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Analysis and Design of Transmission Tower

Gopi Sudam Punse

ABSTRACT: *In this thesis Analysis and Design of narrow based Transmission Tower (using Multi Voltage Multi Circuit) is carried out keeping in view to supply optimum utilization of electric supply with available ROW and increasing population in the locality, in India.*

Transmission Line Towers constitute about 28 to 42 percent of the total cost of the Transmission Lines. The increasing demand for electrical energy can be met more economical by developing different light weight configurations of transmission line towers.

In this project, an attempt has been made to make the transmission line more cost effective keeping in view to provide optimum electric supply for the required area by considering unique transmission line tower structure. The objective of this research is met by choosing a 220KV and 110KV Multi Voltage Multi Circuit with narrow based Self Supporting Lattice Towers with a view to optimize the existing geometry. Using STAAD PRO v8i analysis and design of tower has been carried out as a three dimensional structure. Then, the tower members are designed.

I. INTRODUCTION

1.1 Transmission Line Tower

India has a large population residing all over the country and the electricity supply need of this population creates requirement of a large transmission and distribution system. Also, the disposition of the primary resources for electrical power generation viz., coal, hydro potential is quite uneven, thus again adding to the transmission requirements. Transmission line is an integrated system consisting of conductor subsystem, ground wire subsystem and one subsystem for each category of support structure. Mechanical supports of transmission line represent a significant portion of the cost of the line and they play an important role in the reliable power transmission. They are designed and constructed in wide variety of shapes, types, sizes, configurations and materials. The supporting structure types used in transmission lines generally fall into one of the three categories: lattice, pole and guyed.

The supports of EHV transmission lines are normally steel lattice towers. The cost of towers constitutes about quarter to half of the cost of transmission line and hence optimum tower design will bring in substantial savings. The selection of an optimum outline together with right type of bracing system contributes to a large extent in developing an economical design of transmission line tower. The height of tower is fixed by the user and the structural designer has the task of designing the general configuration and member and joint details.

The goal of every designer is to design the best (optimum) systems. But, because of the practical restrictions this has been achieved through intuition, experience and repeated trials, a process that has worked well. Power Grid Corporations of India Limited has prescribed the following steps to.

Optimized the Design of Power Transmission Lines:-

- Selection of clearances.
- Insulator and insulator string design.
- Bundle conductor studies.
- Tower configuration analysis.
- Tower weight estimation.
- Line cost analysis and span optimization.
- Economic evaluation of line.

Figure 1.1 Transmission line tower

1.2 LITERATURE REVIEW

Research paper

1.2.1 Y. M. Ghugal , U. S. Salunkhe [1] "Analysis and Design of Three and Four Legged 400KV Steel Transmission Line Towers: Comparative Study" H.O.D. Applied Mechanics Department, Govt. College of Engineering, Aurangabad Maharashtra (India), Post Graduate Student of M.E. (Structural Engineering), Applied Mechanics Department, Govt. College of Engineering, Aurangabad.
International Journal of Earth Sciences and Engineering 691
ISSN 0974-5904, Volume 04, No 06 SPL, October 2011, pp 691-694

Abstract:

The four legged lattice towers are most commonly used as transmission line towers. Three legged towers only used as telecommunication, microwaves, radio and guyed towers but not used in power sectors as transmission line towers. In this study an attempt is made that the three legged towers are designed as 400 KV double circuit transmission line tower. The present work describes the analysis and design of two self-supporting 400 KV steel transmission line towers viz three legged and four legged models using common parameters such as constant height, bracing system, with an angle sections system are carried out. In this study constant loading parameters including wind forces as per IS: 802 (1995) are taken into account. After analysis, the comparative study is presented with respective to slenderness effect, critical sections, forces and deflections of both three legged and four legged towers. A saving in steel weight up to 21.2% resulted when a three legged tower is compared with a four legged type.

1.2.2 V. Lakshmi1, A. Rajagopala Rao [2] "EFFECT OF MEDIUM WIND INTENSITY ON 21M 132kV TRANSMISSION TOWER" Assistant Professor, Civil Engineering, JNT University Kakinada, Andhra Pradesh, India, Professor of Civil Engineering (Retd) JNT University Kakinada, Andhra Pradesh, India,
ISSN: 2250–3676 Volume-2, Issue-4, 820 – 824

Abstract:

In this paper 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, modeling and analysis are discussed. The wind intensity converted into point loads and loads are applied at panel joints.

1.2.3 M.Selvaraj, S.M.Kulkarni, R.Ramesh Babu [3] "Behavioural Analysis of built up transmission line tower from FRP pultruded sections" Central Power Research Institute, Bangalore, India , National Institute of Technology Karnataka, Mangalore, India
ISSN 2250-2459, Volume 2, Issue 9, September 2012

Abstract:

The 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 X-braced 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.

1.2.4 S.Christian Johnson 1 G.S.Thirugnanam [4]

Research Scholar, Head & Professor in civil Engg. IRTT "Experimental study on corrosion of transmission line tower foundation and its rehabilitation" International Journal of Civil and Structural Engineering
ISSN 0976 – 4399 Volume 1, No 1, 2010

Abstract:

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 in-service 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, Chemicaland 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.

1.2.5 F.Albermani and M. Mahendran [5] "Upgrading Of Transmission Towers Using Of Diaphragm Bracing System" Dept. of Civil Engineering, University of Queensland, Brisbane, Australia School of Civil Engineering, Queensland University of Technology, Brisbane, Australia Dept. of Building and Construction, City University of Hong Kong, Hong Kong .

Abstract:

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 sub-structure 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.

1.2.6 N.PrasadRao, G.M.Samuel Knight, S.J.Mohan, N. Lakshmanan [6] "Studies on failure of transmission line towers in testing" College of Engineering Gunidy ,Anna University, Chennai 600 025 India, Structural Engineering Research Center, Chennai 600 113,India

Abstract:

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.

1.2.7 G.Visweswara Rao[7] "OPTIMUM DESIGNS FOR TRANSMISSION LINE TOWERS" Senior research Analyst**,** Engineering Mechanics Research India, 907 Barton Centre Bangalore-560 001, India Computer & Structures vol.57.No.1.pp.81-92, 1995

Abstract:

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 toboth 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.

II. ANALYSIS OF TRANSMISSION LINE TOWER

2.1 Details of Electric Tension Tower 220kv over 110kv

Wind Pressure Details:-
Basic wind speed V_b = 44 m/s
Wind zone – 3
Reliability level – 2
Terrain category – 2
Reference wind speed = VR = V_b/K_o
= 44/1.375 = 32m/s
Design wind speed
V_d= VR*K1*K2
K1= 1.11
K2= 1
Vd = 32*1.11*1 = 35.52m/s
Design wind pressure Pd = 0.6*Vd^2
= 0.6*35.52^2
= 757 N/m^2
= 77.17Kg/m^2
Max. Temperature of conductor = 75^0C
Max. Temperature of earth wire = 53^0C
Everyday temperature = 32^0C
Min. temperature = 0^0C

<u>For 220KV :</u> Conductor wire
Total wind load on conductor = Cdc*Gc * Ae* Pd* space factor
Cdc= 1
Gc = 2.32
Ae = 3.16x10^{-2}x1 m^2/m
= 3.16x10^{-2} m^2/m
Space factor = 0.6
For 100% wind, Pd = 1*2.32*3.18 x10^{-2} *77.17*0.6
= 3.416
For 36% wind, Pd= 0.36* 1*2.32*3.18 x10^{-2} *77.17*0.6
= 1.25
For 75% wind, Pd= 0.75* 1*2.32*3.18 x10^{-2} *77.17*0.6

= 2.562

W = 2.004

Q1 = $\frac{\sqrt{Pd^2 + w^2}}{w}$

BY parabola equation

T^2 (T- K + Aaet) = W^2L^2EA / $24Q^2$

T = UTS/FOS = 16438/4 = 4109.5

Initial cond. – at 32^0C & 0% wind

4109.5^2 (4109.5 – K + 1.93X10^{-5}x5.97x10^{-4}x7x10^9x32) = 2.004^2x320^2x7x10^9x5.97x10^{-4}/24x1^2

K = 2450.326

Put K = 2450.326 in above equation, find out tension and sag in conductor as given in below mentioned table.

