Optimal Design of Wind Masts for Indian Conditions

Ramesh N V, Suryanarayana K, and Paneerselvam R

***Abstract*—In the quest for making wind power (typical photograph enclosed) feasible, initial costs, are reduced by making wind masts optimal by making it relocatable with less land use and ensure that land is made reusable after the survey if the site is found not feasible for wind farming. Wind masts are essentially the structure consisting of pole of height between 50m to 70m. (Fig.-1) held in position by guys. Study in made to make effective/efficient use of guys and pole making adoptable for different terrain conditions. Economy by optimization is brought about in this paper. This study pertains to Indian conditions.**

I. Introduction

There is a tremendous source of energy, though only a fraction of the total wind power can be commercially exploited. Estimates indicate that the wind energy potential in India is around 45000 MW as against installed capacity of about 2000 MW. Private agencies have commissioned a 8.37 MW Wind Farm Project at Jogimatti, Hiriyur Taluka Chitradurga District,KARNATAKA.[1],[2]. The estimated project cost is Rs. 41 Crores. All the 36 windmills have been Commissioned and have started commercial operation. The above Wind Farm Project are expected to generate about 23.94 MUS (million units) annually. Wind Data collection and feasibility analysis precedes the wind mill installation.
M/s shah wind inc,. approached CPRI[5] (in recognition with experience in design, Development and testing of transmission line towers, the structures subjected to wind loads) for checking adequacy of 50m mast designed by them.

As **service provider**, customer design validation was done. Same problem was analyzed. Agency was able to get data collection assignment for North eastern region and western region.

Later, in National interest, as a **solution provider**, this problem was viewed for effective/efficient use the resources and minimize land use. It can be seen from the photograph-1 of typical wind farm that extensive area is required for wind farm. This area can be better utilized by burying bamboo culms during the data collection period. Normally two years is taken for data collection. In this period bamboo plantation grows to reasonable biomass quantity capable of producing 1 kWh of electricity/ 1.2 kg of bamboo biomass.

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Four -1500 KW Wind Turbines installed in Davengere, Karnataka

Photograph 1. Typical wind farm

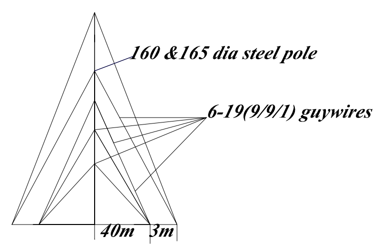

Fig. 1. Typical wind mast

II. Our Approach

The variation of wind velocity is assumed be in power of 1/7.i.e $v_z=v_{10}*(z/10)^{1/7}$. where Vz is wind velocity at height z [3].

Typical wind load on mast based on our assumption is shown is Fig. 1. Decrease in wind load can be observed as the thickness of ice increase for particular velocity

The Pole is designed [4] to withstand wind velocity varying from 33 m/sec to 44 m/sec. This covers almost 90% of wind intensity in our country. In case of ice loading, ice formation is assumed to be nil for .heavy wind velocity 80m/sec and ice thickness is formed inversely with reduced wind speed and maximum ice thickness is 40 mm at still air. Ice thickness and corresponding ice load is interpolated with this assumption. The design was validated for the structure comprising of 165 mm diameter built up tubular sections masts, supported by 6 mm

