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Review of Structural Design and Analysis of Wind Turbine for its Multivariable Height Using Ansys

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Abstract

Wind energy is an indirect form of solar energy since wind is introduce chiefly by the uneven heating of the earth's crust by the sun.The conversion of wind energy in to electrical power can be possible by wind turbine. However, the extent of power generation can vary due to variable wind velocities during the days, place to place, and season to season. This review shows how wind velocity varies as height and power fluctuation which affected by wind velocity.It also shows the impact of extreme gust wind speed variation on active and reactive power of the wind farms.The results show that small wind turbines could be installed in some coast region and medium wind turbines could be installed in the high plateau and some desert regions and utilized for water supply and electrical power generation.

Keywords: Wind Turbine, Anemometer, Wind Gradient, Wind Speed Distribution, Capacity Factor, Extreme Gust Wind, DFIG, FEM, ANSYS, Active Power, Reactive Power

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I. INTRODUCTION

Wind energy is an indirect form of solar energy since wind is introduce chiefly by the uneven heating of the earth's crust by the sun.The conversion of wind energy in to electrical power can reduce the power deficit to a large extent. However, the extent of power generation can vary due to variable wind velocities during the days, place to place, and season to season. Wind turbine system is well known in the world and its utilization is enormously expanding. The impact of extreme gust wind speed variation on active and reactive power of the wind farm is studied with variable speed wind farm equipped with Doubly Feed Induction Generators (DFIG s). The DFIG wind turbine consists of wound rotor induction generator, which is connected to the turbine blades through gearbox. The stator of a wound rotor generator is connected directly to the grid, whreas the rotor is connected to the grid through two back-to-back converters with a common DC link capacitor bank. This arrangement allows for power in the rotor to be at a different frequency than that of the grid frequency, thereby allowing for speed control by adjusting this frequency. DFIG system allows for optimum power to be extracted for a wide range of wind velocity [1]. On the other hand, wind turbine performace also depends on the aerodynamic design of the blade. Cold climate regions represent unavoidable circumstances related to environment. Ice deposition on the blade of wind turbine reshapes the blade aerofoil and affects negatively its aerodynamic properties [2].

The investigation was performed assuming several models of small, medium and big size wind machines representing different ranges of characteristic speeds and rated power suitable for water pumping and electric supply. The results show that small wind turbines could be installed in some coast region and medium wind turbines could be installed in the high plateau and some desert regions and utilized for water supply and electrical power generation [3]. The simulation results of the DeepWind floating vertical axis wind turbine concept, which implies a high potential for cost saving. Applying structural mechanics, generator, floater & mooring systems, control system design, and rotor design using detailed integrated models, results have evolved to a 5 MW windmill design [4]. The effect of wave influenced wind on offshore wind turbines is studied numerically. Computional fluid dynamics (CFD) simulations shows that the air flow does not influence the waves [5]. A wind turbine consists of three elements known as Towers, Nacelles and turbine blades. The blades must be stiff to avoid fatigue failure. Finite Element Analysis is a mathematical modeling and analysis tool used for finding the deformation, natural frequency and mode shape of the blades [6].

II. LITERATURE REVIEW

Omar Noureldeen et al. was investigated the extreme gust wind speed is simulated by simulating the extreme wind conditions. The mathematical model of the extreme gust wind depends on the climatic condition of the site where the wind turbine is located. The wind gradient is the average wind speed as a function of height, h, above the ground. The normal wind profile is given by

$$V(z) = V_{hub}\left(\frac{z}{z_{hub}}\right)^{\alpha}$$

Where, V is the average wind speed at height Z above the ground (m/s), Z_{hub} is the hub height of the wind turbine (m), V_{hub} is the wind speed at hub height and α is a hallman exponent which is related to the region where wind speed is measured. The three different cases were studied at different wind speed 11, 12, 13 m/s respectively.The extreme gust wind speed variations are simulated based on different pre-gust wind speeds of 11, 12, 13 m/s for studying the power fluctuations at different gusts. Also, the power fluctuations are studied during extreme gust wind occurrence for different distances between wind turbine rows equal to 3, 5 and 8 times of rotor diameter. It is noticed that, when the wind farm operates at pre-gust wind speed of 13 m/s and distance between rows equal to 5 times of rotor diameter, the percentage active power fluctuation is decreased by 46% comparing with the case of distance between rows equal to 3 times of rotor diameter.