Sag = W*L^2/8T

Ground wire

Total wind load on conductor = Cdc* Gc * Ae* Pd* space factor

Cdc= 1.2

Gc = 2.39

Ae = 9.45x10^{-3}x1 m^2/m

= 9.45x10^{-3} m^2/m

Space factor =0.6333

For 100% wind, Pd = 1.2*2.39*9.45 x10^{-3} *77.17*0.6

= 1.255

For 36% wind, Pd= 0.36* 1.2*2.39*9.45 x10^{-3} *77.17*0.6

= 0.452

For 75% wind, Pd= 0.75* 1.2*2.39*9.45 x10^{-3} *77.17*0.6

= 0.941

W = 0.429

Q1 = $\frac{\sqrt{Pd^2 + w^2}}{w}$ …………as per IS 5613

By parabola equation

T^2 (T- K + Aaet) = W^2L^2EA / $24Q^2$

T = UTS/FOS = 5913/4 = 1478.25

Initial cond. – at 32^0C & 0% wind

1478.25^2 (1478.25– K + 1.15X10^{-5}x5.46x10^{-5}x1.93x10^{10}x32) = 0.429^2x320^2x1.93x10^{10}x5.46x10^{-5}/24x1^2

K = 1487.374

Sag in ground wire at 0® C & 0% wind = 90% of sag in conductor 0® C & 0% wind

= 0.9*4.981 = 4.48

Put K = 1487.374 in above equation, find out tension and sag in conductor.

Sag = W*L^2/8T

<u>For 110KV :</u> Conductor wire

Total wind load on conductor = Cdc*Gc * Ae* Pd* space factor

Cdc= 1

Gc = 2.12

Ae = 2.1x10^{-2}x1 m^2/m

= 2.1x10^{-2} m^2/m

Space factor =0.6

For 100% wind, Pd = 1*2.12*2.1 x10^{-2} *77.17*0.6

= 2.061

For 36% wind, Pd= 0.36* 1*2.12*2.1 x10^{-2} *77.17*0.6

= 0.742

For 75% wind, Pd= 0.75* 1*2.12*2.1 x10^{-2} *77.17*0.6

= 1.546

W = 0.974

Q1 = $\frac{\sqrt{Pd^2 + w^2}}{w}$

BY parabola equation

T^2 (T- K + Aaet) = W^2L^2EA / $24Q^2$

T = UTS/FOS =9144/4 = 2286

Initial cond. – at 32®C & 0% wind

$2286^2 (2286 – K + 1.78X10^{-5}x2.62x10^{-4}x8.16x10^9x32) = 0.942^2x320^2x8.16x10^9x2.62x10^{-4}/24x1^2$

K = 1848

Put K = 1848 in above equation, find out tension and sag in conductor.

Sag = $W*L^2/8T$

2.2 GEOMETRY OF TOWER

1. Vertical spacing between conductors of 220KV = 5.5 m
2. Vertical spacing between top conductor and ground wire = 7.45 m
3. Vertical spacing between conductors of 110KV = 4.5m
4. Clearance between BC and TC1(including insulator string = 2.34m) = 7m
5. Ground clearance = 7.015m
6. Extra height at ground level = 3.665m
7. Max. sag = 7m
8. Height of Insulator string = 1.82 m

Total height of tower = 1+2+3+4+5+6+7+8+9 = **53.95 m**

Cross arm length 220KV = 4.6m

Cross arm length 110KV = 3.8m

Base width 1/8*53.95 = 6.774 say 6m

Width at waist level = ½*6 = 3m……….standard practice in use

Inclination at base = 2.419^0

Please see the Excel sheet attached

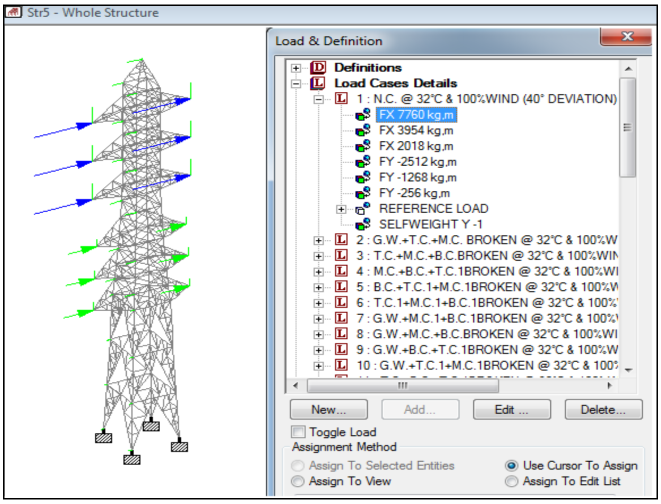

Figure 4.1

<u>LOAD CASE 1:-</u> Loads acting on transmission tower under normal (intact wire) Condition.

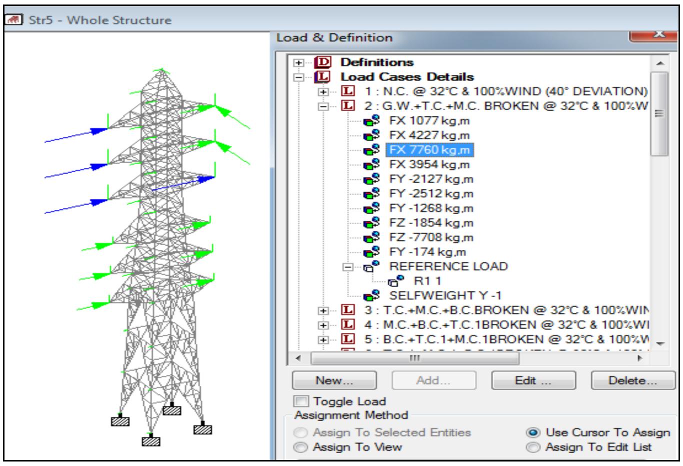

Figure 4.2

LOAD CASE 2:- Loads acting on transmission tower under broken wire condition.