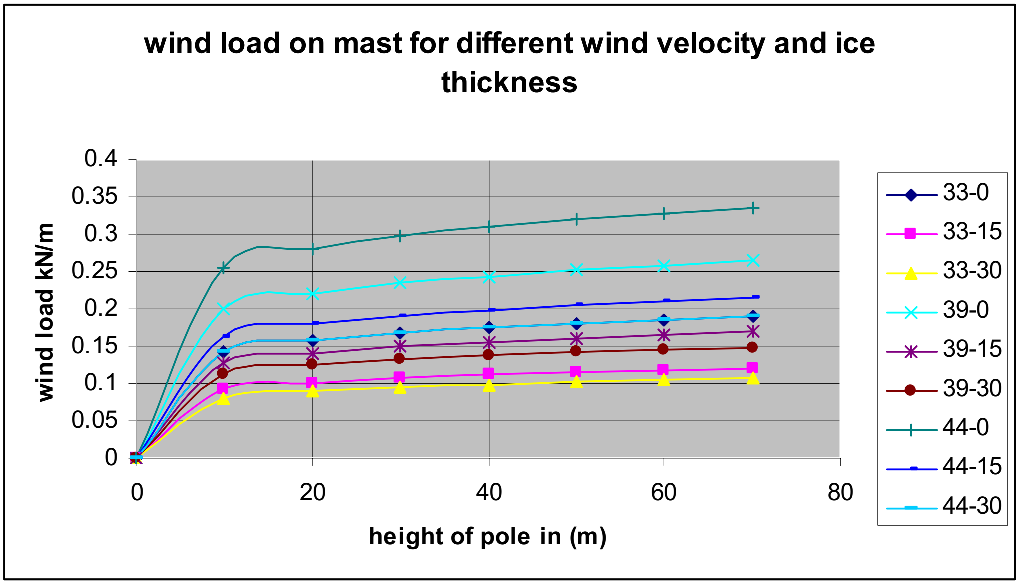

Fig. 2. Wind load on mast for different wind velocity and ice thickness

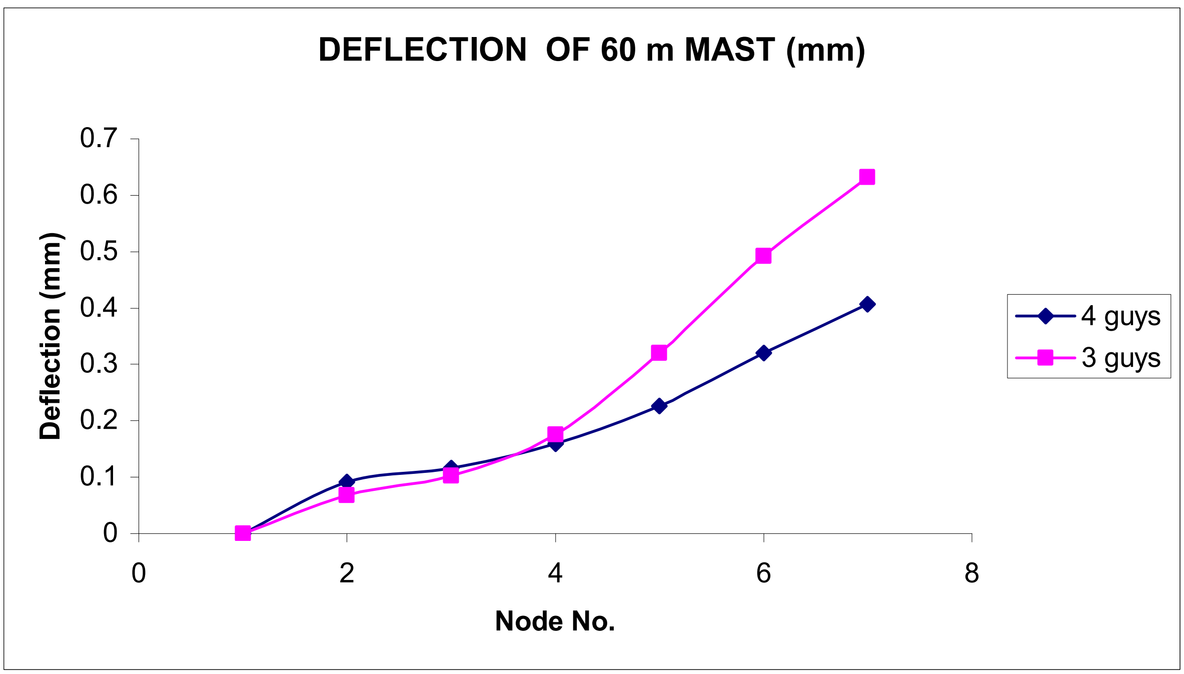

Fig. 3. Comparison of deflection at various levels of mast for 3 guys anchoring and 4 guys anchoring

diameter 6x 19(9/9/1) steel wire rope guys at different heights of the mast, with varying radial anchorage distances, from 18 m to 60 m from base of pole depending upon the height of the mast. By iteration, we observed that the optimum radial distances for inner anchors for 50 m, 60 m and 70 m are masts are at 40 m, 48 m and 56 m respectively.

The validation through analysis indicated higher load carrying capacity, which prompted us to undertake the optimization study. The optimization was conducted by varying the guy locations and also reducing the number of guys. The results of analysis for guys anchored at four locations are compared with that of anchoring at three locations. Typical result as observed for 60 m mast is given in Fig. 3.

The masts are made in modules of 30m. This is to be erected in other region with high wind velocity & heavy ice loading. The foundation is to be designed such that trenching is done quickly and less area is occupied. The guys bunching is done at 3m spacing and the area utilized for mast is kept

