DESIGN OF TRANSMISSION TOWER AND ITS FOUNDATION

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ABSTRACT

The Transmission line towers are one of the important life line structures in the distribution of power from the source to the various places for several purposes. The tower is designed for the wind zone V carrying 132 KV DC. Tower is modeled using constant parameters such as height, bracing system, angle sections, base widths, wind zone, common clearances, span, conductor and ground wire specifications. The loads are calculated using IS: 802(1995). After completing the analysis, the study is done with respect to deflections, stresses, axial forces, slenderness effect, critical sections and weight of tower. Using STAAD PRO v8i analysis and design of tower has been carried out as a three-dimensional structure. Then, the tower members are designed.

Keyword *ACSR Conductor, Earth Wire, Transmission Line Tower, Foundation.*

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1. INTRODUCTION

Transmission Line Tower

The advancement in electrical engineering shows need for supporting heavy conductors which led to existence of towers. Towers are tall structures, their height being much more than their lateral dimensions. These are space frames built with steel sections having generally an independent foundation under each leg. The height of tower is fixed by the user and the structural designer has the task of designing the general configuration, member and the joint details (John D Holmes). A high voltage transmission line structure is a complex structure in that its design is characterized by the special requirements to be met from both electrical and structural points of view, the former decides the general shape of the tower in respect of its height and the length of its cross arms that carry electrical conductors (Visweswara Rao, G 1995). Hence, it has given rise to the relative tall structures such as towers. The purpose of transmission line towers is to support conductors carrying electrical power and one or two ground wires at suitable distance. In this study, a 132kV Transmission line tower is modelled using STADD Pro 2006. The towers are designed for wind zones V with constant base width.

Types of Towers

The types of towers based on their constructional features, which are in use on the power transmission lines are given below.

- Self-Supporting Towers
- Conventional Guyed Towers
- Chainette Guyed Towers
- Self-Supporting Towers: Self-supporting towers are covered under Indian Standard (IS: 802) and other National and International Standards. These fabricated, using tested quality mild steel structural‟s or a combination of tested quality mild steel and High tensile structural‟s conforming to IS: 2062 and IS:8500 respectively.
- Conventional Guyed Towers: These towers comprise portal structures fabricated in „Y‟ and „V‟ shapes and have been used in some of the countries for EHV transmission lines up to 735 kV. The guys may be internal or external. The guyed tower including guy anchors occupy much larger land as compared to selfsupporting towers and as such this type of construction finds application in long unoccupied, waste land.
- Chainette Guyed Tower: This is similar to that of guyed towers but carrying double circuit lines.

2. LITERATURE REVIEW

A nonlinear analytical technique for predicting and simulating the ultimate structural behavior of self supporting transmission towers under static load condition was prepared by Al-Bermani and Kitipornchai(1992).The proposed method considered both the geometric and material nonlinear effects and treated the angle members in the tower as general asymmetrical thin walled beam column elements. Modeling of the material non linearity for angle members was based on the assumption of lumped plasticity coupled with the concept of a yield surface in the force space. Al –Mashary et al (1992) investigated six 132KV tangent towers that failed in a transmission line in Al-Qassim region, owned by Saudi Consolidated Electrical Company. Two towers failed by bending of cross arms and three towers failed at their base. The governing specifications of ASCE Manual No.52-1971 were followed. The laboratory tests on tensile specimens were satisfactory. A three dimensional analysis of the tower, employing the frame-members for the main legs, showed high localized bending moments in legs causing 30 to 40% over stress. These bending moments were neglected in the original design calculation. These moments although consider as secondary and neglected in common design practice, and significantly high at certain locations and leads to unexpected failures.

Natarajan and Santhakumar (1955) conducted studies on reliability based optimization of transmission line towers. Four independent computer programs for component reliability, reliability analysis, optimization and automation of failure mode generation were developed and linked together. This has enabled more economical design of towers and ensured a particular level of chosen reliability. The weight of optimal tower accounting for reliability as a constrain for tangent cover is only 3 to 4% heavier than the tower designed using conventional method. Hemant Patil et al (2010) conducted failure analysis on 400kV S/C horizontal configuration tower by conducting non linear finite element analysis using NE-NASTRAN software. Both geometric and material non linearity‟s have been included in the analysis. It was predicted that the non linear analysis forces are higher compare to linear analysis force. Further the remedial measures have been suggested for the in stability encountered in the structure. Battista et al (2003) presented a new analytical numerical model for structural analysis of transmission line tower under wind action. 3D- Finite element model was constructed for analyzing the dynamic coupled behavior of transmission line tower under the action of wind. The suspension rods formed by the chains of insulators were identified as the most important component of the system in the analysis of wind flow and tower lines coupled model interactive dynamic behavior and response. The tower structure and all cables were discredited with spatial frame elements.