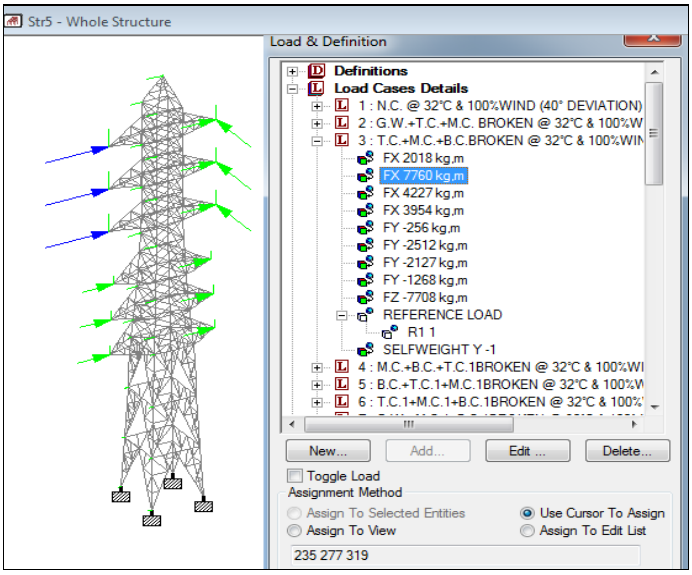

Figure 4.3

LOAD CASE 3:- Loads acting on transmission tower under broken wire condition

2.3 RESULT :-

Different Values of stresses obtained from STAAD - Pro V8i are as,

LEG MEMBER		
Beam	**L/C**	**Axial N/mm2**
57	1	-753.11
58	1	-636.08
59	1	-497.34
75	1	-753.12
76	1	-753.12
77	1	-636.09
78	1	-636.09
79	1	-497.34
80	1	-497.34
195	1	790.005
196	1	672.947
197	1	534.176
213	1	790.003
214	1	790.001
215	1	672.945
216	1	672.943
217	1	534.174
218	1	534.175
333	1	743.78
334	1	634.02

BRACINGS		
Beam	**L/C**	**Axial N/mm2**
6	1	74.992
10	1	80.152
14	1	87.46
33	1	0.157
37	1	0.172
63	1	-174
64	1	-199.8
65	1	-233.7
69	1	-0.371
70	1	-0.44
71	1	-0.532
87	1	-174
88	1	-174
89	1	-199.8
90	1	-199.8
91	1	-233.7
92	1	-233.7
99	1	-0.372
100	1	-0.371
101	1	-0.439

OTHER DIAGONALS		
Beam	**L/C**	**Axial N/mm2**
123	1	-0.004
124	1	0.002
125	1	-0.007
126	1	0.001
127	1	0.004
128	1	-0.004
129	1	0.002
130	1	-0.011
131	1	0.002
132	1	0.004
133	1	-0.001
134	1	0
135	1	-0.008
136	1	0.003
137	1	0.003
153	1	-0.002
154	1	0.001
155	1	0.001
156	1	-0.004
157	1	0.001

335	1	504.169	102	1	-0.439	158	1	0.001
351	1	743.779	103	1	-0.53	159	1	-0.001
352	1	743.776	104	1	-0.53	160	1	-0.003
353	1	634.018	111	1	74.992	161	1	0.002
354	1	634.016	112	1	80.152	162	1	-0.001
355	1	504.167	113	1	87.46	163	1	0
356	1	504.168	117	1	0.157	164	1	-0.001
471	1	-706.89	118	1	0.172	165	1	-0.005
472	1	-597.15	183	1	-0.156	166	1	0.003
473	1	-467.32	184	1	-0.171	167	1	-0.001
489	1	-706.89	185	1	-44.57	261	1	-0.002
490	1	-706.9	189	1	-70.73	262	1	0.001
491	1	-597.15	190	1	-75.45	263	1	-0.001
492	1	-597.16	191	1	-80.22	264	1	0
493	1	-467.33	201	1	0.373	265	1	0.001
494	1	-467.34	202	1	0.442	266	1	-0.004
597	1	-149.32	203	1	0.533	267	1	0.003
598	1	-151.59	207	1	173.96	268	1	-0.002
599	1	179.969	208	1	199.8	269	1	-0.001
600	1	178.235	209	1	233.7	270	1	0.001
605	1	-115.43	225	1	0.373	271	1	-0.003
606	1	-79.894	226	1	0.373	272	1	0.002
607	1	-120.41	227	1	0.44	273	1	0.003
608	1	-81.925	228	1	0.441	274	1	-0.003
609	1	140.432	229	1	0.531	275	1	0.001
610	1	97.978	230	1	0.532	291	1	-0.005
611	1	133.504	237	1	173.96	292	1	0.001
612	1	98.873	238	1	173.96	293	1	0.004
681	1	-52.997	239	1	199.79	294	1	-0.001
682	1	-52.623	240	1	199.79	295	1	0
683	1	71.268	241	1	233.69	296	1	-0.013
684	1	70.752	242	1	233.7	297	1	0.001
689	1	-35.244	249	1	-0.156	298	1	0.004
690	1	-17.945	250	1	-0.171	299	1	-0.001
691	1	-38.693	251	1	-44.57	300	1	0.002
692	1	-17.607	255	1	-70.73	301	1	-0.005
693	1	49.069	256	1	-75.45	302	1	0.001
694	1	25.484	257	1	-80.22	303	1	0.006
695	1	43.915	321	1	-66.62	304	1	-0.003
696	1	27.322	322	1	-70.94	305	1	0.002
761	1	-9.418	323	1	-75.2	399	1	-0.009
762	1	-10.799	327	1	0.156	400	1	0.001
763	1	9.138	328	1	0.172	401	1	-0.001

764	1	17.29
829	1	503.282
830	1	-469.84
831	1	-441.06
832	1	474.501
833	1	479.849
834	1	-432.89
835	1	-406.82
836	1	453.777
873	1	-364.02
874	1	421.143
875	1	444.156
876	1	-387.04
885	1	-351.47
886	1	397.237
887	1	377.707
888	1	-331.94
1022	1	-193.48
1023	1	231.775
1024	1	234.981
1025	1	-196.68
1030	1	-240.57
1031	1	-291.69
1032	1	287.108
1033	1	332.089
1034	1	296.506
1035	1	347.075
1036	1	-249.97
1037	1	-306.68
1304	1	5.326
1305	1	-2.028
1306	1	6.126
1307	1	1.319
1308	1	-10.738
1309	1	-5.346
1310	1	11.164
1311	1	5.767
1328	1	-5.347
1345	1	-6.13
1346	1	6.602
1347	1	6.603
1348	1	-6.136
1349	1	-6.132

329	1	-44.19
339	1	164.16
340	1	188.19
341	1	219.71
345	1	-0.372
346	1	-0.439
347	1	-0.529
363	1	164.16
364	1	164.15
365	1	188.19
366	1	188.19
367	1	219.7
368	1	219.71
375	1	-0.372
376	1	-0.371
377	1	-0.441
378	1	-0.44
379	1	-0.531
380	1	-0.53
387	1	-66.62
388	1	-70.94
389	1	-75.2
393	1	0.156
394	1	0.172
395	1	-44.19
459	1	-0.155
460	1	-0.171
465	1	70.887
466	1	75.633
467	1	82.441
477	1	0.373
478	1	0.441
479	1	0.53
483	1	-164.2
484	1	-188.2
485	1	-219.7
501	1	0.372
502	1	0.373
503	1	0.441
504	1	0.441
505	1	0.532
506	1	0.532
513	1	-164.2

402	1	0
403	1	0.004
404	1	-0.005
405	1	0.001
406	1	0.003
407	1	-0.001
408	1	0.004
409	1	-0.005
410	1	0.001
411	1	0.005
412	1	-0.003
413	1	0.003
429	1	-0.002
430	1	0.001
431	1	0.001
432	1	-0.001
433	1	0
434	1	-0.004
435	1	0.003
436	1	-0.002
437	1	-0.001
438	1	-0.001
439	1	-0.003
440	1	0.002
441	1	0.003
442	1	-0.003
443	1	-0.001
537	1	-0.002
538	1	0.001
539	1	-0.004
540	1	0.001
541	1	0.001
542	1	-0.001
543	1	0
544	1	-0.006
545	1	0.002
546	1	0.001
547	1	0
548	1	-0.001
549	1	-0.005
550	1	0.003
551	1	0.001
567	1	-0.004

1350	1	-6.133		514	1	-164.2		568	1	0.002
1351	1	6.603		515	1	-188.2		569	1	0.004
1352	1	6.605		516	1	-188.2		570	1	-0.007
1353	1	6.605		517	1	-219.7		571	1	0.001
1354	1	6.607		518	1	-219.7		572	1	-0.001
1355	1	-6.134		525	1	-0.155		573	1	-0.001
1356	1	-6.133		526	1	-0.171		574	1	-0.005

III. DESIGN PARAMETERS

Based on the wind speed map the entire country has been divided into six wind zones with max. wind speed of 55 m/sec. and min. wind speed of 33 m/sec. Basic wind speeds for the six wind zones are

Wind Zone	Basic Wind Speed (m/sec)
1	33
2	39
3	44
4	47
5	50
6	55

In case the line traverses across the border of wind zones, the higher wind speed may be considered.