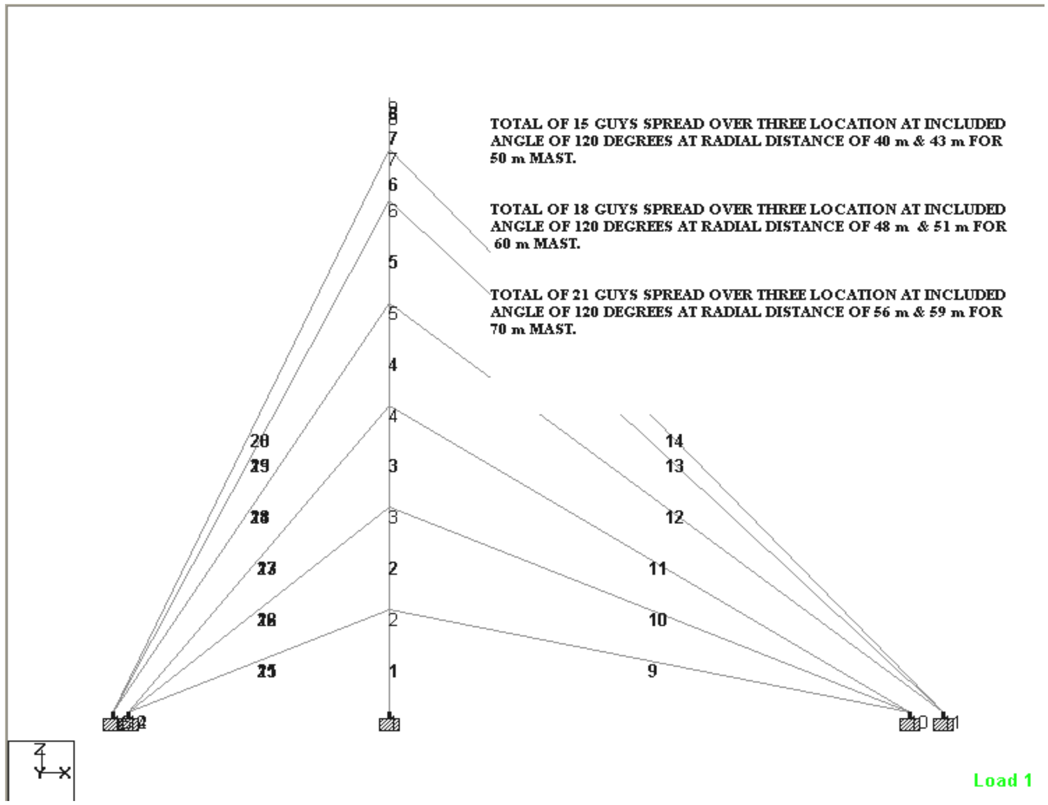

Fig. 4. Optimum configuration of masts

minimum. Incidentally, the land used for data collection will generally be agricultural land and tillage underneath should be allowed hence, clearance of about 2.4 m is assumed to be tillable/usable area. The loads in guys will be less when angle of inclination is about 38^0 Based upon this we started analyzing structure by increasing the angle of inclination of guys and we found that following configuration given in Fig. -3 to be optimum with three guys for 50 m,60 m & 70 m wind masts,

III. RESULTS AND INTERPRETATION

The reference mast and optimized configurations are compared are tabulated and presented in Table-I and presented in Table -II

From Table -I, It can be observed that bottom part of lower mast is top part of next higher mast. This makes lower inventory. The guys are spread and hence erection of mast can be gradual and will be less hazardous. There is saving in length of guys. Meterazzi [6] has considered turbulent wind and reliability based analysis for the masts.

We have made static analysis by iteration and considered ice loading also.

Normally land utilized for data collection will be period of 2 to three years. Based on the feasibility analysis, the land may either be utilized or rejected for wind farming. In order to have efficient land use, Bamboo harvesting may be encouraged .Bamboo is very good plantation for biomass energy. This has following advantages:

TABLE I
COMPARISON OF CONFIGURATION OF REFERENCE AND OPTIMIZED MAST (STRUCTURAL)

Mast height(m)	section	Reference Mast* Bore dia x thk (mm)	Optimized Mast** Bore dia x thk (mm)	Total No of guys	
				reference	optimized
50 20 30	Top part Bottom part	165 x 2.5 165 x 2.5	160 x 2.5 165 x 2.5	18	15
60 30 30	Top part Bottom part	170 x 2.5 170 x 2.5	165 x 2.5 170 x 2.5	21	18
70 30 40	Top part Bottom part	200 x 2.5 200 x 2.5	170 x 2.5 200 x 2.5	24	21

TABLE-II
COMPARISON OF REFERENCE AND OPTIMAL MAST CONFIGURATION (AREA & WEIGHT)

Mast height(m)	Weight of Mast(kg)		Area occupied by guys(sq-m)		% savings	
	reference	optimized	reference	optimized	in area	In weight
50	2759	2433	4489	3450	23.15	11.81
60	3114	2918	7056	4853	31.22	6.29
70	4342	3939	8100	6495	19.81	9.28

1) Conservation of forests by timber substitution. Prevents top soil erosion
2) Bamboo absorbs CO_2 and gives oxygen
3) It can prevent bird menace which one of hazard for wind Mills
4) Bamboo can grow up to 20 m height which will provide sufficient clearance for wind mill.
5) Bamboo has 3 Gross heating value (GJ/t) more than other bio energy crops
6) Its ash content is less than 1
7) The low chlorine content do not corrode boilers at high temperatures

Further to overall aspects of mast actual savings obtained by optimization is presented in Table-II.

IV. CONCLUSION

Optimum configuration yields minimum forces in guys. The comparison is made for 3 guys and four guys and it is found that 3 guys are stable enough to resist the combination of wind and ice loads. It can be seen that the optimized configuration allows more tillable/usable area compared to other proposal. That is 50m mast occupies only 63% of area. 60 m mast occupies 53% of area and 70m occupies 69% area as compared to reference mast. Efficient Utiliasation of modules The land refusal is minimum. Besides this land can be used for bamboo cultivation thereby contribute for non conventional energy using Bamboo plantation for biomass. The adages given by our father of nation that is need based utilization of earth and purpose of conserving means has been obtained less land use and resource besides protecting nature.

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