Elagaaly et al (1992) conducted experiments on 3 dimensional trusses. The trusses were designed such that the target angle would fail first without significant deformations in the remaining members of the truss. Following each test the target angle alone was replaced allowing multiple tests to be conducted in the same setting. Fifty single angle members with each angle were also tested as part of the truss. The results indicates six modes of bucking due to coupling effect of local, flexural, tensional and torssional structural modes. Most of the members failed in local buckling which occurred at bolt hole. A 230KV transmission line with delta type towers was used for the study. The soil structure interaction was also performed taking in to account two types, medium sand and clay soils. Linear elastic springs and rigid elements were used to simulate the soil and concrete footing. The study of the structural dynamic characteristics has shown that, whichever is the soil type, the first 10 lower natural oscillation frequencies do not change. M.V.R.Satyanarayana studies about the reliability assessment of 220kv transmission towers. Using IS Code IS: 802 (part-1/section-1):1995 they calculated the wind load on tower for zone 2 condition. The tower is analyzed for full load condition using STAAD Pro 2007. It has become extremely difficult to secure land for power transmission lines year after year due to various restrictions, such as density of population in the urban areas obtaining forest clearances and nature preservation philosophy. It is necessary to develop technically compact 110/132kV & 220kV transmission line tower structures to minimize the tower dimensions.

V. Lakshmi1, A. Rajagopala Rao studied the performance of 21M high 132kV tower with medium wind intensity is observed. The Recommendations of IS 875-1987, Basic wind speeds, Influence of height above ground and terrain, Design wind speed, Design wind pressure, Design wind force is explained in detailed. An analysis is carried out for the tower and the performance of the tower and the member forces in all the vertical, horizontal and diagonal members are evaluated. The critical elements among each of three groups are identified. In subsequent chapters the performance of tower under abnormal conditions such as localized failures are evaluated. The details of load calculation, modelling and analysis are discussed. The wind intensity converted into point loads and loads are applied at panel joints. M.Selvaraj, S.M.Kulkarni, R.Ramesh Babu studied that power transmission line towers will have to be built with new design concepts using new materials, reduction of construction costs and optimizing power of delivery with restricted right of way. This paper discusses experimental studies carried out on a Xbraced panel of transmission line tower made from FRP pultruded sections. Mathematical model of individual members and members in the X-braced panel are generated using FEM software to study the analytical correlation with the experiments. The member stresses are monitored using strain gauges during full scale testing. Conclusions are drawn based on these studies.

S.Christian Johnson 1 G.S.Thirugnanam In transmission line towers, the tower legs are usually set in concrete which generally provides good protection to the steel. However defects and cracks in the concrete can allow water and salts to penetrate with subsequent corrosion and weakening of the leg. When ferrous materials oxidized to ferrous oxide (corrosion) its volume is obviously more than original ferrous material hence the chimney concrete will undergo strain resulting in formation of cracks. The cracks open, draining the water in to chimney concrete enhancing the corrosion process resulting finally in spelling of chimney concrete. This form of corrosion of stub angle just above the muffing or within the muffing is very common in saline areas. If this is not attended at proper time, the tower may collapse under abnormal climatic conditions. Maintenance and refurbishment of inservice electric power transmission lines require accurate knowledge of components condition in order to develop cost effective programs to extend their useful life. Degradation of foundation concrete can be best assessed by excavation. This is the most rigorous method since it allows determination of the extent and type of corrosion attack, including possible involvement of microbial induced corrosion. In this paper, Physical, Chemical and electro chemical parameters, studied on transmission line tower stubs excavated from inland and coastal areas have been presented. A methodology for rehabilitation of transmission tower stubs has been discussed.

F.Albermani and M. Mahendran [5] "Upgrading of Transmission Towers Using of Diaphragm Bracing System" Many older transmission towers are designed based on tension-only bracing systems with slender diagonal members. However, the increased demand in power supply and changing global weather patterns mean that these towers require upgrading to carry the resultant heavier loading. The failure of a single tower can rapidly propagate along the line and result in severe damage that costs many millions of dollars. Hence, this research project is aimed at developing efficient upgrading schemes using diaphragm bracings. Tower strength improvement was investigated by adding a series of diaphragm bracing types at mid-height of the slender diagonal members. Analytical studies showed that considerable strength improvements could be achieved using diaphragm bracings. They also showed the effects of different types of bracings, including those of joining the internal nodes of diaphragm members and the location of diaphragms. Experimental studies were undertaken using a tower substructure assembly that was strengthened with a variety of diaphragm bracings under two types of loading. The results confirmed the analytical predictions and allow recommendations on the most efficient diaphragm bracing types. This type of upgrading scheme using the most efficient diaphragm bracing type was successfully implemented on an existing 105 m height TV tower. This paper presents the details of both the analytical and experimental studies and their results.

N.PrasadRao, G.M.Samuel Knight, S.J.Mohan, N. Lakshmanan [6] "Studies on failure of transmission line towers in testing" The towers are vital components of the transmission lines and hence, accurate prediction of their failure is very important for the reliability and safety of the transmission system. When failure occurs, direct and indirect losses are high, leaving aside other costs associated with power disruption and litigation. Different types of premature failures observed during full scale testing of transmission line towers at Tower Testing and Research Station, Structural Engineering Research Centre, Chennai are presented. Failures that have been observed during testing are studied and the reasons discussed in detail. The effect of non-triangulated hip bracing pattern and isolated hip bracings connected to elevation redundant in „K‟ and „X‟ braced panels on tower behaviour are studied. The tower members are modelled as beam column and plate elements. Different types of failures are modelled using finite element software and the analytical and the test results are compared with various codal provisions. The general purpose finite element analysis program NE-NASTRAN is used to model the elasto-plastic behaviour of towers. Importance of redundant member design and connection details in overall performance of the tower is discussed.

