: *Wind power, variable length, high wind speed, low wind speed, constant power*

I. Introduction

Wind energy has become one of the fastest growing renewable energy resources. The ability of a wind turbine to transform the wind's kinetic energy into electric power is limited by few factors. These include the Betz limit, the availability of wind, swept area of the turbine blades and the wind speed. The swept area of a wind turbine blade plays an important role in energy output. The larger the swept area the more is the wind energy available for extraction. Hence it is required to design the blades of the wind turbine which can generate the power during high wind speeds. The flexible length blade can generate power during variable wind speeds and improves the efficiency of the system. In this paper the methodology for design of flexible length blade is proposed, the effect of flexible length blade on conventional fixed length blade is discussed.

II. Fabrication Of Wind Turbine Blade

1. WIND POWER

Electrical energy can be generated from wind energy. This is done by using the energy from wind to run a windmill, which in turn drives a generator to produce electricity .The windmill in this case is usually called a wind turbine. This turbine transforms the wind energy to mechanical energy, which in a generator is converted to electrical power. An integration of wind generator, wind turbine, aero generators is known as a wind energy conversion system (WECS).

Modern wind energy systems consist of the following components:

- A tower on which the wind turbine is mounted;
- A rotor that is turned by the wind;
- The nacelle which houses the equipment, including the generator that converts the mechanical energy in the spinning rotor into electricity.

The tower supporting the rotor and generator must be strong. Rotor blades need to be light and strong in order to be aerodynamically efficient and to withstand prolonged used in high winds. In addition to these, the wind speed data, air density, air temperature need to be known amongst others.

2. COMPONENTS REQUIRED

2.1 DC MOTOR

An electric motor is a machine which converts electrical energy to mechanical energy. When a motor is in operation, it develops a torque which produces mechanical rotation. Here a 12v ,60 rpm dc motor is used.

2.2 BLADE

Blades are the energy harvesting units of a wind turbine. These blades convert the wind energy incident on them to rotational motion of the motor. The two important parts of the variable length blade wind turbine are Inboard portion and Outboard portion. The outboard porrtion is mounted inside the inboard portion, guided to be telescoped relative to the inboard portion. An actuator system moves the outboard portion of the blade radially to adjust the wind turbine's rotor diameter.

2.3 SCREW

A lead screw, also known as the power screw or the translation screw is a screw used as a linkage in a machine, to translate turning motion into linear motion.

2.4 CONTROL UNIT

In automotive electronics, Electronic Control Unit (ECU) is a generic term for any embedded system that controls one or more of the electrical system or subsystems in a motor vehicle. Here the control unit compares the wind speed input from anemometer and the cut in speed of the blade. If the wind speed is greater than cut in speed, the motor screw mechanism is used to increase the length of blade. In low wind speeds blade length is reduced. The microprocessor based control unit controls all these mechanisms.

