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Effect of HUD-HUD Wind Intensity on the Structural Behaviour of 220kv Transmission Line Tower at Visakhapatnam

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***Abstract**: The transmission line towers are one of the important transmission line structures in the distribution of power from the source to the various places. Transmission line towers carry heavy electrical transmission conductors at a sufficient and safe height from ground. In addition to their self-weight they have to withstand all forces of nature like strong wind and earthquake. Therefore transmission line towers should be designed considering both structural and electrical requirements for a safe and economical design. In this paper, an attempt has been made to analyse the behaviour of Transmission line tower under the influence of natural disaster hit Visakhapatnam (District) in Andhra Pradesh (State), India recently in the month of November, 2014. The 220kV tower is modeled and analysed using STADD Pro V-8i and Ansys Mechanical APDL for Maximum loading combinations considering HUD-HUD wind intensity of 275 km/hr (76m/s) and the results obtained are compared with the results obtained for regular wind intensity of 180km/hr(50m/s). Also, the velocity profiles are drawn for both the wind speeds.*

Index Terms: **Hud-Hud, Structural Behaviour, Transmission Line Tower, Velocity Profile..**

I. INTRODUCTION

1.1Transmission line tower:

Now – a – days, power has become a basic need for the human life to go in smoother way. For the fulfillment of that need, Transmission of power plays a major role. Keeping in this mind, transmission line tower had come into the picture. Depending upon the voltage requirement, 66kV, 110kV, 132kV, 220kV, 400kV, 800kV Transmission line towers are used. Towers are space and tall structures, their height being much more than their lateral dimensions and built with steel sections. These are having an independent foundation under each leg.

1.2 HUD – HUD:

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HUD - HUD originated from a low-pressure system that formed under the influence of an upper-air cyclonic circulation. It was classified as a Very Severe Cyclonic Storm by the Indian Meteorological Department (IMD) shortly before landfall.

Especially in India, it pounded the coastal districts of Andhra Pradesh and Odisha with heavy rain and winds of almost 275 kmph on Sunday (12.10.2014) leaving a trail of devastation with Visakhapatnam where the very severe storm made landfall bearing the brunt.

The cyclone has badly affected power supply in Visakhapatnam and Vizianagaram while partially affecting Srikakulam. As per official sources, in the three districts of Visakhapatnam, Vizianagaram and Srikakulam, 15,000 electric poles have been uprooted and more than 6,000 transformers have been partially or completely damaged.

Winds gusting at 275 kmph caused severe earth faults which in turn damaged the substation equipment, poles, transformers and power transmission and distribution lines. Two 400 KV substations, 10 sub-stations of 220 KV and 25 sub-stations of 132 KV capacity have been severely hit by the cyclone. Around 15,000 poles are broken or damaged apart from shutting down of the 2000-MW Simhadri power generating plant.

Having considered the above damages, there is interest in the minds of electrical and structural engineers to develop and study the behaviour of the transmission line towers to meet the requirements of wind intensity more than 200kmph. Hence, in this study, a 220kV Transmission line tower is modeled using STADD Pro V-8 for two wind speeds 50m/s (Zone V) & 76m/s (HUD – HUD). The parameters such as constant height, bracing system, steel sections and Wind Speeds were considered in the study.

Figure 1: Collapse Of Transmission Line Tower

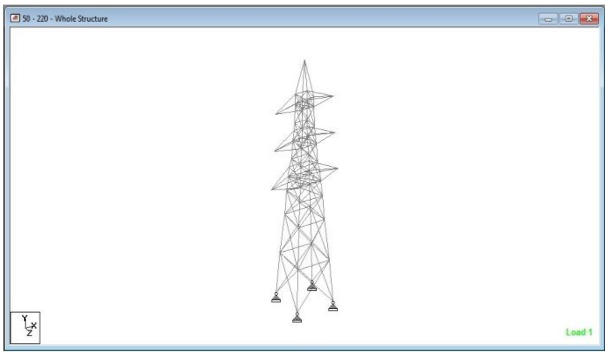

Figure 2: Tower model in Staad Pro due to HUD – HUD Cyclone

1.3 STAAD Pro: STAAD Pro the name itself defines that **St**-structural, **A**-analysis, **A**-and, **D**-design, **Pro**-programming. It is purely used by some companies for Analysizing the structure and Sometimes for Design also. As usually it is developed by Bentley systems that too it is too cost software. In STAAD Pro we will design RCC, Steel as well, it is not meant for only buildings, so we can analyze and design separately water tanks and staircases, retaining walls, steel towers etc...

STAAD Pro features state of the art user interface, visualization tools, powerful analysis and design engines with advanced finite element (FEM) and dynamic analysis capabilities. From model generation, analysis and design to visualization and result verification STAAD Pro is the professional first choice.Figure 2 represents Tower Model in STAAD Pro.