G.Visweswara Rao "Optimum Designs For Transmission Line Towers" A method for the development of optimized tower designs for extra high-voltage transmission lines is presented in the paper. The optimization is with reference to both tower weight and geometry. It is achieved by the control of a chosen set of key design parameters. Fuzziness in the definition of these control variables is also included in the design process. A derivative free method of nonlinear optimization is incorporated in the program, specially developed for the configuration, analysis and design of transmission line towers. A few interesting result of both crisp and fuzzy optimization, relevant to the design of a typical double circuit transmission line tower under multiple loading condition, are presented.

3. CONDUCTOR

A substance or a material which allows the electric current to pass through its body when it is subjected to a difference of electric potential is known as Conductor. The materials which are used as conductors for over head transmission lines should have the following electrical and physical properties.

- It should have a high conductivity
- It should have tensile strength.
- It should have a high melting point and thermal stability.
- It should be flexible to permit us to handle easily and to transport to the site easily.
- It should be corrosion resistance.

4. ACSR CONDUCTORS

Aluminium has an Ultimate Tensile Strength (U.T.S) of 16 – 20 kg / mm2 where as the steel has a U.T.S of about 136 kg / mm2. By a suitable combination of steel and aluminium the tensile strength of the conductor is increased greatly. Thus, there came into use the Aluminium Conductor Steel Reinforced (ACSR).

TABLE I:

Voltage	132KV
Code name of Conductor	PANTHER ACSR
No of Conductor/Phase	4
Stranding/Wire diameter	'30/3.00+'7/3.00
Total sectional Area	261.5mm^2
Overall Diameter	21mm
Approx Weight	974kg/km
Min U.T.S	89.67KN
Modulus of Elasticity	8.158E+05
Co-efficient of Linear Expansion	1.78E-05/°C
Max Allowable Temperature	75°C

5. EARTH WIRE

The earth wire is used for protection against direct lightning strokes and the high voltage surges resulting there from. There will be one or two earth wire depending upon the shielding angle or protection angle. The earth wire to be used for transmission line is

TABLE II: Earth Wire Mechanical and Electrical Properties

Voltage	132kv
Metal of Earthwire	Galvanized Steel
No of Earthwire	One
Stranding/Wire diameter	'7/3.15
Total sectional Area	54.55mm^2
Overall Diameter	9.45mm
Approx Weight	428kg/km
Min U.T.S	55.996KN
Modulus of Elasticity	1.94E+05
Co-efficient of Linear Expansion	1.15E-05
Max Allowable Temperature	53°C

6. PURPOSE OF TRANSMISSION TOWER

The structures of overhead transmission lines, comprising essentially the supports and foundations, have the role of keeping the conductors at the necessary distance from one another and form earth, with the specified factor of safety to facilitate the flow of power through conductor form one point to another with reliability, security and safety. Electrical energy, being the most convenient and cleanest form of energy, is finding the maximum usage the world over for development and growth of economy and therefore generation, transmission and utilization of the same in ever increasing quantities as economically as the latest technological advancements permit, are receiving great attention. The technical, environmental and economic considerations involve in sitting and development of power generation projects required for meeting the demand for electrical energy are gradually resulting in longer transmission distances and introduction of higher and higher transmission voltages, and use of high voltage direct current transmission systems. Thus transmission systems with voltages of 800 KV ac and ± 600 KV DC are already in operation in some of the countries and those with 1000/1100 KV AC and ± 750 KV DC have also been introduced in some countries. In India, 66 KV, 132/110 KV, 230/220 KV, and 400 KV ac. and ± 500 KV DC systems are already in service and 800 KVAC systems are in the process of implementation.

7. CALCULATIONS AND RESULTS

A. Calculation Of Sag Tension

TABLE III: Sag Tension Values for Conductor

Temperature	Wind	Tension(kg)	FOS	Vertical sag
32	No wind	2285.95	4.000	5.454
32	100% of FW	7311.94	1.251	1.705
75	No wind	1766.82	5.175	7.056
0	No wind	2885.62	3.169	4.320
0	36% of FW	4502.27	2.031	2.769
32	75% of FW	6111.68	1.496	2.040

