A Study on Analysis of Transmission Line Tower and Design of 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.**

***Index Terms* – ACSR Conductor, Earth wire, Transmission line tower, Foundation.**

I. 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.

II. 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.

III. ACSR Conductors

Aluminium has an Ultimate Tensile Strength (U.T.S) of 16 – 20 kg / mm^2 where as the steel has a U.T.S of about 136 kg / mm^2. 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 1 Conductor Mechanical and Electrical Properties

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/ºC
Max Allowable Temperature	75ºC

IV. 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 earthwire depending upon the shielding angle or protection angle. The earthwire to be used for transmission line is

TABLE 2 Earthwire 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	53ºC

V. 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.

VI. CALCULATIONS AND RESULTS

CALCULATION OF SAG TENSION

Table 3 Conductor Specifications

S.n	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*p_1)/w^2)	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**	Eατ0	0.00
26	At EDT in °c	**32**	Eατ32	464.66
27	At max temp °c	**75**	Eατ75	1089.05

Table 4 Sag Tension Values for Conductor

Temperature	**Wind**	**Tension(kg)**	**FOS**	**Vertical Sag(m)**

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 = 7.056metres
Maximum Tension = 7311.9kg

CALCULATIONS FOR EARTH WIRE SAG TENSIONS

Table 5 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	A	per C°	1.15E-05
11	Everyday temperature	T	C°	32
12	Sag Tension factors	-	-	-
13	Wt factor =(W/1000)*(100/A)	T	-	0.7846013
14	Wind Load	P_1	-	0
15	Loading factor at still wind =sqrt(1+((1000*p_1)/w^2))	q_1	-	1.00
16	Temperature factors	temp	-	-
17	At min temp in °c	0	Eατ0	0.00
18	At EDT in °c	32	Eατ32	71.25

19	At max temp °c	53	Εατ53	118.01

Table 6 Values of Sag Tension at Different Conditions for earthwire

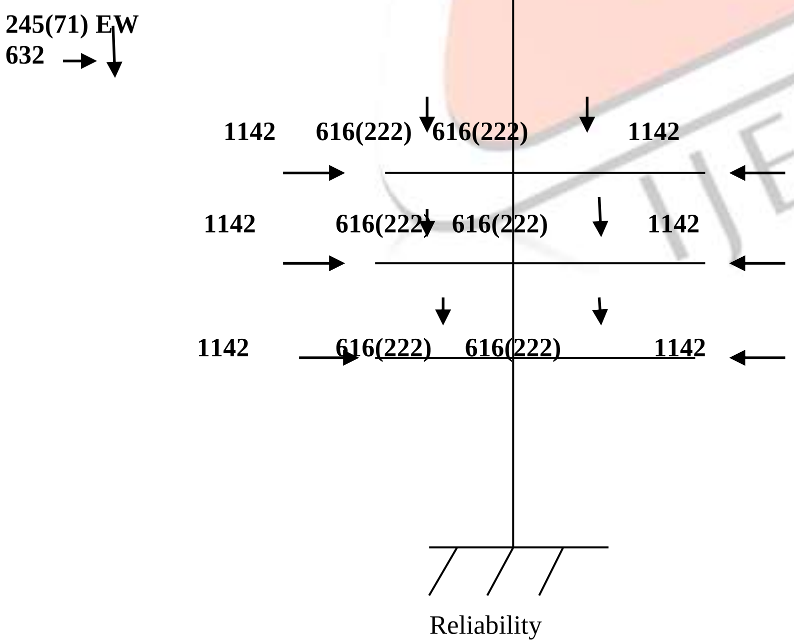
Temperature	Wind	Tension(kg)	FOS	Vertical sag(m)
32	No wind	1507.11	6.067	3.635
32	100% of FW	2398.34	3.813	2.284
53	No wind	1482.81	6.167	3.695
0	No wind	1544.25	5.921	3.548
0	36% of FW	1756.92	5.204	3.118
32	75% of FW	2136.29	4.280	2.564

