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Vibration analysis of small wind turbine

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***Abstract*— Renewable energy sources especially wind energy have gained much attention due to the recent energy crisis and the urge to obtain clean energy. Widely small wind turbines are avoided to install on the building due to vibration and noise. Vibration from small wind turbine which creates uncomfortable to the people present in the building. By reducing vibration ensure that safe and comfortable environment to them. Small wind turbine exist on sree sowdambika sollege of engineering, Aruppukottai, with power of 2.2 kw, which creates more vibration on running condition. By reducing vibration in the wind turbine will avoid vibration transformation on the building. So that we can improve performance, life time and power quality of wind turbine. Noise free environment is possible by eliminating vibration from the wind turbine. Vibration analysis on the small wind turbine model is carried out by doing modal analysis in ANSYS workbench. Influences of the rotating speed, wind velocity and the aerodynamic loads on natural frequencies are discussed.**

Keywords*— *Wind turbine, Modal analysis, Natural frequency variation.

I. INTRODUCTION

Renewable energy sources especially wind energy have gained much attention due to the recent energy crisis and the urge to obtain clean energy. Wind energy is widely available without any limitation. Wind power is the sign of converting energy from wind into other useful forms of energy with the help of wind turbines for making electrical power. Implementation of condition monitoring and fault detection system is very necessary to maintain the wind turbine healthily[1]. Linear vibration analysis of the wind turbine blade should be carried out to get vibratory characteristics and to avoid structural resonance. Natural frequencies and corresponding modes vary as rotating velocity changes on due to wind[2]. When rotor speed is high on smaller the blade length it becomes higher the natural frequency. Similarly, rotor speed decreases so that natural frequency also decreases[3]. Lagwise natural frequencies ascend with the increase of rotating speed; effects of the rotating speed on low-frequencies are dramatic while these effects on high-frequencies become less [4].

The model presented here was found to be capable of generating plausible results in the simulation of two representative yet complex wind turbine operations, integrating the dynamics of the gearbox with the dynamics of the whole body [5]. The incipient failure of key components such as the tower, drive train and rotor of a wind turbine can be detected with appropriate vibration modeling and analysis. Nonlinear State Estimation Technique (NSET) has been applied to model of the wind turbine tower to good effect for understanding the tower vibration dynamic characteristics[6]. The main challenges in testing and monitoring the in-operation vibration characteristics of wind turbines by presenting the results of the analyses performed by using analytical models and vibration infield measurements[10].

Vibration analysis is a very useful technique to analyzing the dynamics of a structure. It provides data of the vibrating body about the natural frequencies, mode shapes and frequency response function. Material undergoes severe failure due to true resonance, when both natural frequency and mode shape match to the applied frequency and propagation of forces. Thus the structure must be designed to avoid the occurrence of resonance. By reducing vibration in small wind turbine exist on the building, create safe environment to the people inside the building. To maintain the wind turbine in operation healthily, condition monitoring of the wind turbine, vibration analysis is a common and effective way to be applied in the feature extraction and fault diagnosis, especially in the rotation parts..

A. Reasons of Vibration

- Unbalance of masses in blade/shaft on the wind turbine due to misalignment of shaft/parts on the wind turbine.
- Bearing over loading due to high speed on continuous rotation.
- Wind impact on the wind turbine blades and tower under various wind velocity.

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II. EXISTING SMALL WIND TURBINE

This Small Wind Turbine Exist on Sree Sowdambika College Of Engineering, Aruppukottai. In this Wind Turbine more vibration occurs on running condition.

Fig 1 Existing small wind turbine on sree sowdambika college of engineering, aruppukottai.

By reducing vibration we can improve performance of wind turbine, life time and power quality. These are the Technical data of the small wind turbine exist on sree sowdambika college Of engineering, Aruppukottai.

TABLE I. TECHNICAL DATA OF THE EXISTING WIND TURBINE

Nominal power	2.2kw
Nominal wind speed	9m/s
Start wind speed	3m/s
Max wind speed allowed	35m/s
Height of wind turbine	16ft
Blade radius	7ft
Maximum speed	600 rpm
Voltage (AC)	230V
Number of blades	2
Positioning	Tail
Power Storage	Batteries

A. *Material properties of Wind Turbine*

However for the validation of the natural frequencies, materials were used for the vibration analysis. Existing wind turbine material properties of the parts available in the table as follows.

TABLE II. MATERIAL PROPERTIES OF THE WIND TURBINE.

