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ANALYSIS AND MODELING THE BLADE STRUCTURE OF WIND TURBINE WITH DFIG IN GRID CONNECTED SYSTEM

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ABSTRACT

In this paper modeling and analysis of rotor blade structure with a double-fed induction generator in a grid-connected system based wind turbine. There is enhancement in need of improvement in new technologies. The physical property of rotor blade is one of the important factors which affect the power generation from the wind turbine. The design of the rotor blades have certain constrains such as expensive, portability and installation facility. A small wind turbine blade designed with mechanical structure modeling is proposed. The motorized power from the wind turbine has modeled by the Blade Element Momentum (BEM) method and the extracted mechanical energy fed to the doubly fed induction generator for various applications.

Keywords: Rotor blade structure, wind turbine, blade length, Doubly Fed Induction Motor (DFIG), Blade Element Momentum (BEM).

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1. INTRODUCTION

Recent days wind power becoming more attractive because of raise of fossil fuels cost as well as of eco-friendly characteristics [1-3]. Wind energy has established, competitive, and virtually pollution-free technology. In 2020, the world's 10% of electricity targeted from wind power has reported. In 2010, The American Wind Energy Association (AWEA) stated that there is a huge demand of power. Due to that there is enlarging in manufacture of wind turbine especially small horizontal axis turbine. In 2012, The National Renewable Energy Laboratory (NREL) in the US reported that the generation of power cannot able to meet demand power 100 kW by the small wind turbines which have the length of about 19m. In the wind, the power generation system of turbine blades is the main component. The design of blades structure involves a lot of consideration [4]. Due to this, the design of a blade structure is the too critical task for any design engineer. Calculate the diameter of a rotor with rated speed, aerodynamic, blade structure, and strength are used to design for obtain the desired shape. The major factor which affects the effectiveness of the wind power generation is the wind blades. It is not easy to achieve, and some expensive materials are used to produce the desired structure and aerodynamic performance [5]. The economic vision is one of the important aspects for the selection of manufacturing methods. A large wind turbine requires a large amount of manufacturing material for designing the blade structure.

The shape of the blade structure is to be designed in efficient way to attain the better results. The operation of DFIG should be in optimal manner. Therefore the DFIG performance should be improved. Computational Fluid Dynamics (CFD) and Blade Element Momentum (BEM) have been developing [6-7] to explore aerodynamics of wind turbines the effectiveness of the above mentioned topologies are analyzed. In this paper, an integration of grid-connected based DFIG proposed. There is the development of modeling of combined dynamic model which comprises of DFIG system which is connected to the grid and the mechanical structural system. The organization of the paper is as follows: The modeling of the DFIG-WTG connected to a grid. The response of the traditional blade structure of wind turbine is better than a conventional construction of turbine [8]. In recent day vehicle-based wind turbine is recently popular. It requires less amount of material and straightforward. Figure1 shows the evolution of rotor diameter, rated power, and height of wind turbines

