Effects of Design Parameters of Wind Turbine on Its Performance

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Abstract- *Due to many advantages wind energy is emerging as a potential renewable source and is expected to be the major alternative of fossil fuels in future. In this paper, the effect of major design parameters such as its rated wind speed, blade radius is analyzed using MATLAB programming. Simulation results as obtained may be useful to select the design parameters, which may result into the better performance of turbine under its operating wind speed zone.*

Keywords- blade radius; MATLAB; rated wind speed; wind energy; wind turbine

I. INTRODUCTION

Renewable energy sources such as wind energy are acquiring more significance, due to shortage and environmental impacts of conventional fuels. Blade aerodynamic forces produce shaft torque and rotation that generators subsequently convert to electrical energy [1]. Horizontal axis wind turbines are more preferable due to its advantages comparing with vertical axis wind turbines. The wind power generation is one of the effective and efficient method for pure and clean form of energy generation.In the wind power generation, it is essential to keep the wind turbine at the optimal generator speed for the stabilization of the power generation regardless of wind speed variations [2].

Variable wind turbine systems are preferred comparing with fixedwind turbine systems because they allow the variation in turbine speed such that more power can be captured by the wind turbine [3]-[6]. In a wind energy conversion system the concept of Maximum Power Point Tracking (MPPT)is to achieve optimum generator speed such that the power will be maximized, it is of the paramount importance in renewable energy conversion system not only to increase the efficiency but also to decrease the return period of installation cost[7].

In order to attenuate the fluctuations in generation caused by the variations in wind speed, the pitch angle of the blade is controlled in the area over the rated wind speed for large size wind turbine generators [8],[9]. Pitch control refers to alerting the pitch angle of the wind turbine's blades so that the rotor speed, and hence rotor torque and generated electrical energy are kept at desired levels, pitch control is the most efficient and popular power control method, especially for variable speed wind turbines.In pitch angle control that is adopted by the turbine models described in the literature, the proportional integral (PI) controller is usually the most used [10]-[13], here pitch angle is determined by using MATLAB programming. It is useful method for power regulation above the rated wind speed.

In this paper, effect of major design parameters on wind turbine performance is analyzed using MATLAB programming.

II. WIND TURBINE MODELING [14]

Power contained in the wind is equal to the rate of change of kinetic energy produced by wind

$$\text{Kinetic energy} = \frac{1}{2}(\text{mass of wind})\ v_w^2 \quad (1)$$

$$\text{Mass of wind} = \rho\ A\ v_w \quad (2)$$

$$P_{wind} = \frac{1}{2}\ \rho\ A\ v_w^3 \quad (3)$$

Where v_w is wind speed, and A are the air density and turbine rotor swept area respectively. Actually the total power available in wind will not utilize to generate mechanical power. The mechanical power generated is

$$P_{mech} = C_p\ P_{wind} \quad (4)$$

C_pIs the power coefficient which will result in to amount of power utilized in wind power, it is a function of tip speed ratio'λ' and pitch angle 'β'as expressed in[15].

III. PROPOSED ALGORITHM

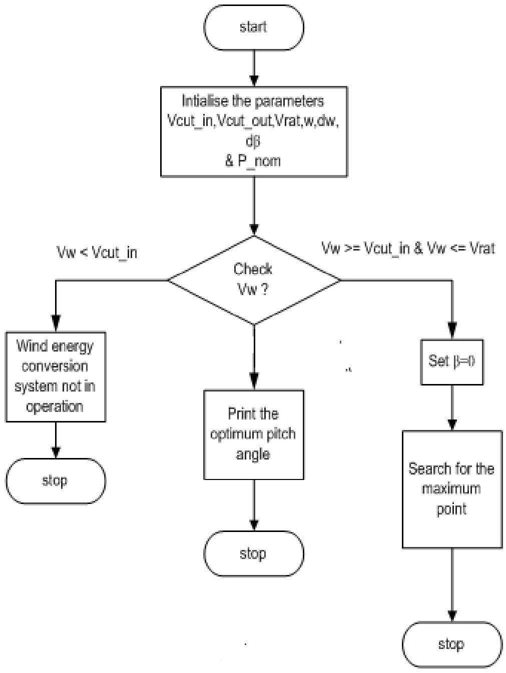

Fig. 1.Flow chart for proposed algorithm

The pitch angle which is required to maintain the rated power beyond the rated wind speed is determined by using algorithm shown in fig. 1. Algorithm as givenfirst requiresinitialization of parameters like cut in speed, rated speed, cut out speed etc., after that it will check for the region of wind speed. Normally wind speeds can be divided into three regions. First region is the region in which wind speed is less than the cut in speed, in this region, wind turbine will not be in operation. Second region is the region in which wind speed range is in between cut in speed and rated speed, in this region optimum pitch angle i.e. 0° is maintained, then only maximum power will be obtained. Third region is the region in which wind speed range is greater than the rated speed and less than the cut out speed, so that power is also greater than the rated but it is required to maintain the rated power to avoid over loading (or) outage. Rated power after the rated wind speed can achieve by increasing pitch angle. The increase in the pitch angle causes decrease in the power, but what is the optimum pitch angle which is required to maintain the rated power is determined using the algorithm shown in fig. 1.

