Seismic and Wind Analysis of Wind Turbine Supportive Structure

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Abstract- Wind turbine support structure is a special structure in structural engineering. For the supporting the wind turbine three type of support structure is provided which are tubular structure, lattice tower and guided roped structure. Now a day's tubular section is very favorable as supporting structure. But designing of a structure is very difficult because on the top of the structure wind turbine is supported which give the horizontal force due to the wind thrust and moment due to the drag and lift force which generate torque on the blade of wind turbine. Second thing is that vibration of the wind turbine cause dynamic condition which is also a problematic. So that on the top of the tower it is very hard to calculate the thrust and moment so manual design is very complex. For that purpose in calculation of wind thrust and modeling of structure in SAP-2000 is to be done

Keywords- Wind turbine tower, Steel, Concrete, wind turbine load, wind load, earthquake load, Model analysis

I. INTRODUCTION

Ever since man decided to build ships and conquer the sea, wind energy was the force blowing those sails and driving these ships. And when he built windmills, either for grinding grains or pumping water, wind energy was the reason those windmills were turning. Still to this day, some farmers use wind energy for those small applications as oppose to using fossil-fueled engines. The introduction of wind turbines as means to generate electricity can be traced back to the late nineteenth century; however, they received little interest all throughout the twentieth century. In the mid-seventies, the spike in oil prices aroused concerns over the limited fossil-fuel resources that were the main stimuli that drove a lot of government-funded programs and researches towards wind energy alternatives. After the emergence of the three-bladed, stall-regulated rotor and fixed-speed, the simple architectural design that is implemented in today's wind turbines, the industry flourished in USA, Europe and worldwide.

This research work presents the work on the wind turbine supportive structure. Generally it is the dynamic structure as it has rotating rotor at the top of the tower. Wind analysis and earthquake analysis is done for the turbine tower. Here modeling has done in the finite analysis software for the tower of different height and material. SAP-2000 is used for the finite analysis of the wind turbine tower. Wind turbine support structure is a special structure in structural engineering. Now in support structure wind turbine tower is affected by high wind force and earth-quake. Sometime mass of tower top becomes very critical during high wind speed and earth quake so that it produce fatigue displacement and it failures from mid or near base due to high moment produce in tower structure So for understanding these problems, study is being done by analyzing the turbine tower behavior for various wind speed and tower height for different mass

This work is based on the analysis of the tower and main objective of the work to analyze the tower for the parameter like time period, frequency, base shear and base moment. Here in this study, materials used for tower is Steel and concrete. And study is done for the height 100m, 150m, 200m, for the power capacity of the 2MW, 3.6MW and 5 MW.

II. METHODOLOGY

Modeling of wind turbine tower

The modeling of wind turbine tower is done by using finite element modeling technique in SAP-2000. Material properties which is used for the making of the model is detailed in table 1. Geometrical properties like the diameter of the tower, height of the tower, thickness of the wall of concrete tower and thickness of the steel plate for the steel tower is shown in table 2. Figure 1 shows the model of the wind turbine which is made in SAP-2000 Vs 17.2.

Table 1- Material Properties Used in Tower

Property of material	Value
Steel tower density	78.5 kg/m^3
Steel tower Modulus	2*10^8 kN/ m^2
Steel Yielding stress	345 kN/ m^2
Concrete tower density	25 Kg/ m^3
Concrete compression strength	40 kN/ m^2
Concrete elastic modulus	31.62*10^3 kN/ m^2

Figure 1- model of wind turbine tower

Wind turbine load at top of the tower:

Wind load includes the load on the top of the tower and wind load distributed along the tower height. Load calculation is done for the steady wind speed at hub height which is rated wind speed V_{rat} = 12.09 m/s and basic wind speed 39 m/s for the sourastra region at 10 m height as per IS 875: part-3-1978. Here (F_X) and ($Fz_)$ are the axial load due to wind force and super dead load due to weight of rotor & turbine respectively. M_x, M_y and M_z are the yaw moment, bending moment due to wind load and rotor weight eccentricity and torsional moment at the top of the tower respectively. Load table is created based on the calculation as per IEC 61400 Part 1: 2005 for the 2 MW/100, 150, 200 m. 3.6 MW/100, 150, 200 m. 5 MW/100, 150, 200 m. wind turbine load is at top of the tower is same for all structural system.