Table - 1
Data of Studied Cases

Cases	*Pre-Gust Wind Speed (m/s)*	*Distance (m)*	*Delay Time (s)*
Case 1	*11*	*3D*	*13.66*
		5D	*22.77*
		8D	*36.44*
Case 2	*12*	*3D*	*12.67*
		5D	*21.12*
		8D	*33.76*
Case 3	*13*	*3D*	*11.81*
		5D	*19.69*
		8D	*31.48*

On the other hand, the percentage reactive power fluctuation is in-creased by increasing pre-gust wind speed, while it decreases by increasing the distance between wind turbine rows. When the wind farm operates at pre-gust wind speed of 13 m/s and distance between rows equal to 5 times of rotor diameter, the percentage reactive power fluctuation is decreased by 42.6% comparing with the case of distance between rows equal to 3 times of rotor diameter. The percentage fluctuation of active power and reactive power is not affected by increasing the dis-tance between wind turbine rows from 5 to 8 times of rotor diameter.From the simulation and investigation, it can be observed that the wind turbine of class 1 with distance between turbines rows not less than 5 times of rotor diameter is appropriate for Gulf El-Zayt site. [1]

Fayçal Lamraoui et al. had researched that Wind turbine performance depends mainly on the wind speed and aerodynamics of blades.

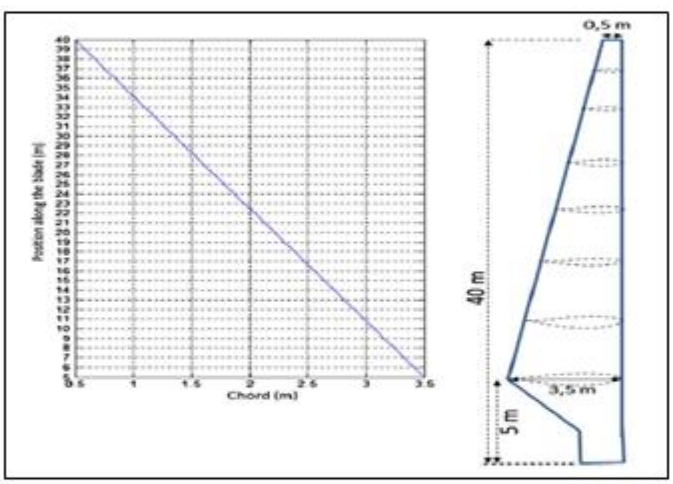

Fig. 1: Chord Variations Along Span.

The roughness generated from ice accretion can significantly reduce the aerodynamics and consequently the power production of the wind turbine. The icing events affect wind assessment and the performance of wind farms by generating measurement errors, power losses, premature mechanical failures, electrical failures and safety hazards. The power generated from the first

20% of the blade is almost neglected (~4%), on the other hand the last 20% of the blade (36%) generates the highest power. Furthermore, an approximate 85% of the power is located in the last 60% of the radial position of the blade starts from r/R = 0.8 to the tip of the blade. Along the blade, the results show that both mass and thickness of ice on the leading edge increase gradually with decreasing the chord size. So, it can be useful to set up a cost effective ice-protection system which cover only 60% of the blade. [2]

A.Chermittia et al. has performed performed assuming several models of small, medium and big size wind machines representing different ranges of characteristic speeds and rated power suitable for water pumping and electric supply. Twelve models of wind energy generators are considered. The models represent different ranges of characteristic speeds and rated power. In addition, they have different fields of application. The models (I), (II) and (III) are small size wind turbines, suitable for low energy needs (water pumping and/or electric supply) in remote areas, although their design, performance and environmental needs are quite different. The medium size Models (IV), (V), (VI), however, is suitable for small electric networks or for grid connection and big size models (VII), (VIII), (IX).

Table - 2
Main Data On Models of Wind Energy Conversion System.

Sr. No.	*Wind turbine*	*No.of blade*	*D (m)*	*Pr (kw)*	*Vc (m/s)*	*Vr (m/s)*	*Voff (m/s)*
I	*EW 50*	*3*	*15*	*50*	*4.0*	*11.3*	*25*
II	*BWCXL 50*	*3*	*14*	*50*	*2.5*	*11.0*	*25*
III	*PGE 50*	*3*	*20*	*50*	*3.0*	*11.0*	*25*
IV	*Notanck 150*	*3*	*24.5*	*150*	*4.0*	*12.0*	*25*
V	*Norwin 150*	*3*	*24.6*	*150*	*4.0*	*12.3*	*25*
VI	*Ades wind turbine 200*	*1*	*30*	*200*	*4.0*	*11.7*	*25*
VII	*Bonus 1300*	*3*	*62*	*1300*	*3.0*	*16.0*	*25*
VIII	*Nordex 70*	*3*	*70*	*1500*	*4.0*	*13.0*	*25*
IX	*BHD FL-1000 IEC IIA GL IIA*	*3*	*55*	*1000*	*3.5*	*13.5*	*25*

The results show that small wind turbines could be installed in some coast region and medium wind turbines could be installed in the high plateau and some desert regions and utilized for water supply and electrical power generation. [3]

Uwe S. Paulsen et al. was investigated simulation results of the DeepWind floating vertical axis wind turbine concept, which implies a high potential for cost saving. The DeepWind rotor, floater, generator, controller and bearings were presented briefly.