III. Indentations And EQUATIONS

(1) Rotational energy = $(1/2)\, M\, v^2$

(2) Power = $(1/2)\, A\, \rho\, V^3$

$A = \pi r^2$, here r is the length of the blade

(3) Power = $C_p\, (1/2)\, \rho\, \pi\, L^2\, V^3$

(4) $L = (\text{power}/(C_p * 1.93 * v^3))^{1/2}$

L = length of blade

C_p = Power coefficient

IV. Figures And Tables

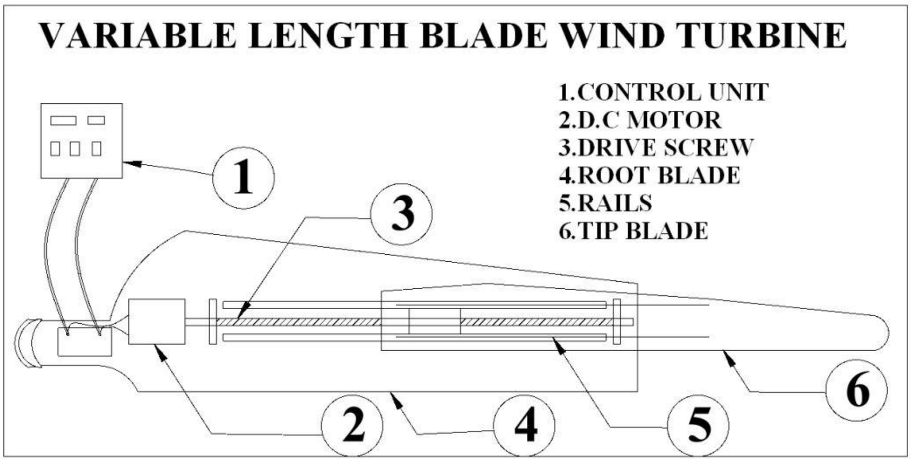

Fig 1. Components of variable length blade

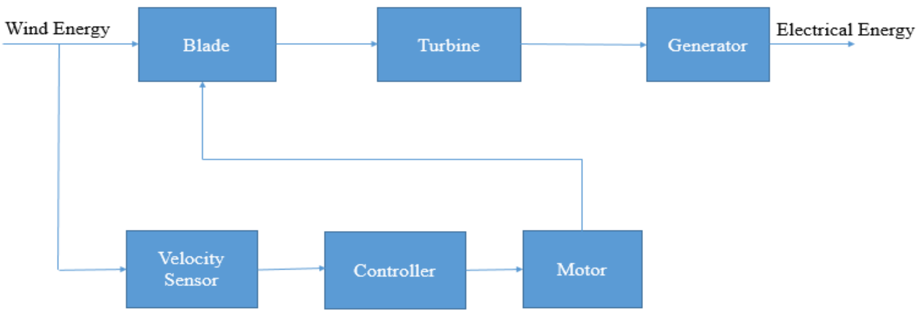

Fig 2 . Working principle

The wind speed sensed by the velocity sensor is fed to the control unit, where the input is compared with the preset value. If the input speed is greater than the preset value control unit utilizes the motor screw mechanism to reduce the blade length. In case of low input speeds blade length is extended.

Fig 3. Fabricated model of variblade wind turbine blade

CALCULATED LENGTH

Wind speed(m/s)	Power generation (kw)	Blade length (m)
5	20	11.85
10	80	8.135
15	120	5.55
20	120	3.62
25	120	2.59

Table 1: Approximate value of blade length from equation (4)

Matlab Simulation

Simulations of the existing wind turbine model and proposed model was performed.

Input given are wind speed , generator speed and pitch angle. Permanent magnet synchronous generator was used in modelling. Output characteristics contain three parameters- power, voltage and current.