	BASE	**TOWER**	**BLADE**	**TAIL & GENR-ATOR**
Material	*CONCRETE*	*STEEL*	*EPOXY*	*STEEL*
Youngs modulus (N/m^2)	2.5E+10	2E+11	3.226E+09	2E+011

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Poisson ratio	0.3	0.266	0.375	0.266
Density (kg/m³)	2320	7860	1200	7860
Yield strength (N/m²)	0	2.5 E+08	5.5E+007	2.5E+08

III. COORDINATE SYSTEM OF THE WIND TURBINE

The coordinate system is important in the structure vibration analysis. According to the needs of the analysis and the structure of the wind turbine, established 4 main coordinate systems. Inertial coordinate system $R_0(O_0x_0y_0z_0)$. The origin of coordinate O_0 is located in the center of the tower root and the base vector is $[i_0,j_0,k_0]^T$. Tower coordinate system $R_t(O_t X_t Y_t Z_t)$. In this system is fixed on the tower intersecting surface and its origin point O_t is in the center of joint face of cabin and tower, i.e., the tower top center. Its base vector is $[i_tcj_tk_t]^T$. Cabin coordinate system $R_n(O_nx_ny_nz_n)$.

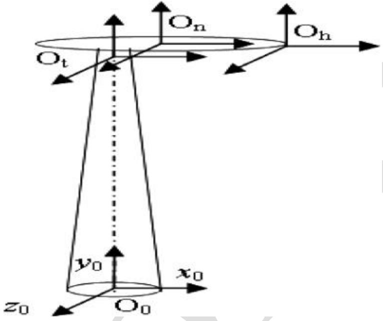

Fig 2 Coordinate system of the wind turbine

This system is fixed on the cabin and its origin point O_n is located on the cabin bar center, and z_n is perpendicular to the intersecting surface of the tower top. Its base vector is $[i_nj_nk_n]^T$. Rotate coordinate system $R_h(O_hx_hy_hz_h)$. The origin of coordinate O_h is located in the center of the blade-hub system of the wind turbine, this system rotates around y_n axis in the cabin coordinate system, in the angular velocity of X. Its base vector is $[i_hj_hk_h]^T$.

A. Tower Loads

Steady tower loads arise primarily from aerodynamically produced thrust and torque. The loading on the tower is evaluated at stationary at survival wind speed. The effects of loading must be considered especially on bending and buckling. Then the feasibility of the load was determined and the resulting stress and deflection analyzed by tower load calculation. The section loads in the tower can be viewed as a cantilever beam as shown in figure 3.

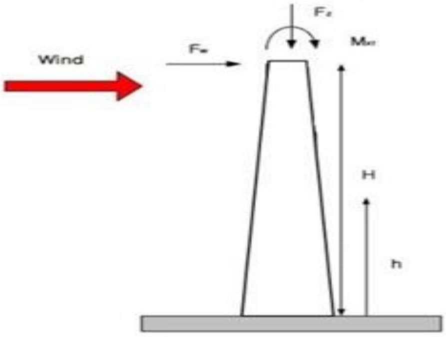

Fig 3 Cantilever beam model of tapered tower

Wind turbine tower shear deformation is assumed to be negligible and is ignored. Tower torsion is assumed to be negligible and is ignored which is an appropriate assumption for passively controlled furling wind turbines which do not transfer any torsional moment to the tower. Tower deflection is only allowed in a 2D plane (plane defined by the wind direction, which in

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X-Axis, and the vertical direction in Y-Axis) and out of plane loads and deflections are assumed to be negligible. For the simple case, a uniform cantilever with a point mass on the top of the tower, the following equation may be used.

$$f_n = \frac{1}{2\pi}\sqrt{\frac{3EI}{(0.23m_{tower} + m_{turbine})L^3}}$$

Where,

f is the fundamental natural frequency (Hz),
E is the modulus of elasticity,
I is the moment of inertia of tower cross-section,
m_{tower} is the mass of tower,
$m_{turbine}$ the mass of turbine, and
L is the height of tower.

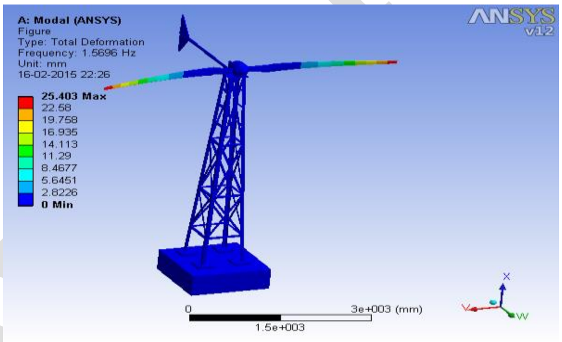
A tower should be designed so that its natural frequency does not coincide with the turbine's excitation frequencies (the rotor frequency or blade passing frequency). In addition of the excitation frequencies should generally not be within 5% of tower natural frequency during prolonged operation.

IV. FINITE ELEMENT ANALYSIS

A finite element program uses iterative techniques to determine a set of frequencies and shapes that satisfy the finite element matrix equation. Modal Analysis is carried out by using the ANSYS Workbench software. Wind turbine model created in CATIA and Modal analysis is done on ANSYS workbench.