Maximum Vertical sag=7.056
Maximum Tension=7311.9

TABLE IV: Conductor Specifications

S.no	Description	Symbol	Unit	Power Conductor
1	Voltage	V	KV	**132**
2	Span	L		**320**
3	Power conductor	FOS		**4**
4	IS398(part5/1996)			PANTHER ACSR
5	Overall diameter	D	mm	21
6	Sectional area	A	mm^2	261.5
7	Mass	W	kg/Km	974
8	UTS(Breaking load)	U	kgf	9143.8
9	Modulus of elasticity	E	kgf/Cm^2	8.16E+05
10	Coefficient of linear expansion	α	per C°	1.78E-05
11	Everyday temperature	t	C°	32
12	Sag Tension factors			
13	Wt factor =(W/1000)*(100/A)	δ		0.3724665
14	Wind Load	P_1	-	0
15	Loading factor at still wind =sqrt(1+((1000*p1)/w²)	q_1	-	1.00
16	Wind zone			5
17	Basic Wind speed	m/sec		50
18	Reliability level			3
19	Terrain category/Ground roughness			1
20	Height of the clamping point of the top conductor			31.56
21	Height of the clamping point of the Earth wire			36.26
22	Power conductor Sag at 0° at no wind			4.320
23	earth wire Sag at 0°at no wind			3.888
24	Temperature factors	temp		
25	At min temp in °c	**0**	Eαt0	0.00
26	At EDT in °c	**32**	Eαt32	464.66
27	At max temp °c	**75**	Eαt75	1089.05

8. CALCULATIONS FOR EARTH WIRE SAG TENSIONS

TABLE V: Earth wire Specifications

Sl no	Description	Symbol	unit	Power Conductor
1	Voltage	v	Kv	**132**
2	Span			**320**
3	HTGS Earth wire	FOS		
4	IS398(part5/1996)			7/3.15 HTGS
5	Overall dia	D	mm	9.45
6	Sectional area	A	mm^2	54.55
7	Mass	W	kg/Km	428
8	UTS(Breaking load)	U	kgf	5710.0
9	Modulus of elasticity	E	kgf/Cm^2	1.94E+05
10	Coefficient of linear expansion	α	per C°	1.15E-05
11	Everyday temperature	t	C°	32
12	Sag Tension factors			
13	Wt factor =(W/1000)*(100/A)	τ		0.7846013
14	Wind Load	P_1	-	0
15	Loading factor at still wind =sqrt(1+((1000*p_1)/w²)	q_1	-	1.00
16	Temperature factors	temp		
17	At min temp in °c	**0**	Eαt0	0.00
18	At EDT in °c	**32**	Eαt32	71.25
19	At max temp °c	**53**	Eαt53	118.01

9 ANALYSIS OF TOWER

Analysis of tower of this paper is as shown in bellow Figs.1 to 4

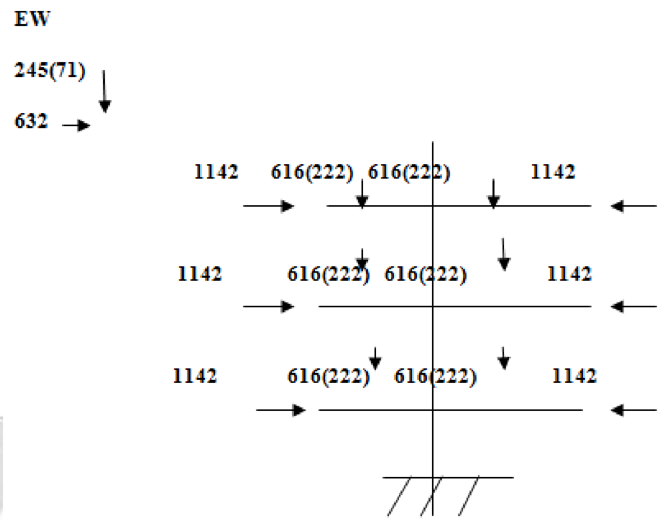

Fig.1. Reliability.