Comparison of existing and variable length wind turbine using Simulink

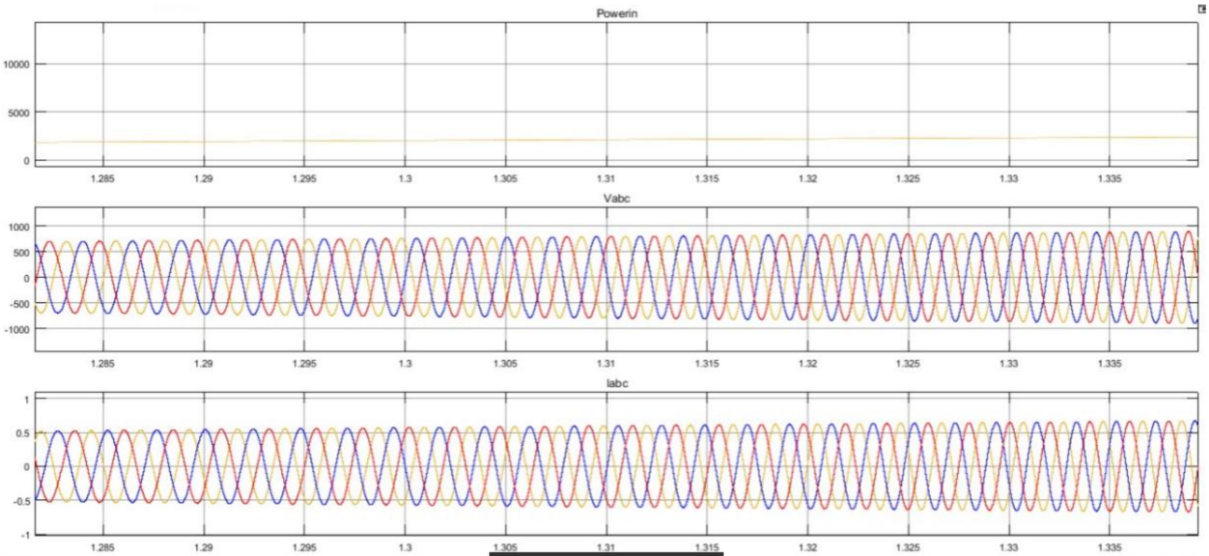

Fig 3: Wind speed, voltage and current characteristics of existing wind turbine

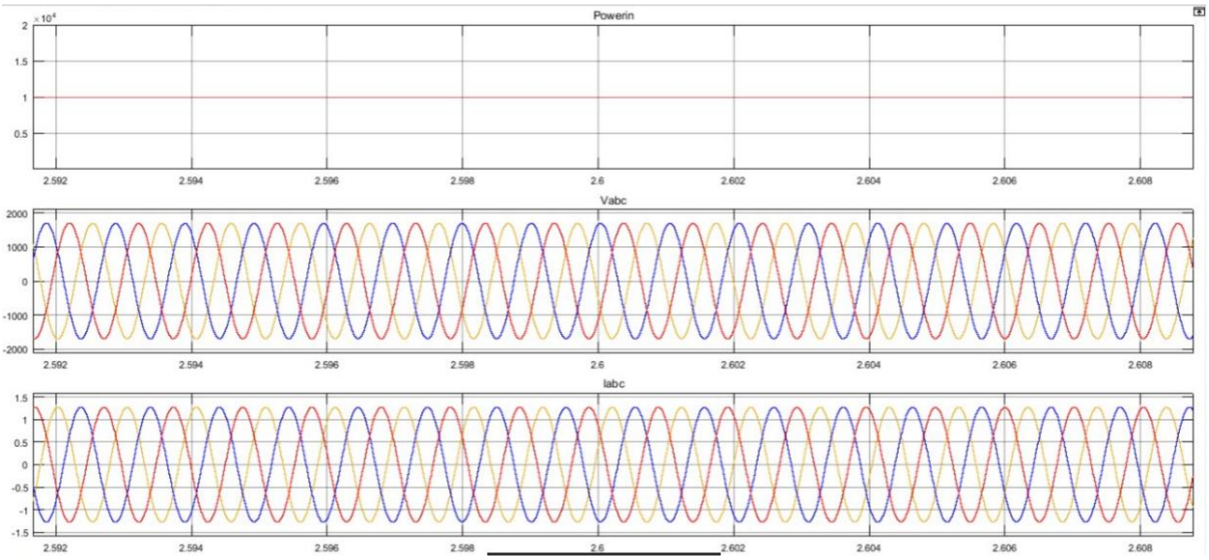

Fig 4: Power, voltage and current characteristics of variable length wind turbine

For existing wind turbine model power output is variable with variable wind speed where as in our proposed model power remains constant throughout the variable wind speeds.

V. Conclusion

Current wind turbine technology utilizes wind turbine blades of fixed length, the use of variable length blades has much more effect on wind turbine's performance, efficiency and cost effectiveness. These blades are fitted with a tip that automatically extends outwards in response to light winds and retracts in stronger winds. This action allows higher energy capture in low wind conditions, while minimizing mechanical loads in high wind conditions. The increase in efficiency associated with this innovative development is found to increase production by as much as 25% over the blades replaced by Variblade. Variable length blade can be used in regions where wind velocity is not constant and constant power output is required.

Advantages

- Improves production in low winds
- Allows turbine to continue generation even in higher wind speeds
- Improves capacity factor without running turbines beyond rated capacity
- Allows areas with low wind speeds that could not support wind viable for development
- Reduces the need for different size blade for different wind regimes
- Allows owner to control power output of the wind farm easily and in an efficient way
- Reduces array losses. Turbines in the rear of an array have larger rotor to compensate the lower wind speeds
- Lowers the cost of wind energy
- Makes shipping and installation easier by shipping in shortened position
- Allows blades to be self-cleaning for dirt and ice
- Limits damage in extreme winds as they can be shortened during heavy winds
- Compatible with existing technologies of fixed pitch, variable pitch, and variable speed turbines
- Improves performance to compare normal wind turbine
- High Efficiency

Disadvantages

- Repairing cost is high
- Initial cost of fabrication is very high
- Blade design is complex

References

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