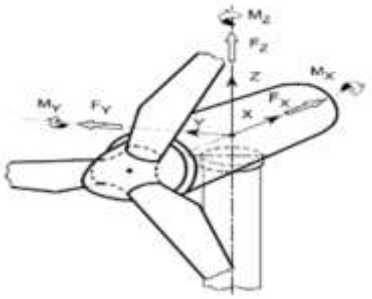

Figure 2-Coordinate of force and moment

Table 2- Wind Turbine Load at Tower Top

Force / moment	2 MW	3.6 MW	5 MW
Fx (kN)	447.85	644.9	995.22
Fz (kN)	568.90	869.0	1399
Mx (kN.m)	3483.28	7165.6	13269.6
My (kN.m)	1492.83	3070.9	4976.12
Mz (kN.m)	2612.46	5374.2	9952.22

Frequency Analysis for tower structure

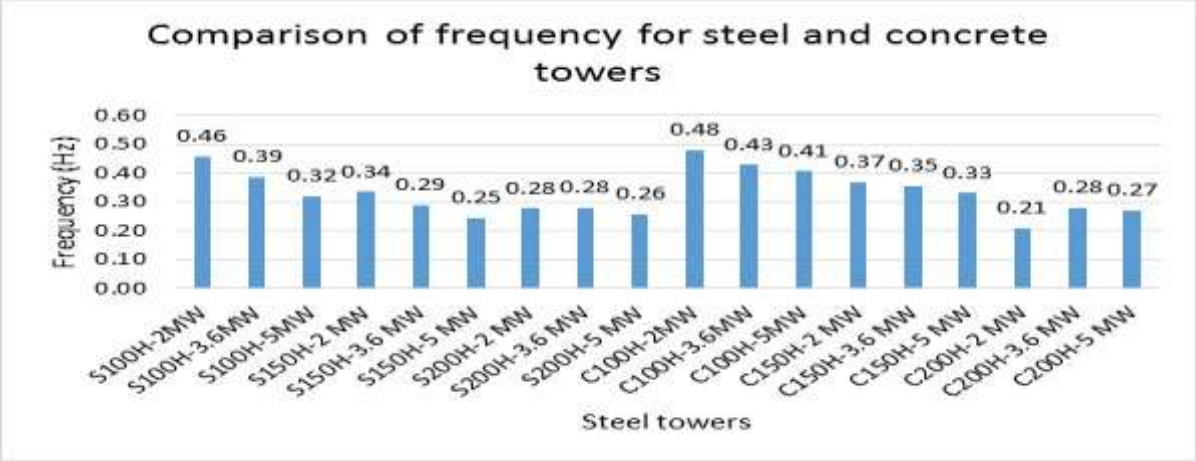

Figure 3 Frequency Analysis of Different tower structure

III. RESULTS AND ANALYSIS

Here in this paper following results is based on the base shear and base moment which is calculate from the finite element analysis. For the seismic analysis following consideration is taken in mind.

- Zone Factor (Z) = 0.10 for Saurastra (Gujrat)
- Importance factor = 1
- Response reduction factor = 5
- Soil Type = Medium (Type-II)
- Frequency (ZPA) = 33

Wind load analysis is calculate on the basis of the following data:

- Terrain category = 1
- Basic wind speed = 39 m/s
- Structure class = C
- Risk coefficient = 1
- Topography factor = 1
- H/B ration = 20

Data of the base shear and base moment for steel and concrete tower is given in figure which is as below.