3.1 Reference Wind Speed VR

It is extreme value of wind speed *over* an average period of 10 minute duration and is to be calculated from basic wind speed 'vb' by the following relationship

VR = Vb/K

Where K_o is a factor to convert 3-second peak gust speed into average speed of wind during 10 minutes period at a level of 10 meters above ground. K_o is to be taken as 1.375.

3.2 Design Wind Speed Vd

Reference wind speed obtained shall be modified to include the following effects to get the design wind speed:

(i) Risk Coefficient K_1

(ii) Terrain Roughness coefficient K2

It is expressed as follows:-

$V = V_R \times K1 \times K_2$

3.3 Risk Coefficient K_1

Below Table gives the values of Risk Coefficient K_t for different wind zones for three Reliability Levels.

Risk Coefficient K_1 for Different Reliability Levels and Wind Zones

Table No. 5.1

Reliability Level	1	Coefficient K, wind 2 zones: 3	4		5	6
1(50 yr return period)	1.00	1.00	1.00	1.00	1.00	1.00
2(150 yr return period)	1.08	1.10	1.11	1.12	1.13	1.14
3 (300 yr return period)	1.17	1.22	1.25	1.27	1.28	1.30

3.4 Terrain Roughness Coefficient K2

Below, gives the values of coefficient K_2 of the three categories of terrain roughness corresponding to an average 10-minute wind speed.

Terrain Roughness Coefficients K_2

Terrain Category	1	2	3
Coefficient K2	1.08	1.00	0.85

3.5 Terrain Categories
(a) Category 1 - Coastal areas, deserts and large stretches of water.
(b) Category 2 - Normal cross-country lines with very few obstacles.
(c) Category 3 - Urban built-up areas or forest areas.

3.6 Design Wind Pressure Pd
The design wind pressure on towers, conductors and insulators shall be obtained by the following relationship:-
$Pd = 0.6Vd^2$
where Pd = design wind pressure in N/m^2 and Vd = Design wind speed in m/s.

Design wind pressure Pd for all the three Reliability levels and pertaining to six wind zones and the three terrain categories have been worked out and given in Table below :

Design Wind Pressure Pd, in N/m^2
(Corresponding to wind velocity at 10 m height)
Table No. 3.2

Reliability Level	Terrain Category	Wind pressure Pd for wind zones 1	2	3	4	5	6
1	1	403	563	717	818	925	1120
	2	346	483	614	701	793	960
	3	250	349	444	506	573	694
2	1	470	681	883	1030	1180	1460
	2	403	584	757	879	1010	1250
	3	291	422	547	635	732	901
3	1	552	838	1120	1320	1520	1890
	2	473	718	960	1130	1300	1620
	3	342	519	694	817	939	1170

3.7 Wind Loads
(A) Wind Load on Tower
In order to determine the wind load on tower, the tower is divided into different panels having a height 'h'. These panels should normally be taken between the intersections of the legs and bracings. For a lattice tower, the wind load Fwt in Newtons, for wind normal to a face of tower, on a panel height 'h' applied at the centre of gravity of the panel is :-
$Fwt = Pd \times C_{dt} \times Ae \times G_T$
Pd = Design wind pressure in N/m^2
C_{dt} = Drag Coefficient pertaining to wind blowing against any face of the tower. Values of C_{dt} for the different solidity ratios are given in Table
Ae = Total net surface area of the legs and bracings of the panel projected normally on face in m^2. (The projections of the bracing elements of the adjacent faces and of the plan-and-hip bracing bars may be neglected while determining the projected surface of a face).
G_T = Gust Response Factor, perpendicular to the ground roughness and depends on the height above ground. Values of GT for the three terrain categories are given in Table below,

Drag Coefficient C_{dt} for Towers
Table No. 3.3

Solidity Ratio	Drag Coefficient, C_{dt}
Upto 0.05	3.6
0.1	3.4
0.2	2.9
0.3	2.5

0.4 2.2
0.5 and above 2.0

Solidity ratio is equal to the effective area (projected area of all the individual elements) of a frame normal to the wind direction divided by the area enclosed by the boundary of the frame normal to the wind direction.

Gust Response Factor for Towers (GT) and for Insulators (Gl)
Table No. 3.4

Height above Values of GT and Gl for terrain Category Ground m 1
2 3

Upto 10	1.70	1.92	2.55
20	1.85	2.20	2.82
30	1.96	2.30	2.98
40	2.07	2.40	3.12
50	2.13	2.48	3.24
60	2.20	2.55	3.34
70	2.26	2.62	3.46
80	2.31	2.69	3.58

(B) Wind Load on Conductor and Groundwire

The load due to wind on each conductor and groundwire, Fwc in Newtons applied at supporting point normal to the line shall be determined by the following expression :

Fwc = Pd. L. d. Gc. Cdc

where:

Pd = Design wind pressure in N/m^2;

L = Wind span, being sum of half the span on either side of supporting point, in metres.d = Diameter of conductor/groundwire, in metres.

Gc = Gust Response Factor which takes into account the turbulance of the wind and the dynamic response of the Conductor. Values of Gc are already discussed for the three terrain categories and the average height of the conductor above the ground.

Cdc = Drag coefficient which is 1.0 for conductor and 1.2 for Groundwire.

(C) Wind Load on Insulator Strings

Wind load on insulator strings 'Fwi' shall be determined from the attachment point to the centre line of the conductor in case of suspension tower and upto the end of clamp in case of tension tower, in the direction of the wind as follows :

Fwi = 1.2. Pd. Ai. Gi

Where

Pd = Design Wind pressure in N/m^2

Ai = 50 Per cent of the area of Insulator string projected on a plane parallel to the longitudinal axis of the string (1/2 x diameter x length).

Gi = Gust Response Factor, depending on the ground roughness and height of insulator attachment above ground. Values of Gi for the three terrain categories.

3.8 Temperature

To evolve design of tower, three temperatures i.e. Max. temperature, min. temperature and everyday temperature are very important. Tower height as well as sag and tension calculations of conductor and earthwire vary with the change in the above three temperatures.

The temperature range varies for different parts of India under different seasonal conditions. The absolute max. and min. temperatures which may be expected in different localities in country are indicated on the maps of India respectively. The temperatures indicated in these maps are the air temperatures in shade. The max. conductor temperatures may be obtained after allowing increase in temperature due to solar radiation and heating effect due to current etc. over the absolute max. temperature given below. After giving due thought to several aspects such as flow of excess power in emergency during summer time etc. the following three designs temperatures have been fixed :-

(a) Max. temperature of ACSR conductor = 75 deg C
(b) Max. temperature of AAAC conductor = 85 deg C
(c) Max. temperature of earthwire = 53 deg C
(d) Min. temperature (ice-free zone) = **-** 5 deg C to + 10 deg C
(depends on location of the trans, line however 0°C widely used in the country)
(e) Everyday Temperature 32°C (for most parts of the country).