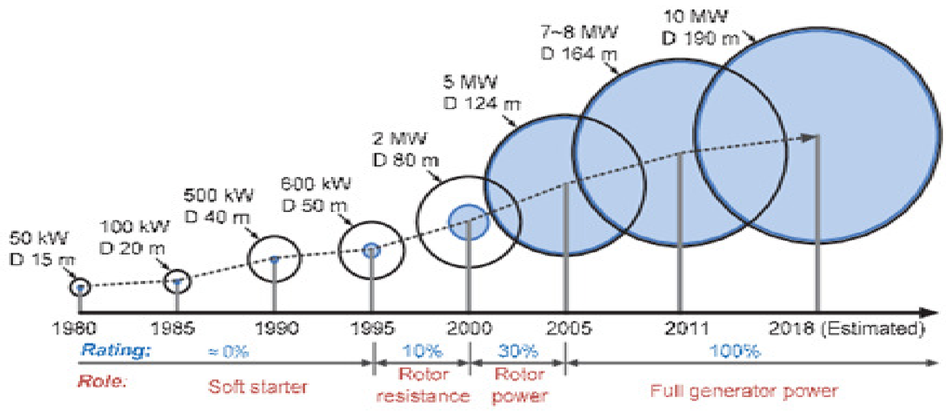

Figure1. Evolution of rotor diameter, rated power, and height of wind turbines

2. PROPOSED METHODOLOGY

This proposed system of consist of following blocks namely wind turbine, gearbox, Double Fed Induction Generator (DFIG) and grid. The main part of the wind turbine is a rotor that collects the wind energy in the form of rotational and the rotor will rotate which connected to the shaft of the gearbox that is connected to the low-speed shaft (30-60) rpm and the main shaft spins the generator to create the electrical energy. Controllers are required to start up the motor at wind speed. Figure 2 and 3 Shows General structure of wind turbine and the Wind turbine to grid connected system with the control mechanism.

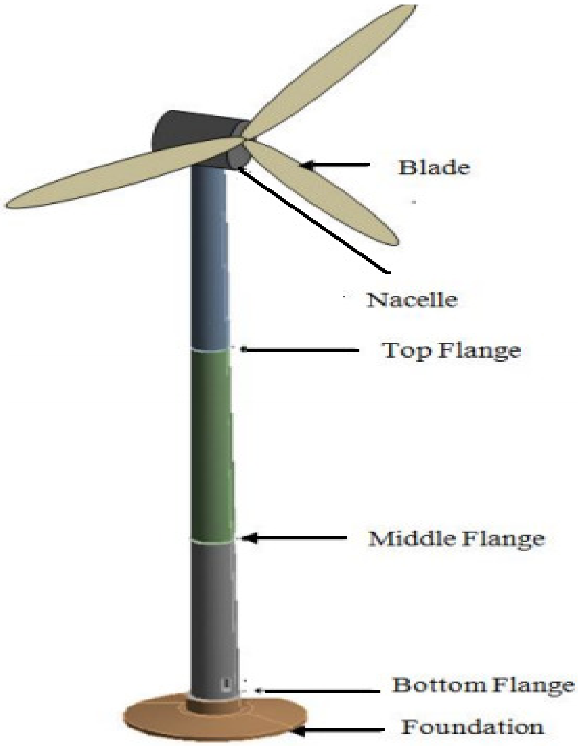

Figure 2. A general structure of the wind turbine

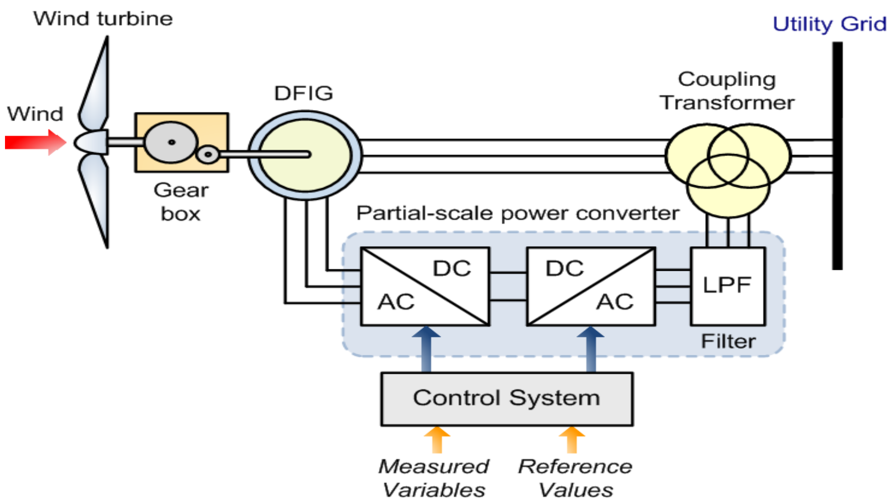

Figure 3.A general structure of wind turbine to the grid-connected system with the control mechanism

2.1. Blade Design

The design of the blades of the turbine invokes the rated speed of about 8.5 m/s which is based on the aerodynamic design. The blade doesn't consider on a velocity of the wind. Wind turbine blades are working under various conditions like the direct exposure of rain, summer, ice, humidity. The blade structure and main frame shaft of the generator is responsible for the transfer of kinetic energy of the wind to the useful mechanical energy. Estimation of wind resources is used design the wind turbine. The lifespan of the wind turbine blade is about 18-20 years. Aerodynamics is one of the factors to be considered while designing of the blade structure. Wind turbine design is based on the blade structure. The blade design analysis helps to attain the optimum configuration of the module by the selection of desired material for the construction of blade. Figure 4 show the ideal model of a wind turbine. Based on the conservation of energy law, energy cannot be created or destroy it can be convert into another energy. Mass flow rate is function of air in Continuity equation is given below.