1.4 Ansys Mechanical APDL: ANSYS Mechanical APDL for Finite Element Analysis provides a hands-on introduction to engineering analysis using one of the most powerful commercial general purposes finite element programs on the market. Students will find a practical and integrated approach that combines finite element theory with best practices for developing, verifying, validating and interpreting the results of finite element models, while engineering professionals will appreciate the deep insight presented on the program's structure and behavior.

Figure 3 represents Three Dimensional Tower Model using Ansys Mechanical APDL.

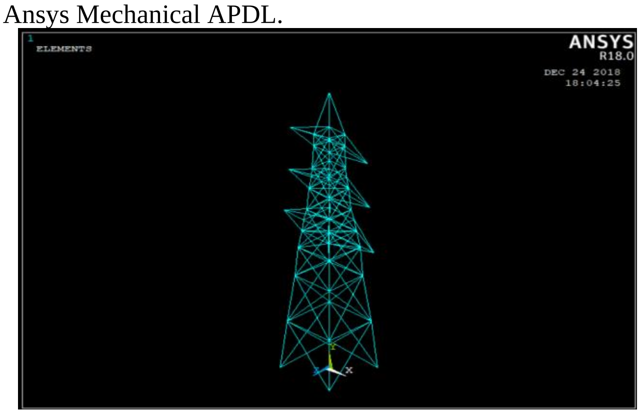

Figure 3 3-D Tower Model using Ansys Mechanical APDL

II. LITERATURE REVIEW

(Visweswara Rao, G 1995) Based on the electrical and structural points of view, the designer decides the shape of the tower to be modeled and the length of crossarms that carry conductors. The purpose of transmission line towers is to support conductors carrying electrical power and one or two ground wires at a suitable distance. For different voltages, type of conductor and earthwire specification specified in the CBIP Manual are used.

(Gopi SudamPunse, 2014) 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.

(Umesh S. Salunkhe and Yuwaraj M. Ghugal, 2013) The present work describes the analysis and design of three legged self-supporting 400 kV double circuitsteel transmission line towers models with an angle and tube sections. In this study constant loading parameters including wind forces as per IS: 802 (1995) are taken into account in both models. The study shows that tower with tube sections are efficient and have better force –weight ratio including 20.6% saving in weight of steel with tubes against steel with angles in three legged transmission line tower.

III. TOWER

A transmission line tower is a three-dimensional cantilever truss. As transmission line towers are comparatively light weight structures and also that the maximum wind pressure is the main criterion for the design, also concurrence of earthquake and maximum wind pressure is unlikely to take place. Its analysis as a space frame is highly tedious. The analysis of all framed structures is carried out by STAADPrO and ANSYS International analysis and design software package.

3.1 Loading on the Tower:

The various loads coming on the tower under the normal and broken-wire conditions (BWC) have been calculated as per IS 802:1995& CBIP manual. The wind load on each point is then calculated based on solidity ratio as per IS: 875-part III, V for wind zone Visakhapatnam – 50m/s & HUD – HUD wind speed intensity 76 m/s. An appropriate combination of the various loads under the two conditions should be considered for design purposes. Figures 4 and 5 gives a summary of the various load combinations under the two conditions for a typical 220 kV transmission line in the form of load tree diagrams using a twin-conductor bundle.

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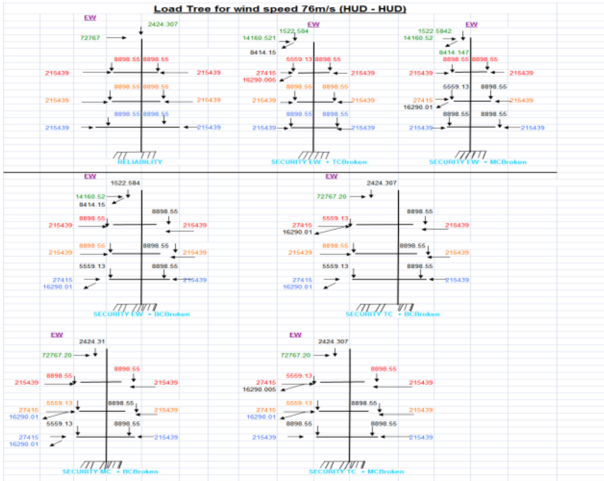