For region with colder climates (-5 deg C or below) the respective Utility will decide the everyday temperature.

3.9 Lightning Consideration for Tower Design

As the overhead transmission lines pass through open country, these are subjected to the effects of lightning. The faults initiated by lightning can be of the following three types:-

(i) Back flash over: When lightning strikes on a tower or on the earthwire near the tower which raises the tower potential to a level resulting in a discharge across the insulator string.

(ii) Midspan flash over: When lightning strikes on earth wire raising local potential of the earth wire such that a breakdown in the air gap between earthwire and phase conductor results.

(iii) Shielding failure: When lightning strikes on the phase conductor directly resulting in a flashover across the insulator string.

3.10 Seismic Consideration

The transmission line tower is a pin-jointed light structure comparatively flexible and free to vibrate and max. wind pressure is the chief criterion for the design. Concurrence of earthquake and max. wind condition is unlikely to take place and further siesmic stresses are considerably diminished by the flexibility and freedom for vibration of the structure. This assumption is also in line with the recommendation given in cl. no. 3.2 (b) of IS: 1893-1984. Seismic considerations, therefore, for tower design are ignored and have not been discussed in this paper.

3.11 New Concepts in Transmission Line Design

The new concepts in transmission line design philosophy include the following major changes in the design method :-

(i) Design based on limit load concept;
(ii) Use of probablistic method of design;
(iii) Use of Reliability levels in transmission lines design;
(iv) Use of Co-ordination in strength of line components;
(v) Use of six basic wind speeds converted to 10-minutes average speeds corresponding to 10-meter height over mean retarding surface as the basis for wind loads on transmission lines instead of three wind zones corresponding to 30 metre height over mean retarding surface in use earlier;
(vi) Consideration of the effects of terrain category and topography of transmission line corridors in the design wind speeds.

IV. DESIGN OF TRANSMISSION LINE TOWER

4.1 Design of leg member

NC 32°C & 100% wind
GW (2018+745) * 53.95 = 149064
TC (2*7760+2777)*46.5 = 850811
MC (2*7760+3030)*41 = 760550
BC (2*7760+2972)*35.5 = 656466
TC1 (3954*2+3308)*28.5 = 319656
MC1 (2*3954+2662)*24= 253680
BC1 (2*3954+2739)*19.5= 207617

M = $3198X10^3$ Kg- m
Max. Stress = M/2wcosø = $3198bX10^3/2*5.4*0.9982$
= $296 X 10^3$
Vertical load max = $\frac{256 +2512*6+1268*6}{4}$

= 5734

Vertical load min = $\frac{119+1871*6+956*6}{4}$

= 4270

Self wt of tower = 10000/4 = 2500 approx.

Compression = 305 X 10^3

Tension = 290 X 10^3

Use ISA 100X100X8 Double angle back to back section

L= 2340/0.999 = 2342.342

l/r = 234.23/3.07 = 76.296

yield stress of mild steel = 2550 Kg/cm^2

from curve no. 1 Fc = 2503

ultimate compressive stress = 2503*30.78 = 77204 < 305 X 10^3

Use ISA 200X200X25 Double angle back to back section

l/r = 38.5 = 39

ultimate compressive stress = 2427*183.30 = 445 X 10^3 > 305 X 10^3

S.M. = 1.46

K = $\frac{5A_1}{5A_1 + A_2}$

= $\frac{5*200*25}{5*200*25+200*25}$

= 0.833

Net area for tension = (200*25+0.833*200*25)*2

= 183.30

ultimate tensile stress = 2550*183.30 = 467 X 10^3 > 305 X 10^3

S.M. = 1.233

Use 20mm dia bolts 6Nos.

Ultimate shearing strength (single shear) = 59586 kg

Ultimate bearing strength (single shear) = 98018 kg

Ultimate shearing strength (double shear) = 119X10 kg

4.2 Design of bracings

∑Fb for transverse face bracing

GW	(2018+745) * 0.2 =	2763
TC	(2*7760+2777)*3 =	54891
MC	(2*7760+3030)*3 =	55650
BC	(2*7760+2972)*3 =	55476
TC1	(3954*2+3308)*3.59 =	40265
MC1	(2*3954+2662)*3.97=	41963
BC1	(2* 3954+2739)* 4.52 =	47912

∑Fb = 355 X 10^3

Stress = ∑Fb / 4wcosø = 355 X10^3 / 4*5.4*0.9982

= 16 X 10^3 (C&T)

L= 2320

Use ISA 90 X 90 X 12 Double angle back to back section

l/r = 232/2.270 = 85.6

ultimate compressive stress = 1726*28.74 = 48 X10^3 > 16 X 10^3

S.M. = 3

K = $\frac{5A_1}{5A_1 + A_2}$

= $\frac{5*90*12}{5*90*12+90*12}$

= 0.833

Net area for tension = (90*12+0.833*90*12)*2

= 40 cm^2

ultimate tensile stress = 2550* 40 = 102 X 10^3 > 16 X 10^3

S.M. = 6.37

Use 20mm dia bolts 4Nos.

Ultimate shearing strength (single shear) = 39724
Ultimate bearing strength (single shear) =65345
Ultimate shearing strength (double shear) = 79333

4.3 Design of other diagonals
Stress = 16 $X10^3$ (C&T)
L= 2390
Use ISA 65X65X8 single angle section
l/r = 239/1.25 = 191.2
Ultimate compressive stress = 1387*9.76 = 13.53x $10^3 <$ 16 X 10^3
Use ISA 100 X 100 X 8 single angle section
l/r = 239/3.07 = 77.85

$$K = \frac{3A_1}{3A_1 + A_2}$$

$$= \frac{3*100*8}{3*100*8+100*8}$$

= 0.75
Net area for tension = (100*8+0.75 *100 *8)
= 14
ultimate tensile stress = 2550*14 = 35.7 X 10^3 > 16 X 10^3
S.M. = 2.18

Use 20mm dia bolts 6Nos.
Ultimate shearing strength (single shear) = 39724
Ultimate bearing strength (single shear) = 65345
Ultimate shearing strength (double shear) = 79333

4.4 Design of cross arm
a) Upper member:-
Length = $\sqrt{(1.375^2+4.84^2)}$ = 5.032

$$St = \frac{1406*5.032}{2*4.84}$$

= ± 731

$$Sv = \frac{3214*5.032}{2*1.375}$$

= 5881

$$Sl = \frac{4109*5.032}{2*3}$$

= ± 3446
Compression = 10056
Tension = 4177
L = 5.032/3 = 1.677
l/r = 167.7 / 3.07 = 54.625
ultimate compressive stress = 1970*28.74 = 55 $X10^3$ >10 $X10^3$
S.M. = 3.43

$$K = \frac{5A_1}{5A_1 + A_2}$$

$$= \frac{5*100*8}{5*100*8+100*8}$$

= 0.833
Net area for tension = (100*8 + 0.833*100 *8)*2
= 29.32
Ultimate tensile stress = 2550*29.32 = 75 $X10^3$ > $4.1X10^3$

b) Lower member :-
Length = $\sqrt{(1.375^2+4.84^2+3^2}$ = 5.858

$$Sv = \frac{3984*5.858}{2*1.375}$$

= 8487

l/r = 585.8 / 3.07 = 191
Ultimate tensile stress = 2550*30.7 = 78 $X10^3 > 4.1 X10^3$

Use 20mm dia bolts 6Nos.
Ultimate shearing strength (single shear) = 39724
Ultimate bearing strength (single shear) =65345
Ultimate shearing strength (double shear) = 79333

CONCLUSION:

Use ISA 200X200X 25 Double angle back to back section for leg member
Use ISA 90X90X 12 Double angle back to back section for bracings and cross arm
Use ISA 100x100X 8 Single angle section for other diagonals.