IV. RESULTS AND DISCUSSIONS

Simulation results as discussed in the next subsections are for 1.9669 MW wind turbine with 40m rotor radius, 11m/s rated wind speed & 1.225 kg/m^3 air density.

Performance with different rotor radius but with fixed rated wind speed

Fig. 7-11. Shows the variation of mechanical power, pitch angle, power coefficient, rotor speed and torquewith different blade radius but with fixed rated wind speed 11m/s.

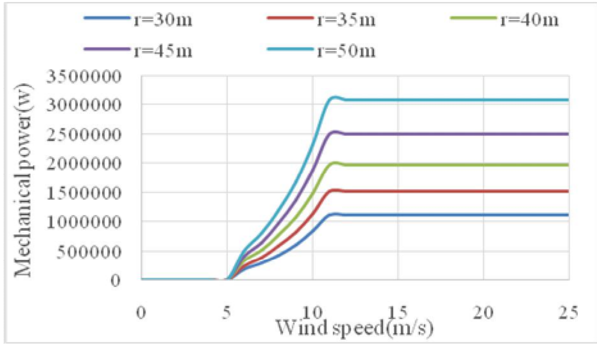

Fig. 7. Variation of mechanical power with wind speed.

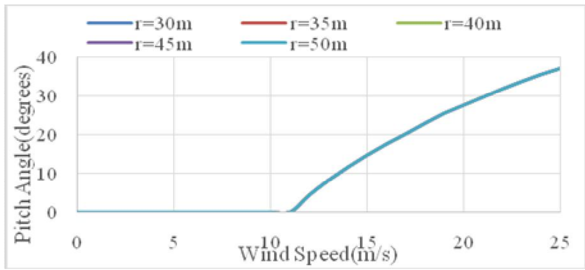

Fig. 8. Variation of pitch angle with wind speed.

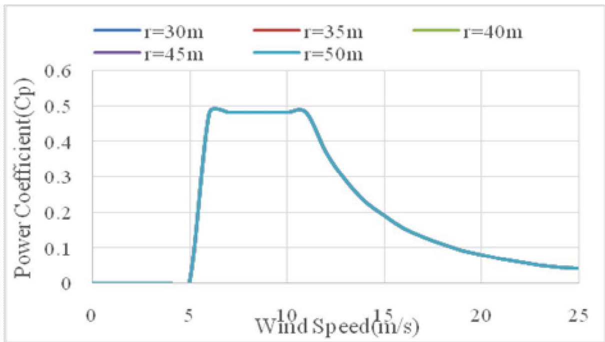

Fig. 9. Variation of power coefficient with wind speed.

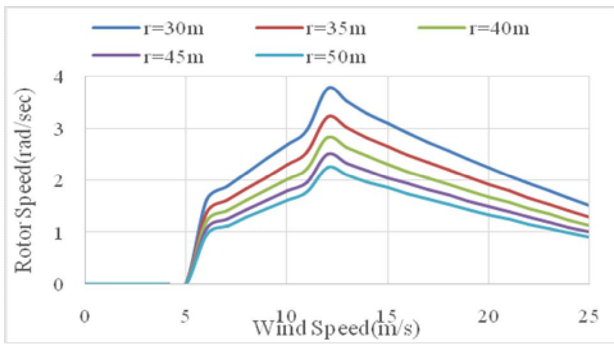

Fig. 10. Variation of rotor speed with wind speed.

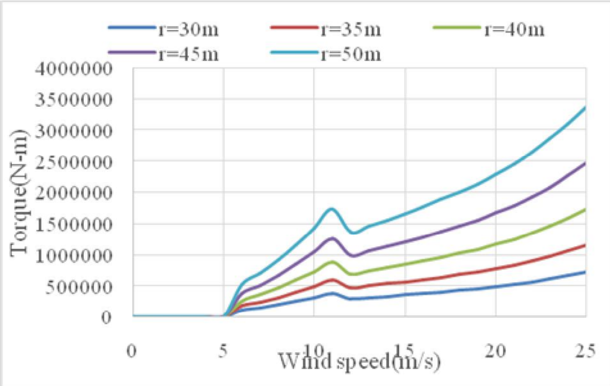

Fig. 11. Variation of torque with wind speed.

From the simulation results as shown above, it is observed that the mechanical power is increasing with increase in rotor radius at a fixed rated wind speed. Pitch angle required to maintain rated power after the rated wind speed & power coefficient are constant even if rotor radius altered, that means change in rotor radius not effecting neither pitch angle nor power coefficient. Rotor speed is decreasing and torque is increasing with increase in rotor radius.

As observed any change of blade radius does not effects the operating zone at all.

V. CONCLUSION

In this paper, effect of design parameters such as its rated wind speed, blade radius is analyzed using MATLAB programming. Simulation results as obtained may be useful to select the design parameters, which may result into the better performance.

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