Figure 4 Load Tree for Different Load Cases under Wind Speed 76 m/s

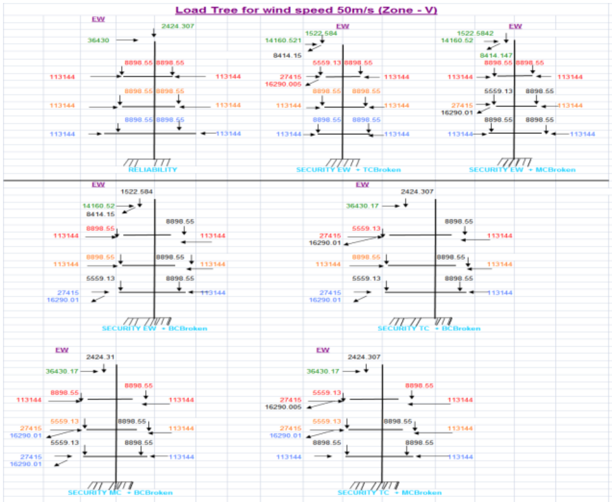

Figure 5 Load Tree Diagram For Different Load Cases For Wind Speed 50m/S

3.2 Tower Modelling: The tower is first divided into a number of parts corresponding to the ground wire and conductor support points. A tower is modelled for two different wind speeds HUD – HUD (76m/s) and normal (50m/s) respectively using STADD Pro V-8i and Ansys Mechanical APDL. The tower is built up with a steel single angle section, and 3 cross arms with double circuit lines and a ground wire at the peak with 12 panels. The isometric view of model and deflected shape of tower are shown in Figure 6 and 7.

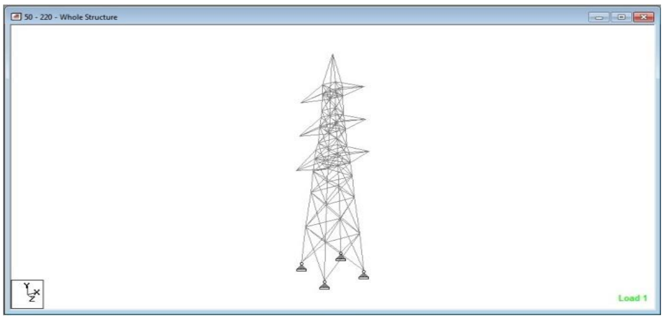

Figure 6: Isometric View Of Tower Model In STAAD Pro

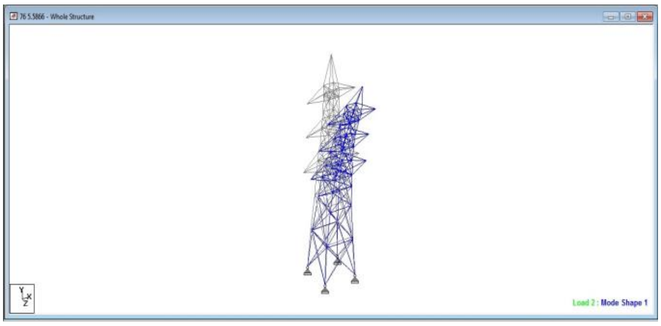

Figure 7: Deflected Shape Of Transmission Line Tower Using STAAD Pro For 76 M/S

IV. DISCUSSION AND RESULTS

The following results were drawn out after the analysis of tower with respect to wind speeds 50m/s(Visakhapatnam) and 76m/s(HUD – HUD).

4.1 Velocity Profiles: The velocity profiles were drawn to both the wind speeds using the below equation taken from [3]

$$\bar{U}(z) = \bar{U}(z_{ref})\,\left(\frac{z}{z_{ref}}\right)^{p},\ p=0.\ 15$$

The wind velocity profiles for wind intensity 50m/s and 76 m/s were calculated and presented in Figure 8. A comparison between the velocity profiles indicates that the distributed force profiles acting on the tower are almost equal for both cases. On the other hand, the forces acting on the tower due to HUD-HUD wind loading is large significantly those due to normal loading.

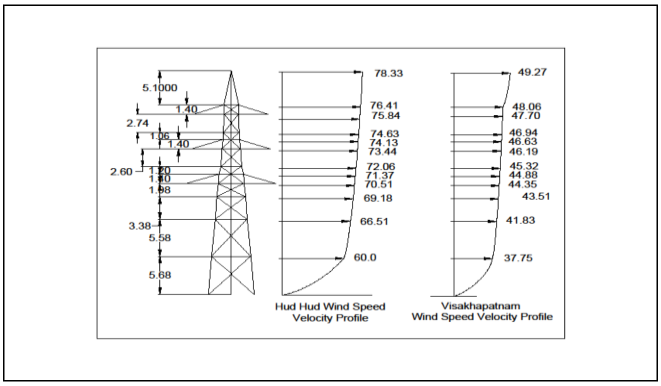

Figure 8 Velocity Profile Of Windzone – V And Hud-Hud Intensity

4.2 Maximum deflection:

The behaviour of the tower model under the effect of HUD – HUD (76m/s) was studied in this project. The maximum deflections in X, Y and Z directions for two wind intensities obtained from STAAD Pro analysis are presented in Table 1and represented graphically in Figures 9.