4.5 RESULT :-
Compression and Tensile force acting on the tower and obtained from STAAD Pro-V8i are as,
Table No. 6.1

LEG MEMBER				BRACINGS				OTHER DIAGONALS			
Beam	**L/C**	**Compres s-ion kg**	**Tension Kg**	**Beam**	**L/C**	**Compress-ion kg**	**Tension Kg**	**Beam**	**L/C**	**Compress-ion kg**	**Tension Kg**
57	1	-2.34E+05	2.34E+05	6	1	14841.721	-14841.721	123	1	-0.829	0.453
58	1	-1.98E+05	3.12E+05	10	1	15860.281	-19851.965	124	1	0.418	0.437
59	1	-1.55E+05	3.59E+05	14	1	16901.445	-22902.618	125	1	-1.113	0.428
75	1	-2.34E+05	3.24E+05	33	1	-54.179	-21272.222	126	1	0.136	0.435
76	1	-2.34E+05	2.90E+05	37	1	-59.751	-19508.161	127	1	0.705	0.441
77	1	-1.98E+05	2.55E+05	63	1	-34421.587	-17593.517	128	1	-0.798	0.448
78	1	-1.98E+05	2.39E+05	64	1	-39525.147	-16374.135	129	1	0.36	0.452
79	1	-1.55E+05	3.07E+05	65	1	-46225.431	-20052.837	130	1	-1.545	0.438
80	1	-1.55E+05	2.75E+05	69	1	130.627	-18332.961	131	1	0.235	0.444
195	1	2.46E+05	2.43E+05	70	1	154.341	-16457.506	132	1	0.673	0.451
196	1	2.10E+05	3.26E+05	71	1	185.709	-21182.74	133	1	-0.47	0.434
197	1	1.67E+05	2.94E+05	87	1	-34421.643	-19307.288	134	1	0.092	0.441
213	1	2.46E+05	2.90E+05	88	1	-34421.805	-19223.915	135	1	-0.961	0.441
214	1	2.46E+05	2.92E+05	89	1	-39524.799	-19396.77	136	1	0.37	0.441
215	1	2.10E+05	2.87E+05	90	1	-39525.847	-19313.396	137	1	0.642	0.442
216	1	2.10E+05	2.85E+05	91	1	-46222.823	-19424.788	153	1	-0.506	0.442
217	1	1.67E+05	1.44E+05	92	1	-46224.895	-8827.504	154	1	0.313	0.471
218	1	1.67E+05	2.10E+05	99	1	130.386	-13042.086	155	1	0.188	0.458
333	1	2.36E+05	2.50E+05	100	1	130.659	-15611.98	156	1	-0.847	0.45
334	1	2.01E+05	2.21E+05	101	1	154.67	-14324.424	157	1	0.136	0.455
335	1	1.59E+05	1.92E+05	102	1	154.66	-12927.625	158	1	-0.172	0.461
351	1	2.36E+05	1.64E+05	103	1	186.274	-11407.839	159	1	-0.015	0.466
352	1	2.36E+05	1.49E+05	104	1	186.303	-10304.371	160	1	-0.511	0.469
353	1	2.01E+05	2.06E+05	111	1	14841.632	-13220.955	161	1	0.235	0.458
354	1	2.01E+05	1.80E+05	112	1	15860.208	-11840.116	162	1	-0.188	0.463
355	1	1.59E+05	1.53E+05	113	1	16901.384	-10357.731	163	1	-0.213	0.469
356	1	1.59E+05	2.23E+05	117	1	-54.179	-14243.94	164	1	0.021	0.455

471	1	-2.24E+05	1.96E+05	118	1	-59.751	-12748.756	165	1	-0.747	0.46
472	1	-1.89E+05	1.92E+05	183	1	54.877	-12695.395	166	1	0.37	0.461
473	1	-1.48E+05	1.94E+05	184	1	60.565	-12829.239	167	1	-0.188	0.46
489	1	-2.24E+05	1.90E+05	185	1	-5686.867	-12775.879	261	1	-0.398	0.461
490	1	-2.24E+05	1.88E+05	189	1	-13992.334	-12874.265	262	1	0.207	0.462
491	1	-1.89E+05	5.23E+02	190	1	-14923.574	12.473	263	1	-0.253	0.499
492	1	-1.89E+05	4.83E+03	191	1	-16265.538	896.249	264	1	0.05	0.499
493	1	-1.48E+05	3.44E+04	201	1	-130.396	42.547	265	1	0.188	0.493
494	1	-1.48E+05	4.05E+04	202	1	-154.044	589.199	266	1	-0.749	0.492
597	1	-4.55E+04	6.72E+04	203	1	-185.83	-325.072	267	1	0.522	0.487
598	1	-5.07E+04	7.05E+04	207	1	34422.623	244.492	268	1	-0.588	0.487
599	1	58371.334	9.44E+04	208	1	39527.652	-744.483	269	1	-0.056	0.482
600	1	5.38E+04	9.91E+04	209	1	46225.82	-703.693	270	1	0.188	0.481
605	1	-3.50E+04	1.08E+05	225	1	-130.33	-1189.658	271	1	-0.544	0.48
606	1	-2.38E+04	1.10E+05	226	1	-130.151	-1012.746	272	1	0.309	0.479
607	1	-3.94E+04	1.17E+05	227	1	-154.52	-1505.023	273	1	0.12	0.478
608	1	-2.75E+04	1.18E+05	228	1	-154.033	-1341.662	274	1	-0.204	0.478
609	1	45677.371	1.24E+05	229	1	-186.139	-1838.798	275	1	0.188	0.476
610	1	32185.73	1.98E+05	230	1	-185.827	-15860.281	291	1	-0.924	-0.418
611	1	4.05E+04	2.64E+05	237	1	34422.082	-21371.774	292	1	0.295	-0.441
612	1	2.96E+04	3.02E+05	238	1	34422.309	-24727.628	293	1	0.705	-0.455
681	1	-1.56E+04	2.71E+05	239	1	39526.762	-22934.119	294	1	-0.474	-0.449
682	1	-1.79E+04	2.40E+05	240	1	39526.351	-20993.571	295	1	0.05	-0.442
683	1	2.35E+04	2.12E+05	241	1	46223.461	-18887.38	296	1	-1.944	-0.435
684	1	21053.535	1.98E+05	242	1	46225.393	-17546.002	297	1	0.319	-0.429
689	1	-1.06E+04	2.57E+05	249	1	54.877	-21592.743	298	1	-0.028	-0.443
690	1	-5.04E+03	2.29E+05	250	1	60.565	-19700.799	299	1	-0.056	-0.436
691	1	-1.28E+04	2.02E+05	251	1	-5686.867	-17637.717	300	1	0.297	-0.429
692	1	-6.14E+03	2.74E+05	255	1	-13992.246	-22835.685	301	1	-0.825	-0.448
693	1	1.60E+04	2.47E+05	256	1	-14923.499	-20772.602	302	1	0.239	-0.44
694	1	8548.971	2.43E+05	257	1	-16265.479	-20680.889	303	1	0.334	-0.44
695	1	13216.783	2.44E+05	321	1	-13345.315	-20871.037	304	1	-0.204	-0.441
696	1	8.01E+03	2.40E+05	322	1	-14213.476	-20779.323	305	1	0.266	-0.441
761	1	-2.58E+03	2.36E+05	323	1	-15488.474	-20901.858	399	1	-1.554	-0.443
762	1	-3.51E+03	1.22E+05	327	1	-54.355	-9542.891	400	1	0.298	-0.393
763	1	3.60E+03	1.78E+05	328	1	-59.594	-14179.118	401	1	-0.488	-0.412
764	1	5.11E+03	2.11E+05	329	1	-5820.379	-17006.116	402	1	0.052	-0.423