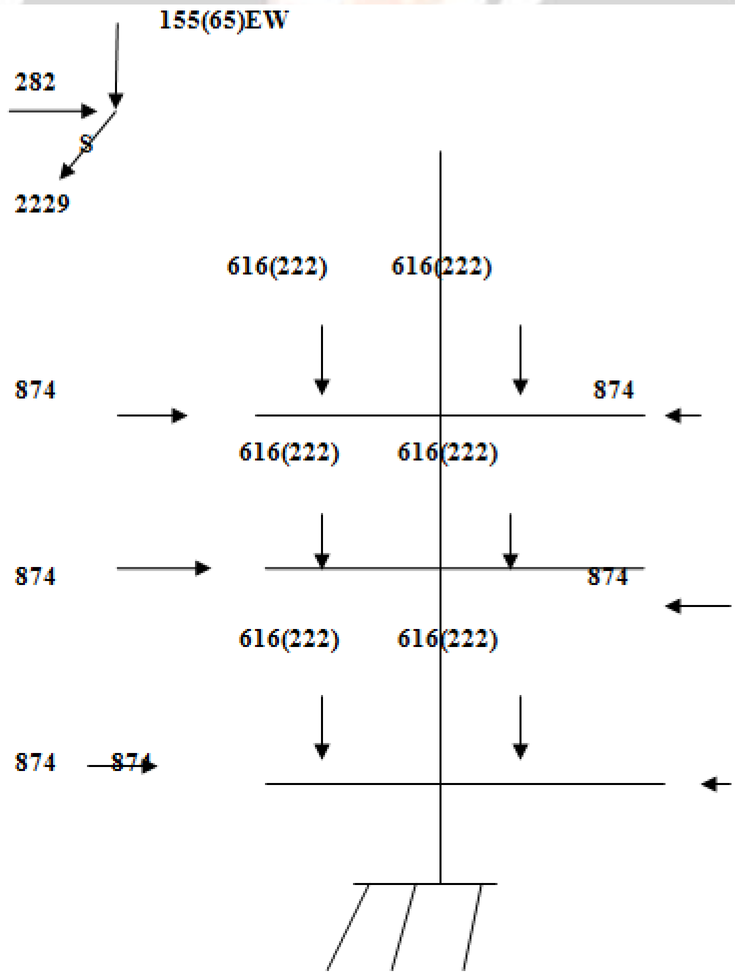

Fig.2. Security ew broken.

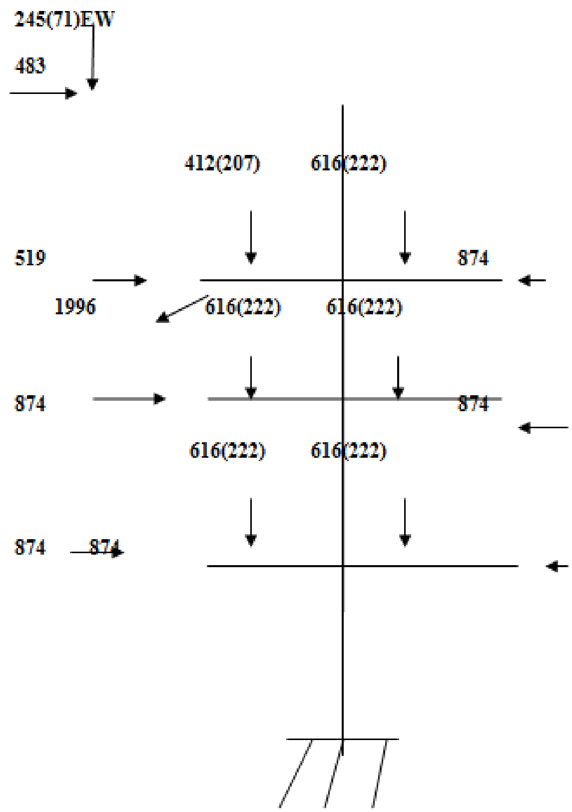

Fig.3. Security conductor broken.

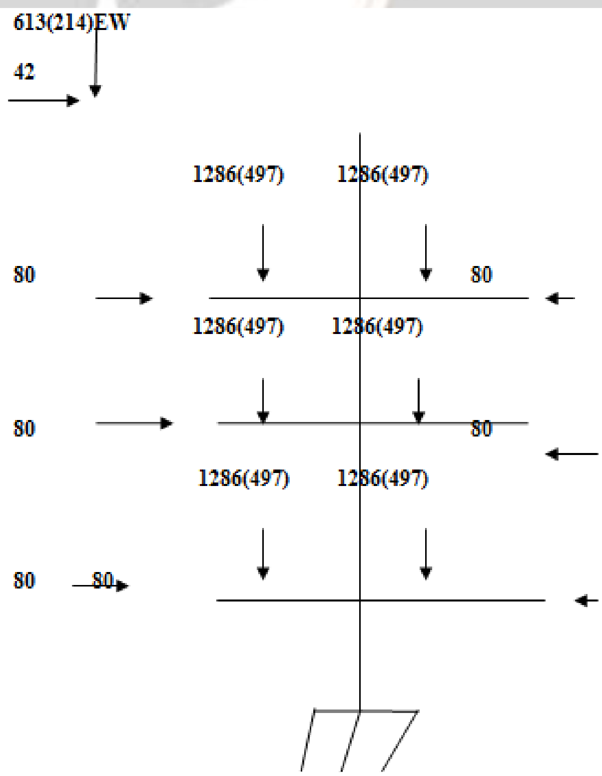

Fig.4. Safety normal.

10.DESIGN OF TOWER MEMBERS

Design of tower members of this paper is as shown in bellow Figs.5 to 10.

A. Assigning Supports To Tower

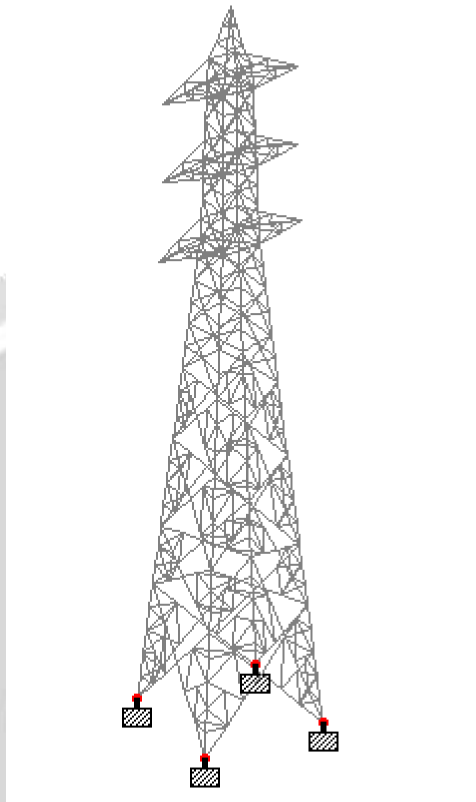

Fig.5. Tower with fixed supports.