Table - 3
Baseline of 5 MW Rotor Design.

Geometry		*Performance*	
Rotor radius (R)	*60.48 m*	*Rated power*	*5000kW*
Rotor height (H)	*143 m*	*Rated rotational speed*	*0.6 rad*
Chord (c)	*5 m*	*Rated wind speed*	*15 m/s*
Solidity (σ)	*0.165*	*Cut in wind speed*	*4 m/s*
Swept Area	*11996 m^2*	*Cut out wind speed*	*25 m/s*

A major result is that the full aeroelastic/hydro modelling has showed that the present baseline concept without any horizontal struts applied in the rotor/blade design performs with expected performance and can operate during the whole wind speed range without stability problems. [4]

Siri Kalviga et al. the effect of wave influenced wind on offshore wind turbines is studied numerically. The wave is seen as a dynamical roughness that influences the wind flow and hence the wind turbine performance. The wave movements periodically modify the wind profiles up to approximately 100 meter over the sea surface. The wind turbine with the nacelle at 88 meter height with rotor radius of 61 meter will experience these fluctuations and it will lead to slightly larger tangential forces than comparable situations over a flat surface. [5]

Ashwani Kumara et al. have performed experiment on material for wind turbine blades. Al 2024 is selected for the suitability analysis. Finite Element method is used for the analysis of complex objects and geometries.The design of wind turbine blade made in Solid Edge software and it is imported to ANSYS 14.0 for modal analysis. The one end of wind turbine blade is supported by the hub and another end is free in air. In this study the hub end is provided a constant angular velocity of 10 rad/sec and different values of deformations and stresses are calculated. Through study one conclusion is that the deformations, stresses and natural frequencies for first six modes shape of Al 2024 wind turbine blade.

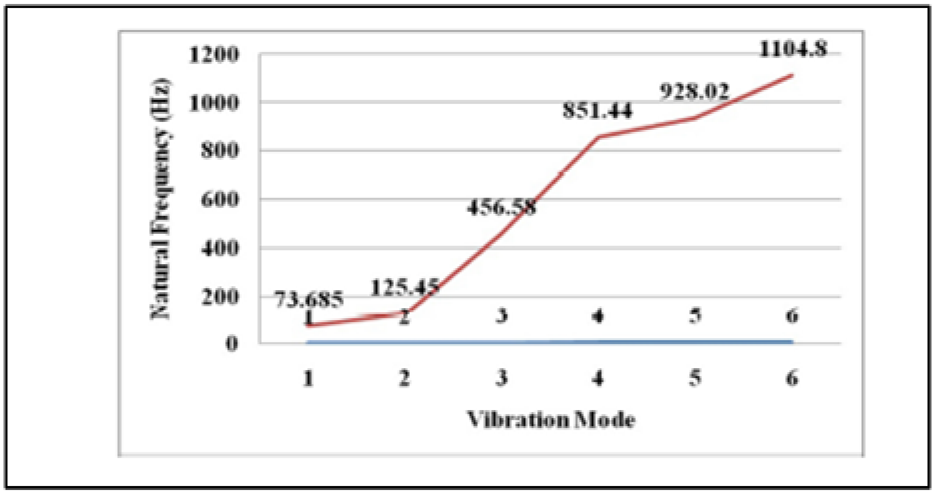

Fig. 2: Natural Frequency Vs Vibration Mode of The Al 2024 Wind Turbine Blade

According to the experimental investigation the maximum deformation occurs at tip and the stresses are very less for Aluminium lightweight materials.The 3D solid model is prepared by applying SOLIDEDGE software and is transferred to ANSYS 14.0. In this research work the structural and vibration problem of the Al 2024 wind turbine blade done by using FEM method. The analysis results were verified with experimental result available in literature. [6]

III. CONCLUDING REMARKS

On the basis of this literature survey we concluded the following remarks.

- The wind gradient is the average wind speed as a function of height, h, above the ground. The normal wind profile is given by

$$V(z) = V_{hub} \left(\frac{z}{z_{hub}} \right)^{\alpha}$$

- The above formula shows that wind speed varies with hub height.
- The power generated from the first 20% of the blade is almost neglected (~4%), on the other hand the last 20% of the blade (36%) generates the highest power.
- 85% of the power is located in the last 60% of the radial position of the blade starts from r/R = 0.8 to the tip of the blade.
- It can be observed that the wind turbine of class 1 with distance between turbines rows not less than 5 times of rotor diameter is appropriate for Gulf El-Zayt site.

IV. FUTURE SCOPE

- To prevent the structure of wind turbine from the wind gust by trail down it to optimum height.
- To generate high power by adjusting the height of WTG (wind turbine generator).
- To maintain constant power over seasonal effects.
- Possibility of wind turbine generator in urban areas for residential purpose.

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