829	1	1.59E+05	1.84E+05	339	1	32880.296	-15589.747	403	1	0.705	-0.419
830	1	-1.49E+05	1.59E+05	340	1	37701.356	-14053.207	404	1	-0.899	-0.414
831	1	-1.41E+05	1.35E+05	341	1	44024.688	-12381.374	405	1	0.32	-0.408
832	1	1.51E+05	1.23E+05	345	1	130.405	-11167.509	406	1	-0.063	-0.403
833	1	1.54E+05	1.73E+05	346	1	154.517	-14375.882	407	1	-0.05	-0.414
834	1	-1.33E+05	1.49E+05	347	1	186.313	-12856.898	408	1	0.673	-0.408
835	1	-1.24E+05	1.27E+05	363	1	32879.77	-11226.208	409	1	-0.817	-0.402
836	1	1.45E+05	1.87E+05	364	1	32879.033	-15501.213	410	1	0.235	-0.418
873	1	-1.08E+05	1.65E+05	365	1	37700.494	-13856.443	411	1	0.304	-0.412
874	1	1.37E+05	1.61E+05	366	1	37701.614	-13797.744	412	1	-0.192	-0.412
875	1	1.45E+05	1.62E+05	367	1	44022.448	-13944.979	413	1	0.642	-0.413
876	1	-1.17E+05	1.58E+05	368	1	44024.287	-13886.278	429	1	-0.396	-0.413
885	1	-1.08E+05	1.55E+05	375	1	130.473	-13994.508	430	1	0.205	-0.414
886	1	1.30E+05	5.76E+02	376	1	130.652	13.566	431	1	0.188	-0.355
887	1	1.20E+05	4.95E+03	377	1	154.046	985.761	432	1	-0.254	-0.348
888	1	-9.90E+04	3.20E+04	378	1	154.534	46.651	433	1	0.052	-0.349
1022	1	-5.55E+04	3.74E+04	379	1	186.008	647.994	434	1	-0.739	-0.344
1023	1	7.33E+04	6.12E+04	380	1	186.328	-357.743	435	1	0.513	-0.346
1024	1	7.89E+04	6.39E+04	387	1	-13345.404	268.804	436	1	-0.593	-0.341
1025	1	-61205.534	8.43E+04	388	1	-14213.549	-819.112	437	1	-0.05	-0.344
1030	1	-68855.223	8.75E+04	389	1	-15488.535	-774.241	438	1	-0.188	-0.343
1031	1	-8.72E+04	9.44E+04	393	1	-54.355	-1308.823	439	1	-0.536	-0.345
1032	1	9.26E+04	9.54E+04	394	1	-59.594	-1114.211	440	1	0.302	-0.343
1033	1	1.05E+05	1.01E+05	395	1	-5820.379	-1655.738	441	1	0.103	-0.345
1034	1	9.97E+04	1.00E+05	459	1	55.06	-1476.032	442	1	-0.192	-0.344
1035	1	1.13E+05	1.04E+05	460	1	60.507	-2022.903	443	1	-0.188	-0.347
1036	1	-75980.945	1.55E+05	465	1	14195.828	-16901.445	537	1	-0.508	0.737
1037	1	-9.57E+04	2.07E+05	466	1	15149.086	-24335.337	538	1	0.316	0.847
1304	1	1.54E+03	2.35E+05	467	1	16099.075	-28262.859	539	1	-0.847	0.914
1305	1	8.58E+01	2.07E+05	477	1	-130.19	-25499.538	540	1	0.134	0.876
1306	1	1.60E+03	1.82E+05	478	1	-154.237	-22723.928	541	1	0.188	0.836
1307	1	7.79E+02	1.60E+05	479	1	-186.385	-19676.647	542	1	-0.366	0.793
1308	1	-3364.292	1.50E+05	483	1	-32878.314	-18270.415	543	1	0.166	0.767
1309	1	-1671.922	1.98E+05	484	1	-37700.855	-24093.307	544	1	-0.98	0.85
1310	1	3.51E+03	1.74E+05	485	1	-44023.549	-21464.388	545	1	0.229	0.811
131	1	1.82E+03	1.54E+05	501	1	-130.432	-18796.407	546	1	0.188	0.769

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1328	1	-1.67E+03	2.12E+05	502	1	-130.158	-25633.943	547	1	-0.22	0.875
1345	1	-1.92E+03	1.91E+05	503	1	-154.311	-22965.958	548	1	0.028	0.833
1346	1	2.07E+03	1.88E+05	504	1	-154.159	-22439.97	549	1	-0.729	0.831
1347	1	2072.773	1.87E+05	505	1	-185.824	-22831.554	550	1	0.357	0.834
1348	1	-1.93E+03	1.83E+05	506	1	-185.802	-22305.566	551	1	0.188	0.832
1349	1	-1.92E+03	1.78E+05	513	1	-32878.379	-22197.94	567	1	-0.831	0.833
1350	1	-1.92E+03	9.52E+04	514	1	-32878.535	-10465.731	568	1	0.416	0.611
1351	1	2074.123	1.40E+05	515	1	-37699.825	-16702.273	569	1	0.705	0.704
1352	1	2076.314	1.64E+05	516	1	-37701.11	-20004.543	570	1	-1.099	0.76
1353	1	2074.688	1.40E+05	517	1	-44022.345	-17794.725	571	1	0.134	0.73
1354	1	2076.878	1.19E+05	518	1	-44023.786	-15575.305	572	1	-0.468	0.698
1355	1	-1.92E+03	9.98E+04	525	1	55.06	-13011.355	573	1	0.049	0.663
1356	1	-1.92E+03	9.16E+04	526	1	60.507	-11735.359	574	1	-0.659	0.639

4.6 <u>Foundation Details :-</u>

FOUNDATION LOADINGS Kg

Compression = $2.77 * 10^5$
Tension = $2.77 * 10^5$
Transverse = 23860.5
Longitudinal = 10594.9

STRUCTURE DETAIL

Width (Trans.) X Width (Long.)
6M X 6M
Slope (Trans.) X Slope (Long.)
2.419509 ° X 2.419509 °
True Length Factor
Transverse 1.00089
Longitudinal 1.00089

FOUNDATION PROFILE

Depth of Foundation = 2M
Transverse Width = 1.8 M
Longitudinal Width = 1.8M
Height of concrete block = 1.5M
Depth of Anchor/Grout bar = 1.2M
Height of chimney = 0.5M
Chimney Width = 0.75M
Muffing Height = 0.35M

SOIL DETAIL

Type of Soil ----------- HARD ROCK
Weight of Rock = 1600 Kg/cu.m
U.B.C = 125000 Kg/Sq.m
Frictional resistance between rock and concrete = 4 kg/Sq.cm
Frictional resistance between rock and grout (As per CBIP manual pg. no. 267) = 2 kg/Sq.cm.