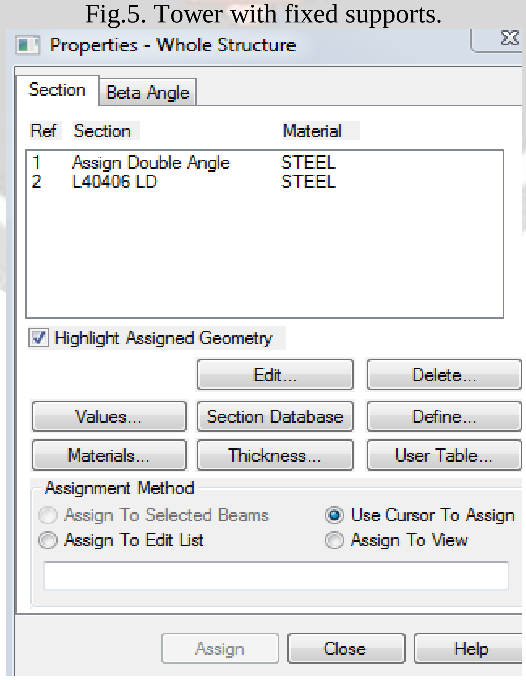

Fig.6. Property of Tower.

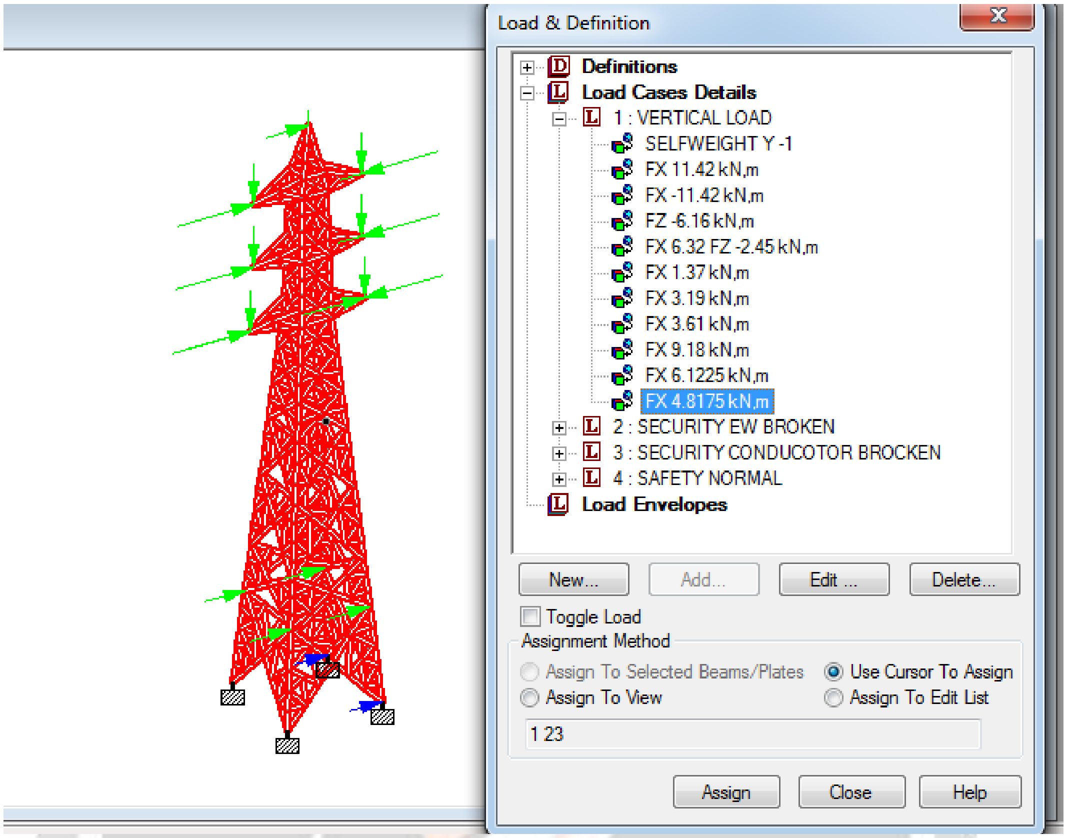

Fig.7. vertical loads.