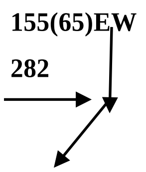
Maximum vertical sag=3.695metres

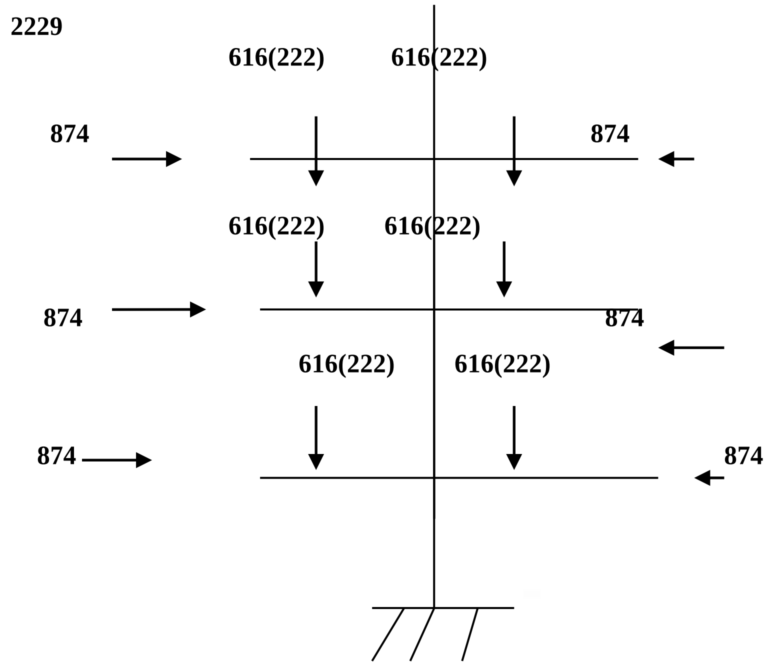
Maximum tension=2398.35kg

VII. Analysis of Tower

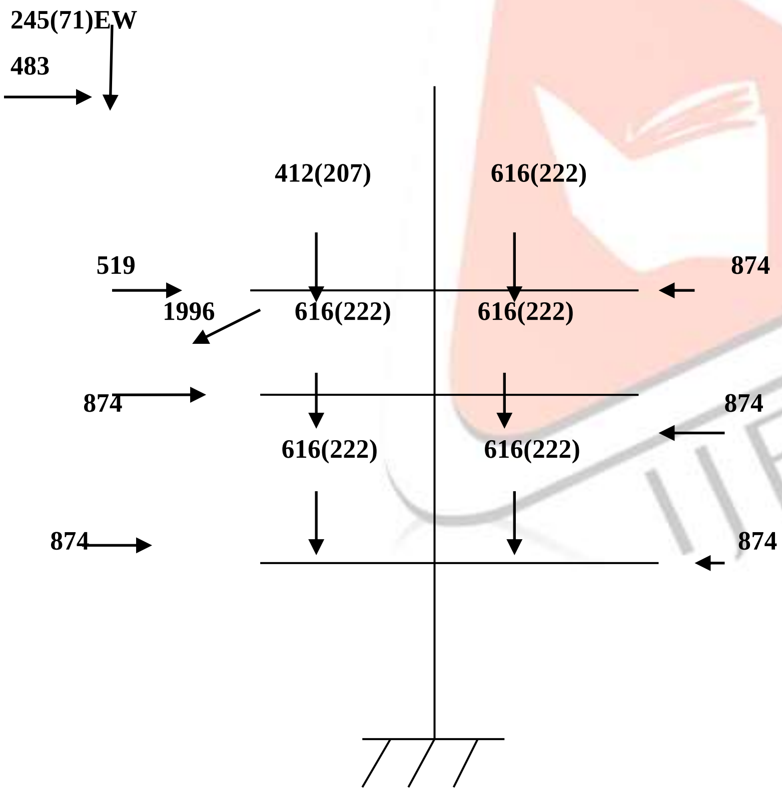
LOAD TREE DIAGRAMS