$$\frac{dm}{dt} = \delta A U \quad (1)$$

Here δ - Air density, A- swept area, U- Air velocity

The tangential input forces by wind given below.

$$F_{Wind}(t) = [f_{blade} f_{blade} f_{blade} f_{tower}]^T \quad (2)$$

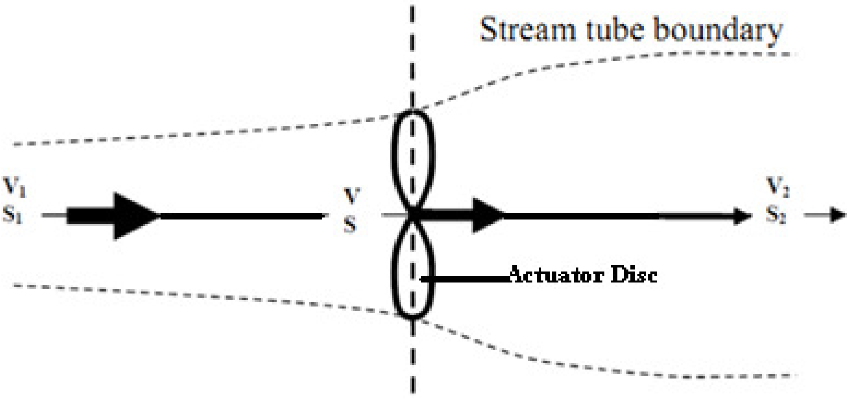

Figure 4. An ideal model of a wind turbine

Generally, blade structure classified into two types; there are Horizontal Axis Wind Turbine structure and Vertical Axis Wind Turbine Structure. In the vertical construction of wind turbine is further organized into the following types Darrieus, Giromill, Helical Blades, Cycloturbine, Savonius type. Figure 5 show the various types of the wind turbine. Horizontal axis wind turbine (HAWT) performs good when compared to a vertical axis wind turbine (VAWT). So that Horizontal axis wind turbine is widely used for this reason. In HAWT requires yawing because of fluctuation of wind direction. Beltz limits develop wind turbine model to predict and improve the performance of the blade structure. Here, reducing the blade size and increasing the efficiency with decreasing a cost for designing of blade and turbine structure.

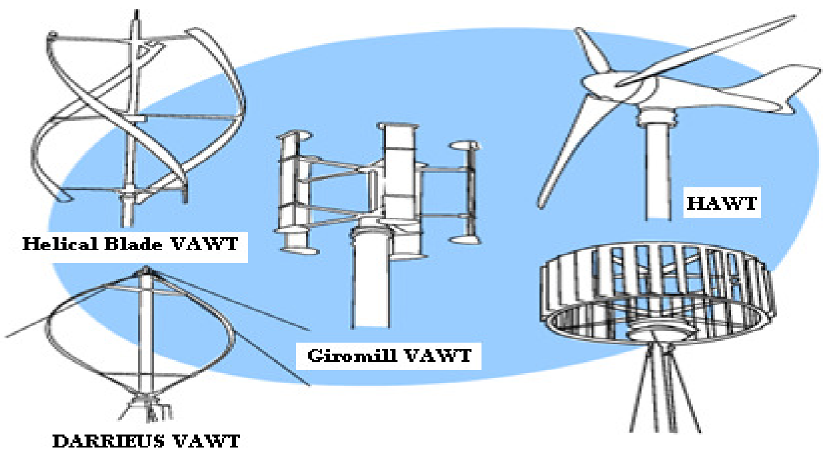

Figure 5. Different types of a wind turbine based on blade structure

When designing the rotor blades material selection should take care. Essential properties are Specific weight (kg/m3), Strength limit (Pa), Modulus of elasticity (N/m2), Fatigue strength (Pa) after millions of cycle. While a selection of blade structure airfoil section must. Thick airfoil should not choose because of its less performance. More power can be produced by the thin airfoils with minimum power. Figure 6 show the lift and drag forces on airfoil blades. When air strikes the blade and it will split into drag and lift force. Lift is better than drag. Mostly lift is preferred, due to the reduction of cost and large requirement of material. The representation of the lift and drag force coefficient shown in Figure 7. The power existing in the wind can express as