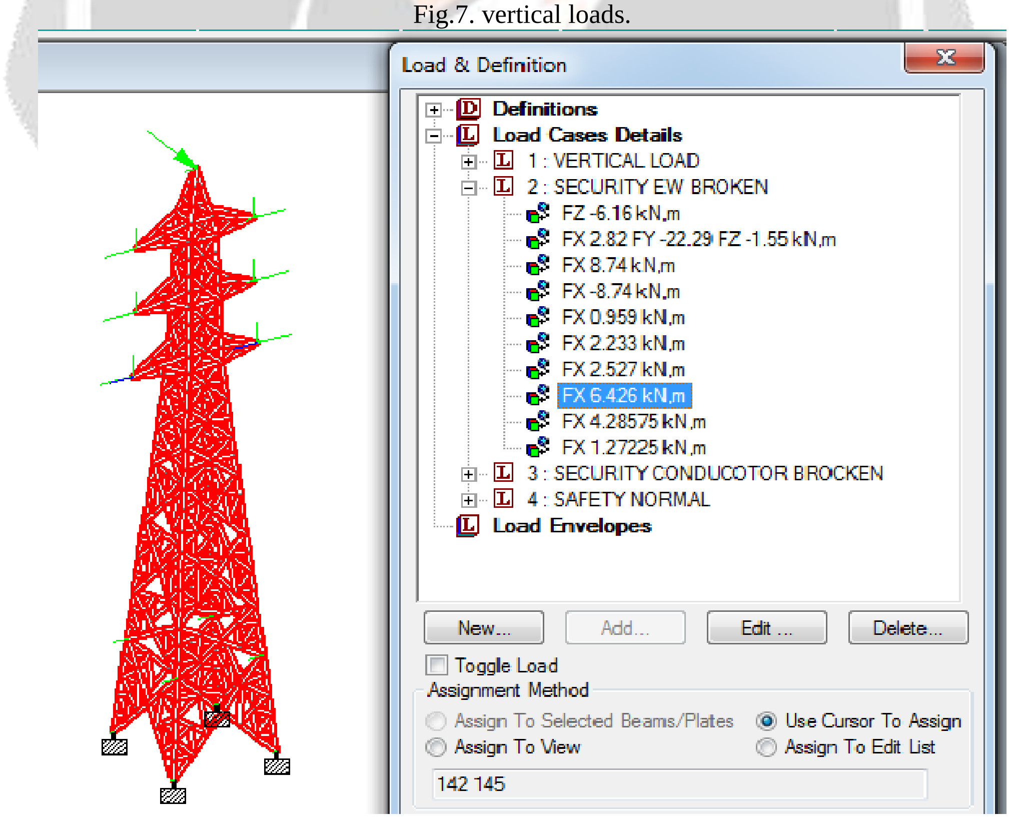

Fig.8. Security EW Broken.

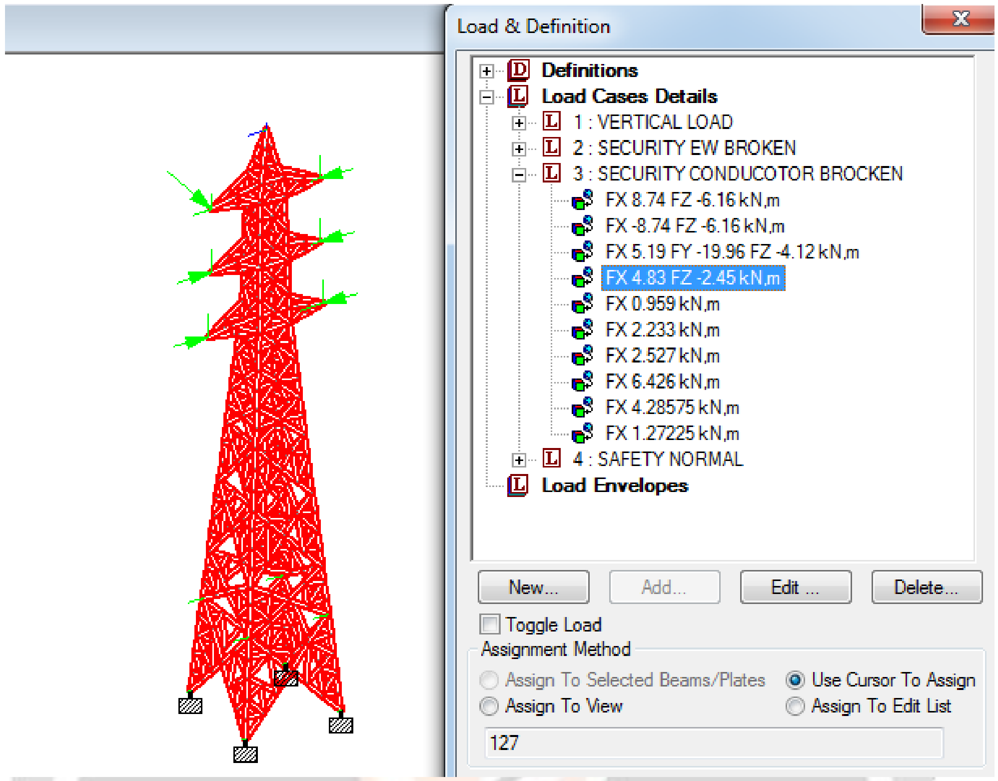

Fig.9. Security Conductor broken.