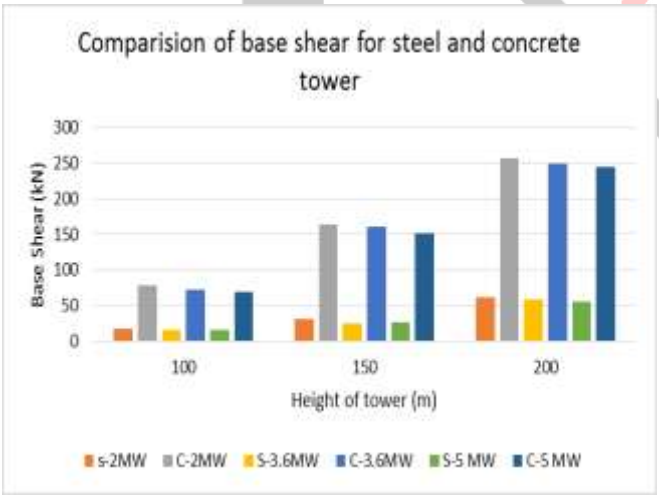

Figure 4 Base shear comparison for steel and concrete tower

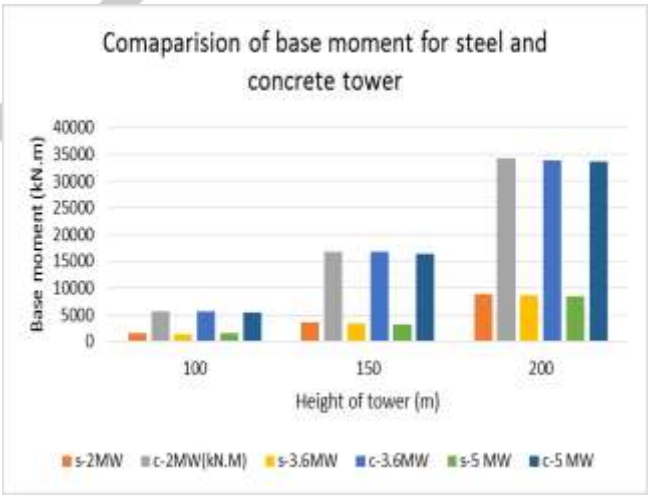

Figure 5 Base moment comparison for steel and concrete tower.

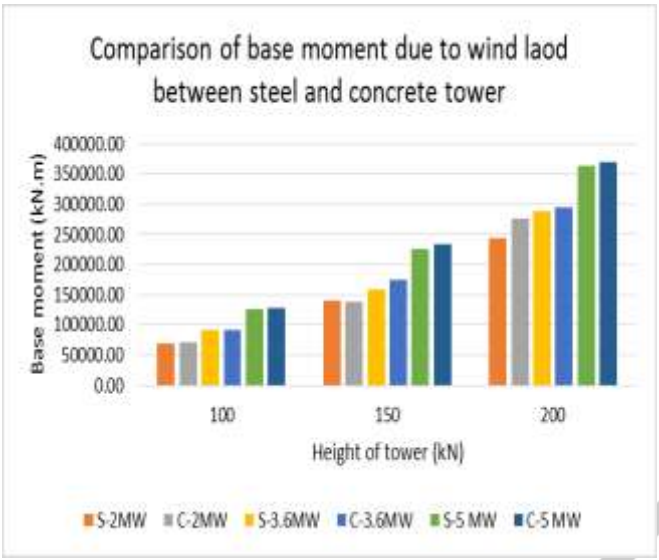

Figure 6 Comparison of Base moment for steel and concrete tower

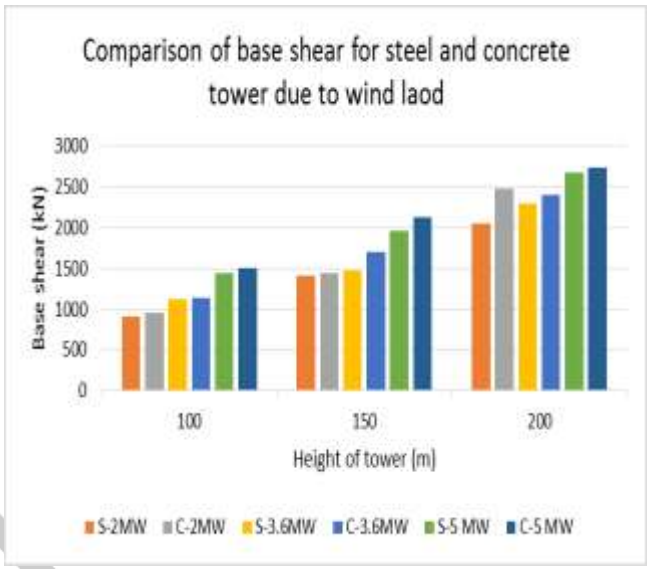

Figure 7 Comparison of Base Shear for steel and concrete tower

IV. Conclusion and Discussion

Wind turbine supporting system is made for the different height, material, and turbine mass at the top of the tower. In this work comparative study is presented addressing the influence of the tower using various engineering parameters which is as follows:

- It seems that time period is influenced by height of the tower.
- It is found that the base shear & base moment of the tower is effected by the height of tower and turbine mass at the top of the tower.
- Deflection of the tower is increase with capacity of power generation because length of the blade require large for more wind cultivation so it retain more force so as height and power capacity increase deflection is increase.
- Tower dimension depend upon the power capacity and height of the tower.

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