$$P_{wind} = \frac{1}{2}\rho A v^{3} \tag{3}$$

Air velocity at rotor plane and the tip speed ratio of a blade (TSR) given in below equation

$$\lambda = 1 - \frac{V_{\infty} - V_{R}}{V_{\infty}} \tag{4}$$

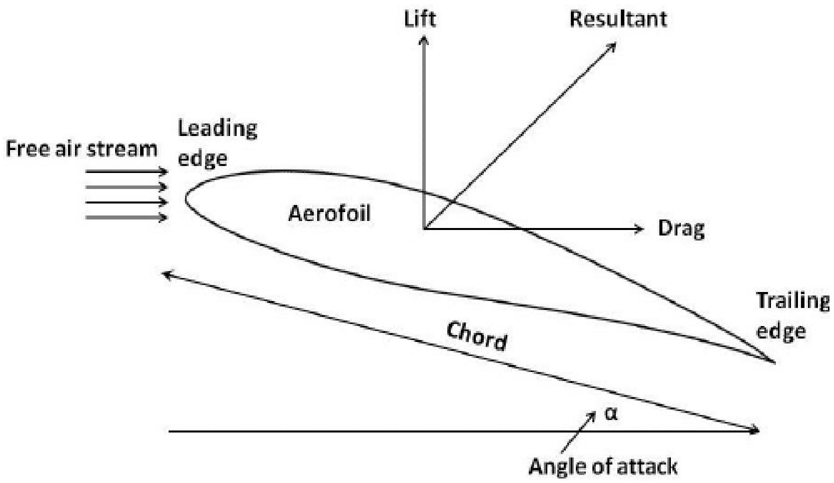

Figure 6. Forces of lift and drag

Forecast of blade performance explained with two theories such as Momentum, Blade element theory. From these two theories combination can predict the rotor blade performance.

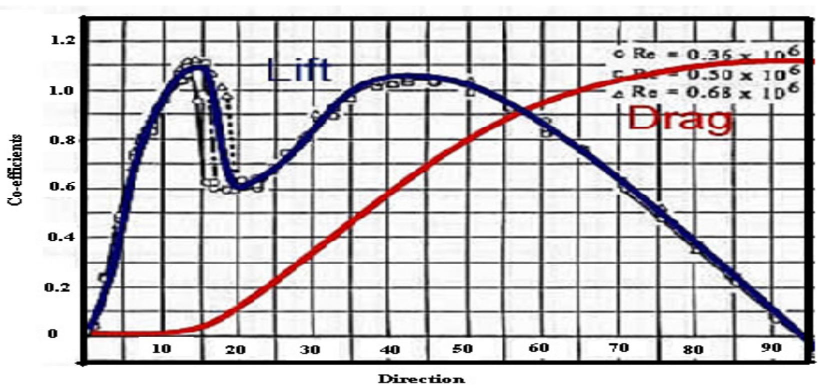

Figure7. Coefficients of lift and drag in airfoil

2.2. Design of Rotor Hub

Design of rotor hub is necessary for the horizontal axis wind turbine, and it extracts the force of wind that will transfer into somewhat energy. The power produced by the blades that converted into torque for particular applications. The structure of the hub also bears the torque into the rotor. Figure 8 shows the basic structure of the rotor hub. The primary function of the hub is to provide the structural support to the blades and accommodate the machine when the high wind has occurred. There are several designs of the hub can be used in the connecting part of the blade and mainframe shaft. It will regulate the startup problem of machines and controls the high wind conditions. Design of rotor hub have some steps; determine the parameter of rotor, choose the aerodynamic condition of blade shape, and calculation the performance of rotor, modify the design performance of blade. Hub is a connecting part which is used to connect the main shaft of rotor. It can be classified into three major types