Weight of concrete = 2300 Kg/Sq.m
Fe = 415 N/mm^2
Fck = 2 N/mm^2

FOUNDATION DESIGN CALCULATION

Volume of concrete in M^3

Muffing = 0.197 M^3

Chimney = 0.281 M^3

Concrete block = 4.860 M^3

Total = 5.338 M^3

Over load due to Concrete in Kg

Muffing = 452.81

Chimney = 196.88

Concrete block = 3402.00

Total = 4051.69 Kg

Total thrust on foundation = 277000 + 4051.69

= 281051.69 Kg

CHECK OF FOUNDATION IN BEARING

Ultimate strength of rock in bearing = 1.8^2 x 125000

= 405000 Kg

= 405000 > 281051

F.O.S = 1.44

CHECK OF FOUNDATION IN UPLIFT

Concrete block

Net uplift = 277000 - 4051.69

= 272948 Kg

Ultimate frictional strength between rock and concrete = 180 X 150 X 4 X 4

= 432000 Kg

Uplift resisted by 4 NOS. 20 ϕ

= (No. of bar X pi(π) X Dia. of bar X Depth of anchor bar X Bond between rock & Grout)

= 4 X 3.14 X 2 X 120 X 2

= 6028.80 …….. (I)

= Bond between rock anchor steel and grout

= π X 2 X 120 X 12 X 4

= 36191.14 > 6028.80 ………. (II)

Total resistance against uplift = 432000 + 6028.80 (Min. of ((I) & (II))

= 438028.80 > 272948

FOS = 1.623

ANCHOR (TOR) BARS ASSUMED

CHECK AGAINST UPROOTING OF STUB

SECTION OF STUB JL 200X200X16

Cover = 10 Cm

Design Uplift = 277000 Kg

Cleats Provided = 6 NOS OF 110X110X10

Bolts = 24 Nos of 20 mm dia.

Ultimate resistance of Stub in Bond =

U_S = [D x{X x 2.0+ (X-Ts) x 2.0}-Np x {X+(X-Ts)} x k] x S

Where , X = Flange width of Stub = 20 cm

D = Depth of Stub in slab (Concrete Block) = 140 cm

S = Ultimate permissible bond stress between stub and concrete = 12 kg/cm²……. Page No.267 (CBIP manual)

Ts = Thickness of stub section = 1.6 cm

Np = No of cleat pair (Pair consists of outer & inner cleats) = 6 Nos.

k = Flange width of cleat section = 11 cm

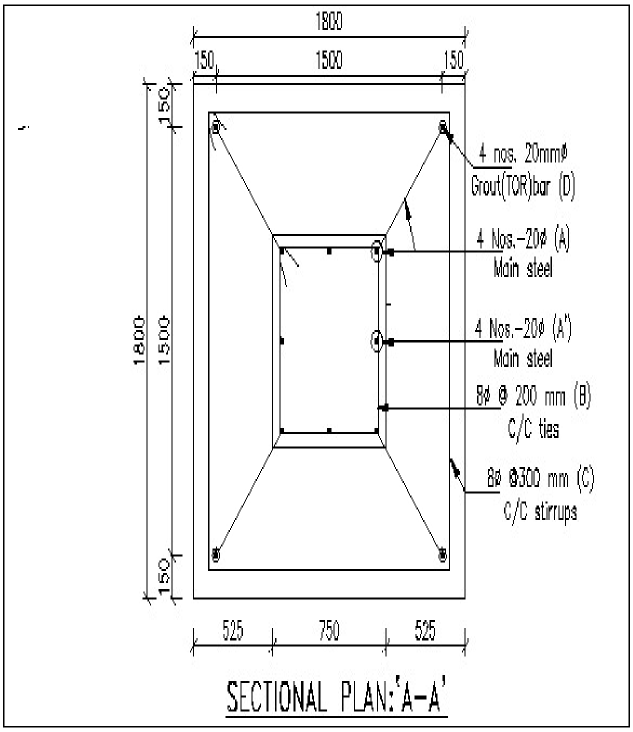
Us = (140 X (20 X 2.0 + (20 - 1.6) X 2.0) - 6 X (20+ (20 - 1.6)) X 11) X 12

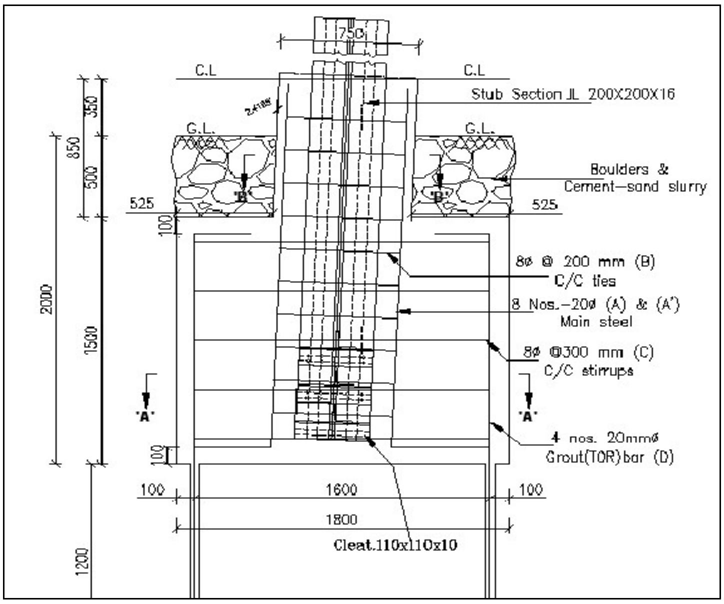
= 98611 kgs

Load resisted by cleat in bearing :-
Least resistance offered by cleats in bearing / bolt :- Uc = b x (Lo+Li) x Np x (k-Ct)
Where,
b = Ultimate bearing pressure in concrete = 91.75 cm
Lo = Length of outer cleat = 40 cm
Li = Length of inner cleat = 25 cm
Ct = Thickness of cleat section = 1.0 cm
Uc = 91.75 X (40 + 25) X 6 X (11 - 1)
= 357825 kg…………. (I)
Resistance against uplift : -
= 98611.2 + 357825
456436 > 277000
FOS = 1.648

NOTE:
1 Nominal Reinforcement provide.
2 Stub to be cut, holes to be drilled and cold zinc rich paint/galvanising to be applied at site.
3 Grout holes to be 20 mm bigger than dia of grout bar.
4 Cement sand mix 1:1 Ratio to be used for grouting through grouting pump.
5 Entire concrete block (slab) should be embedded in hard rock irrespective of level of hard rock encountered.

4.6.1 Details of foundation drawing is given





V. CONCLUSION

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 paper can safely withstand the design wind load and actually load acting on tower. The bottom tier members have more role 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 behavior of the tower structure. The effect of twisting moment of the intact structure is not significant. The Geometry parameters of the tower can efficiently be treated as design Variables and considerable weight reduction can often be achieved as a result of geometry changes.The tower with angle section and X-bracing has the greater reduction in weight after optimization . Tube section is not economic to use in this type of transmission tower. Total weight of tower considering weight of nut bolts, anchor bolts, hardware etc works out to 30 to 35 Tonne.

Scope of Present Work:-

a) Continuous demand due to increasing population in all sectors viz. residential, commercial and industrial leads to requirement of efficient, consistent and adequate amount of electric power supply which can only fulfilled by using the Conventional Guyed Transmission Towers.
b) It can be substituted between the transmission line of wide based tower where narrow width is required for certain specified distance.
c) Effective static loading on transmission line structure, conductor and ground wire can be replaced with the actual dynamic loading and the results can be compared.
d) Attempt in changing the shape of cross arm can lead to wonderful results.
e) Rapid urbanization and increasing demand for electric, availability of land leads to involve use of tubular shape pole structure.
f) lso restricted area (due to non-availability of land), more supply of electric energy with available resources and for continuous supply without any interruption in the transmission line, will demand the use of high altitude narrow based steel lattice transmission tower

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