A. Modal Analysis

A modal analysis determines the vibration characteristics (natural frequencies and corresponding mode shapes) of a structure or a machine component. The natural frequencies and mode shapes are important parameters in the design of a structure for dynamic loading conditions. Boundary condition applied to the wind turbine tower, the base of wind turbine is fixed rigidly with 0 DOF and the narrow end is free end.



A: Modal (ANSYS)
Figure
Type: Total Deformation
Frequency: 1.5696 Hz
Unit: mm
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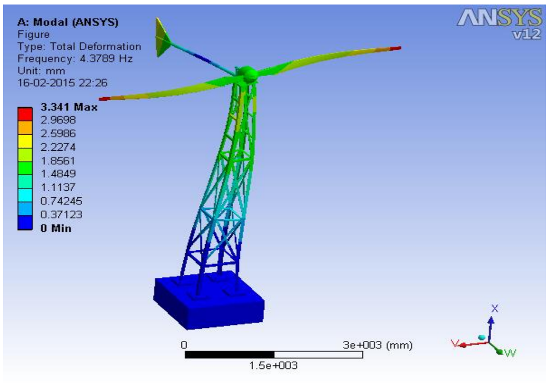
Fig 4 Maximum Deformation of Mode 2.



A: Modal (ANSYS)
Figure
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Frequency: 4.3789 Hz
Unit: mm
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Fig 5 Maximum Deformation of Mode 5.

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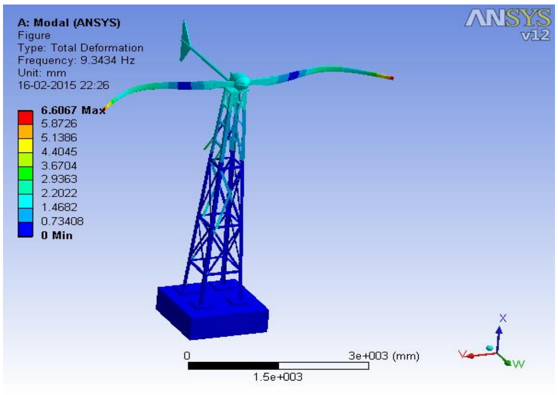

Fig 6 Maximum Deformation of Mode 11.

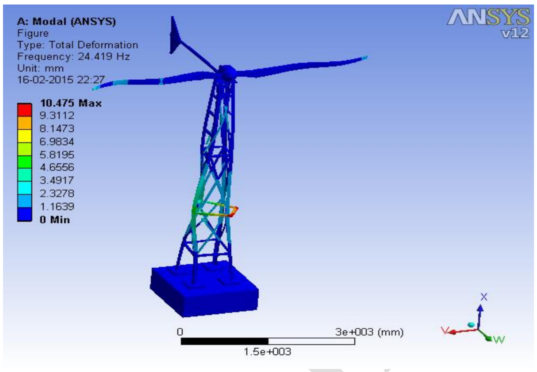

Fig 7 Maximum Deformation of Mode 26.

The first 30 modes to be calculated are selected in the analysis settings option. Modal analysis is performed on the existing Wind turbine.

B. *Modal Analysis Result Chart*

The modal analysis of the wind turbine is performed on ANSYS workbench which is resulted in the values of the first 30 frequencies. These values were compared with those obtained from the reference.

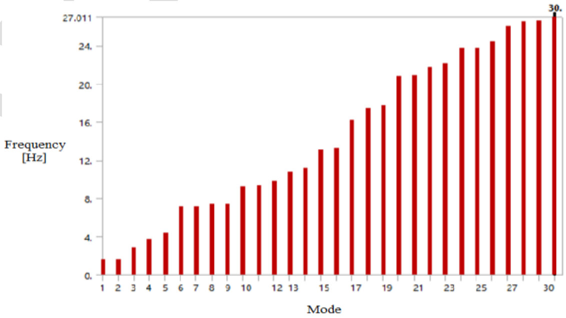

Fig 8 Modal Analysis Result Chart

The mode shape for the wind turbine model is set up to 30 modes to get exact value of the frequency. Chart illustrated the modes respect to the frequency of the wind turbine on Modal analysis.

V. CONCLUSION

In this paper wind turbine model is created in CATIA and then imported in ANSYS workbench for the Modal Analysis. The models developed include some approximation. From that Modal Analysis, the deformation is created on the wind turbine

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parts like blade, tail, tower and base due to wind impact on the blade. Modal analysis used to find the frequency of the model to avoid experimental vibration measurement. In small wind turbine vibration is created generally due to wind impact on the blades. By implementing vibration dampers on the existing wind turbine, reduce vibration on the building. The most important properties like natural frequencies damping and the mode shapes can be determined by ANSYS workbench modal analysis method.

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