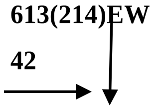


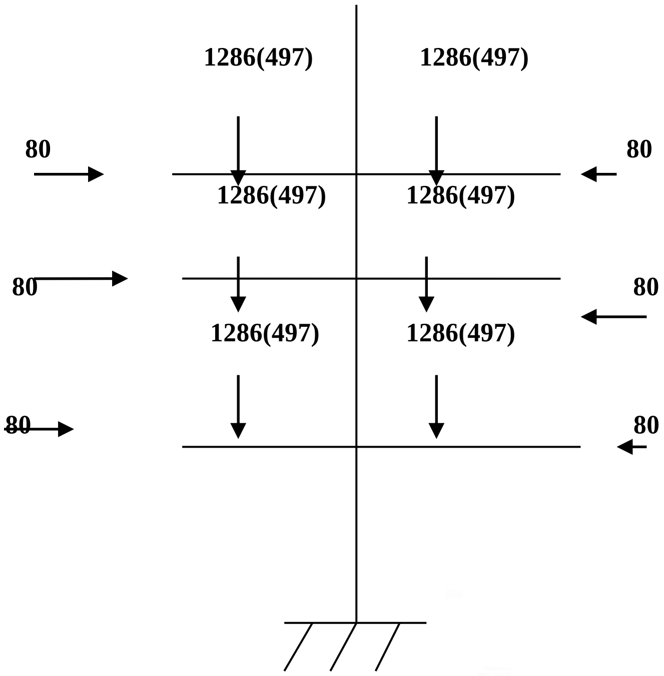


SECURITY EW BROKEN



SECURITYCONDUCTOR BROKEN

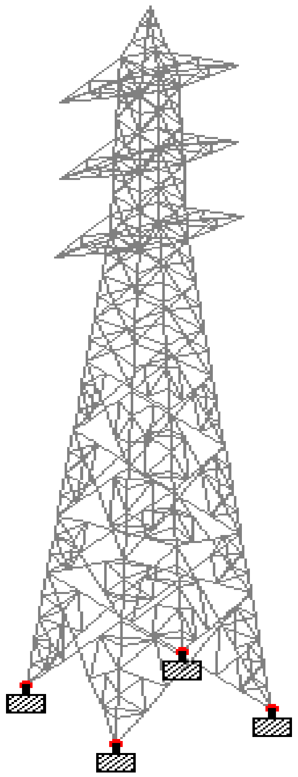




SAFETY NORMAL

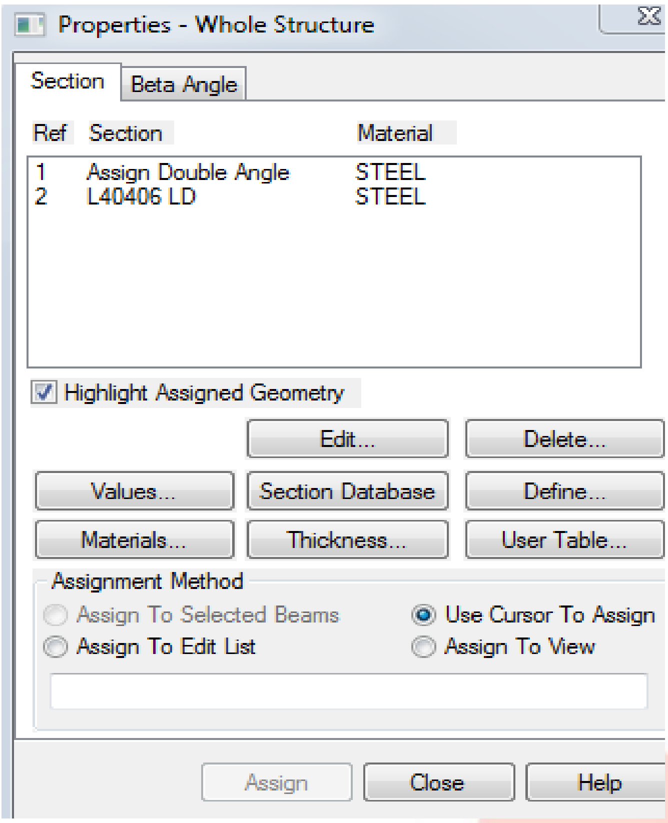
VIII. DESIGN OF TOWER MEMBERS