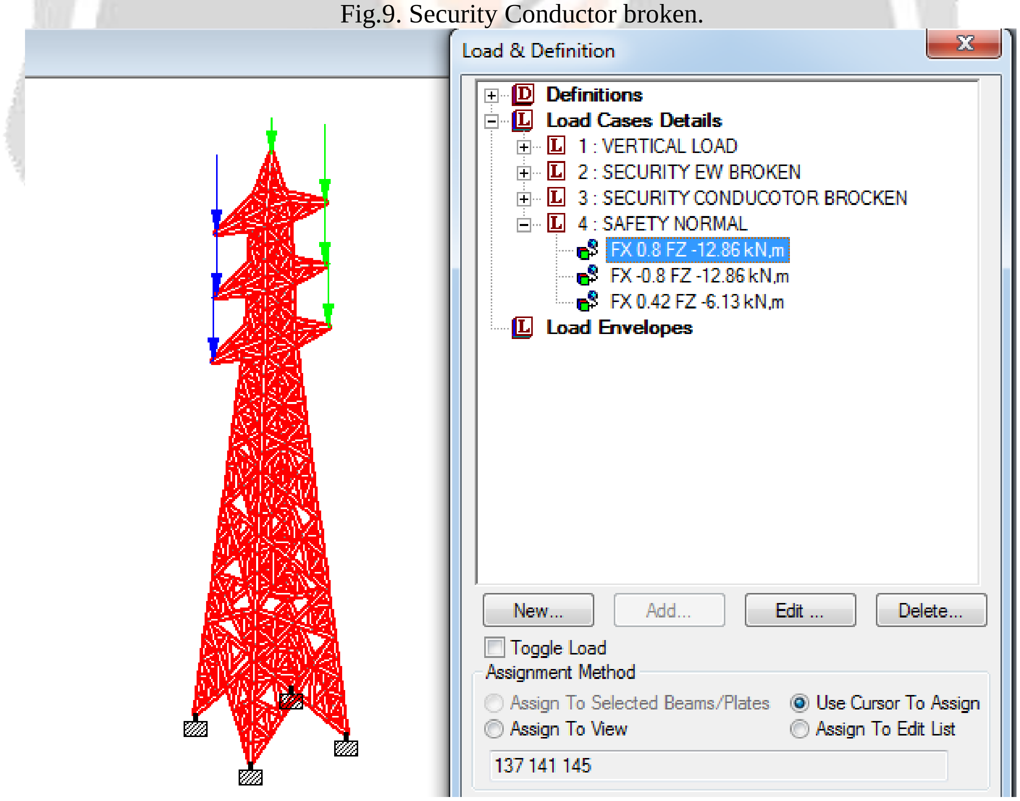

Fig.10. Safety Normal.

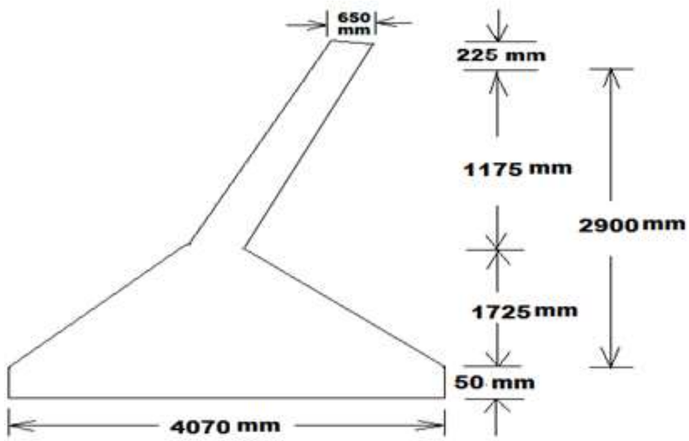

Fig.11. Foundation.

TABLE X. Data from The Super Structure

Description	Normal condition(reliability kgs)	Broken wire condition (security kgs)
Downward thrust	29485.4	25653.8
Upward thrust	24954.6	22564.9
Side thrust(R)	4044.7	3515.7
Side thrust(L)	3403.0	2760.5

CONCLUSION

This work attempts to optimize the transmission line tower structure for a 132KV double circuit with respect to configuration and different materials as variable parameters. Optimization of tower geometry with respect to member forces, the tower configuration having 3 panels and base width 6.05metres is concluded as safe with respect to geometry. The tower with 45˚ angle section and K-bracing with 7833.41kg/m3 has the greatest reduction in weight optimization. Analysis of tower with STAAD PRO software is showing transmission line tower with a height of 31.53metres with 132KV. Tower structures with less height is directly associated in reduction of wind loading and also structure construction. Narrow based steel lattice transmission tower structure plays a vital role in its performance especially while considering eccentric loading conditions for high altitude as compared to other normal tower. Narrow based steel lattice transmission tower considered in this can safely withstand the design wind load and actually load acting on tower. The bottom tier members have more roles in performance of the tower in taking axial forces and the members supporting the cables are likely to have localized role. The vertical members are more prominent in taking the loads of the tower than the horizontal and diagonal members, the members supporting the cables at higher elevations are likely to have larger influence on the behaviour of the tower structure. The effect of twisting moment of the intact structure is not significant.

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