- Rigid Hub
- Teetering Hub
- Hinged blades

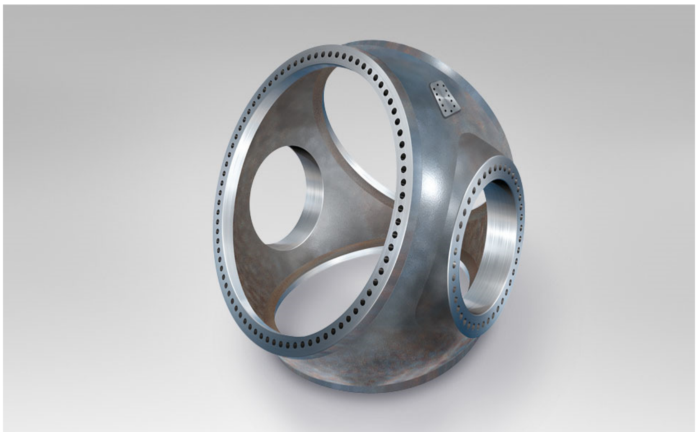

Figure 8. The basic model of Rotor hub

2.3. Doubly Fed Induction Generator

The main function of DFIG in wind turbine is to developing the continuous output power from wind turbine blades. From this type of generated we extract the rated output power is may about approximately 250KW. This wind turbine connected generator has widely used in recent days. Figure 9 shows the output power get from the turbine versus turbine speed. The generated output power from the doubly fed induction generator is supplied to the transmission where the consumer can consume the power through the transmission line.

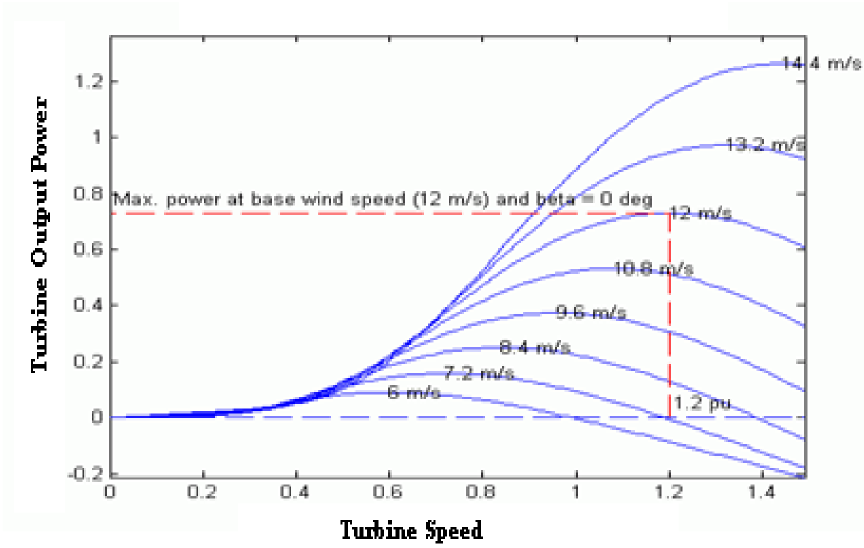

Figure 9. Power output from the generator

3. RESULT AND DISCUSSION

New designed blade does not generate the maximum power because the calculation of aerodynamic was wrong. So that here to increase the life span and rotation speed were designed. Increase the pitch angle of the blade in tip speed and increase performance. Characteristics of airfoil were analyzed. Subsequently, the analyses of blade, life span, power efficient by using doubly fed induction generator.

4. CONCLUSION

This paper reported the analysis and modeling of wind turbine blade structure with DFIG in grid-connected system. And increasing the wind turbine power output and increasing efficiency. The saving cost percent is increased about 18% to 28% because of diminish in weight of the turbine which makes the system cheaper. The burden that will be reduced by using a control mechanism and decrease the stress occurs in the blade structure that could replace by using the BEM model with the feed-forward back-propagation neural network. The analysis exhibits there is occurrence of variations in DFIG. The vibration frequency has been varying according to the speed of the DFIG. During super- synchronous speed & sub synchronous speed the vibration frequency is high and low respectively. In addition to that a significant disturbance electrical system induces the vibration in and tower.

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