1. ASSIGNING SUPPORTS TO TOWER



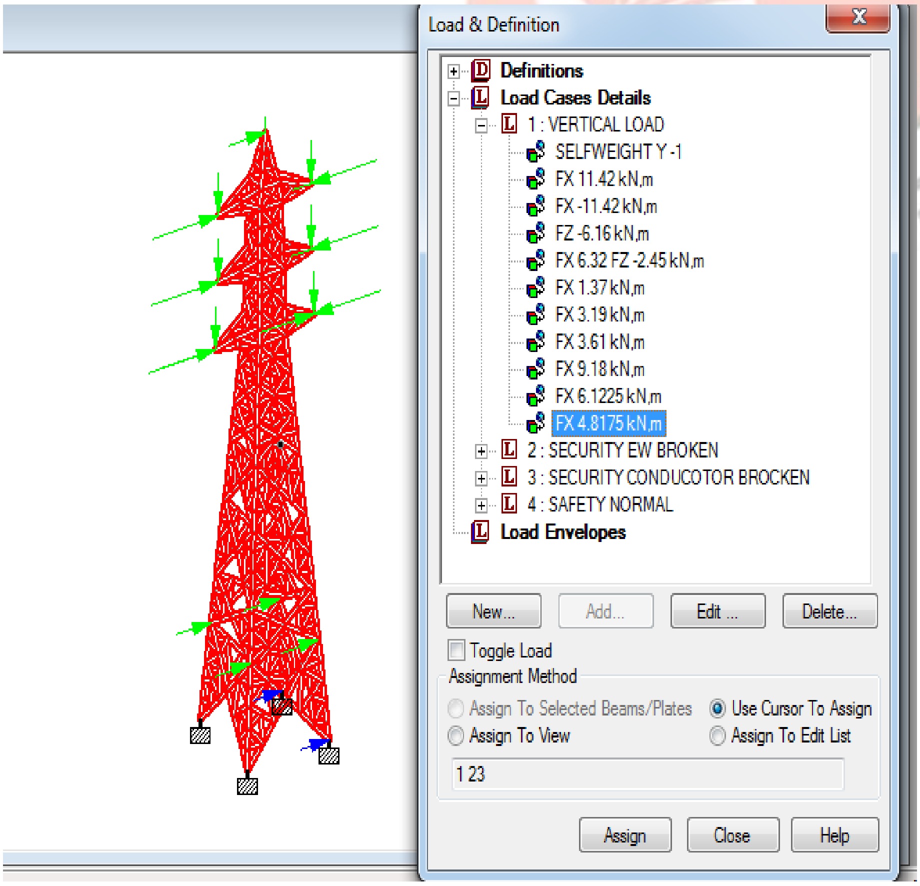
Tower with fixed supports

2. ASSIGNING MEMBER PROPERTY

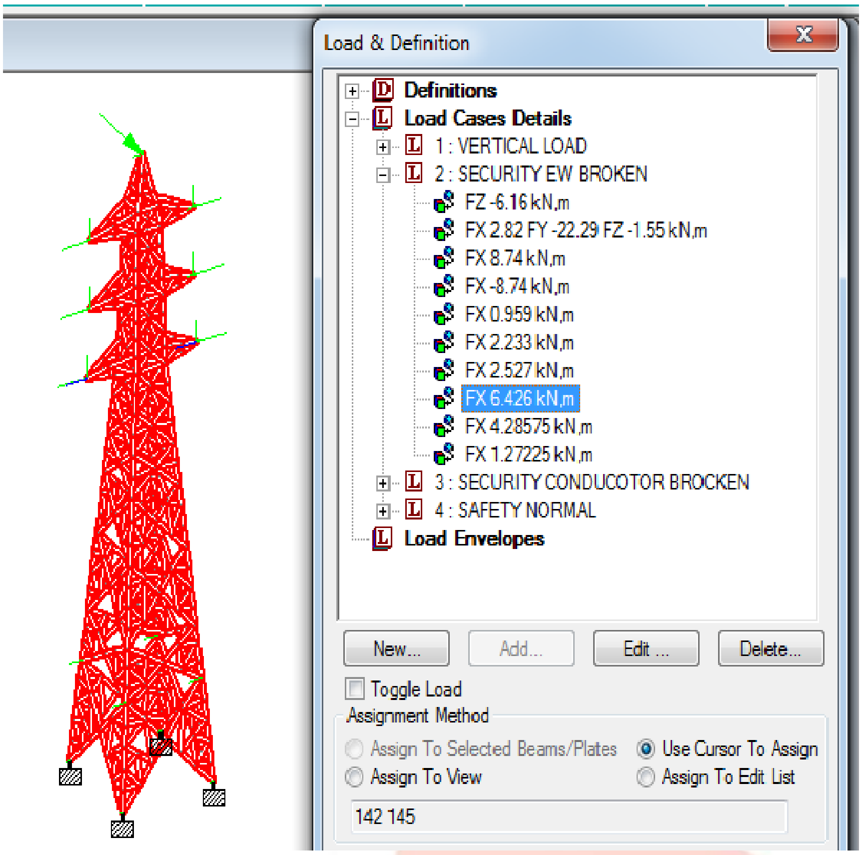


Property of Tower

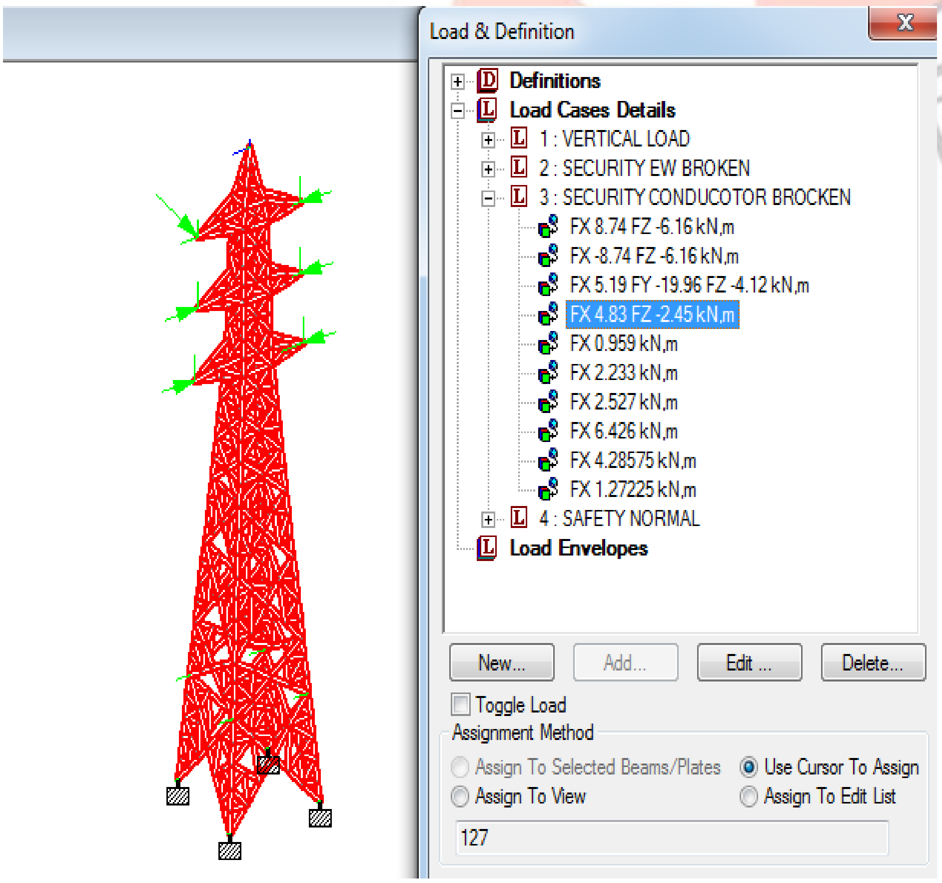
3. ASSIGNING LOADS ON TOWER



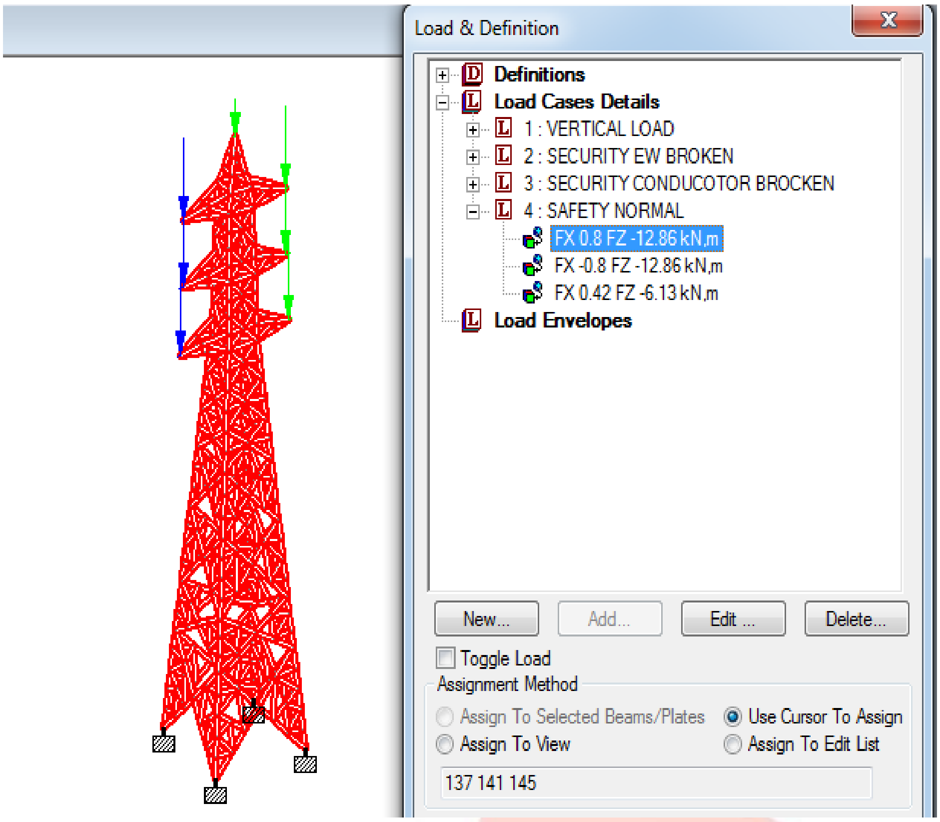
Vertical loads



Security EW Broken

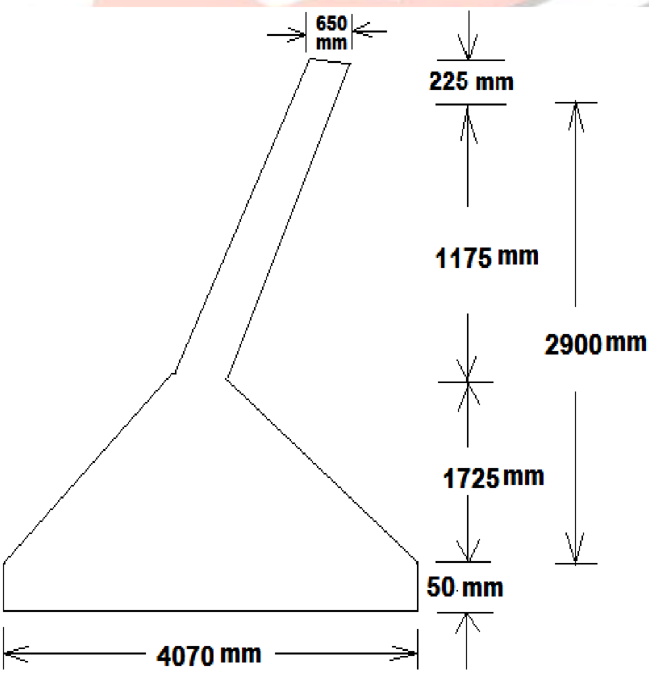


Security Conductor broken



Safety Normal

4. Design of foundation



Foundation

Table 7 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

IX. CONCLUSIONS

- 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/m^3 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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