Table 1: Displacements For Windzone – V And Hud – Hud Using Staad Pro And Ansys

	Wind Zone V		Hud-Hud	
Node	Staad Pro V8i	Ansys Mechanical APDL	Staad Pro V8i	Ansys Mechanical APDL
panel 1	0	0	0	0

panel 2	4.841	4.7	9.13	8.9
panel 3	18.084	17.635	34.089	33.562
panel 4	32.241	31.464	60.714	59.807
panel 5	46.369	45.124	87.16	85.607
panel 6	73.383	71.09	137.333	137.92
panel 7	61.465	59.91	115.643	137.92
panel 8	86.982	84.55	163.452	160.17
panel 9	96.544	94.168	181.637	178.78
panel 10	108.531	136.13	204.246	200.94
panel 11	145.775	142.27	274.174	269.76
panel 12	156.189	152.45	294.18	289.1
panel 13	217.699	212.54	410.844	403.47

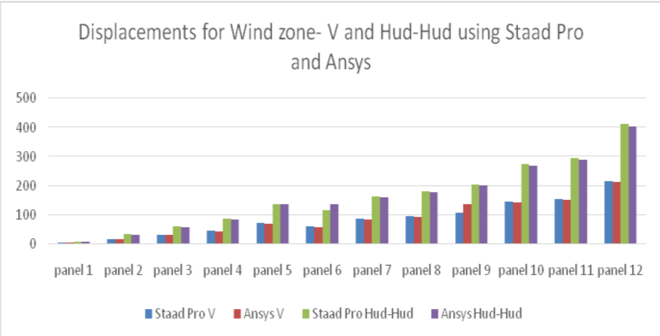

Figure 9 Displacements For Windzone – V And Hud – Hud Using Staad Pro And Ansys

From the Table 1, the displacements using Staad Pro is observed to be 217.699 mm and using Ansys Mechanical APDL is observed to be as 212.54 mm for Windzone – V. For Hud-Hud Intensity, the displacements using Staad Pro is observed to be 410.84mm and using Ansys Mechanical APDL is observed to be as 403.47 mm.

4.3 Maximum support reactions under each leg:

The maximum positive and negative support reactions obtained from the analysis are provided in Table 2, 3and shown graphically in Figures 10 –11.

From Tables 2,3 and Figures 10 - 11, it is observed that the difference between value of support reactions obtained for two wind speeds is very large 278N/mm^2. Hence, design governs for the HUD-HUD wind intensity.

Table 2: Maximum Support Reaction for the tower with wind speed of 50m/s

Node	Staad Pro V8i FX	Staad Pro V8i FY	Staad Pro V8i FZ
1	-304.1	-1466.32	-190.49
2	304.1	-1466.28	-197.08
3	324.1	1580.09	-210.6
4	324.1	1580.125	-210.6

Node	Ansys Mechanical APDL FX	Ansys Mechanical APDL FY	Ansys Mechanical APDL FZ
1	-309.8	-1509	-197.8
2	309.8	-1509	-197.8
3	-315.2	1537.4	-203.27
4	315.3	1534.5	-203.28

Table 3: Maximum Support Reaction For The Tower With Wind Speed Of Hud-Hud 76m/S

Node	Ansys Mechanical APDL FX	Ansys Mechanical APDL FY	Ansys Mechanical APDL FZ
Node 1	-591.199	-2886.2	-383.344
Node 2	591.98	-2886.1	-383.44
Node 3	-597.4	2941.6	-388.91
Node 4	597.41	2941.6	-388.92

Node	Staad Pro V8i FX	Staad Pro V8i FY	Staad Pro V8i FZ
Node 1	-582.188	-2816.89	-372.467
Node 2	582.181	-2816.85	-372.461
Node 3	-602.221	2930.662	-392.56
Node 4	602.227	2930.697	-392.566

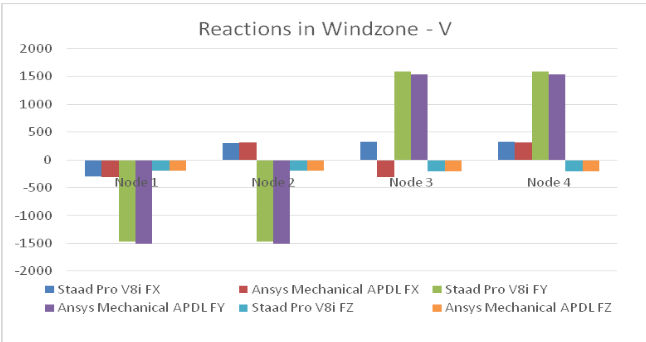

Figure 10 Reactions Fx, Fy and Fz for Windzone – V using Staad Pro and Ansys

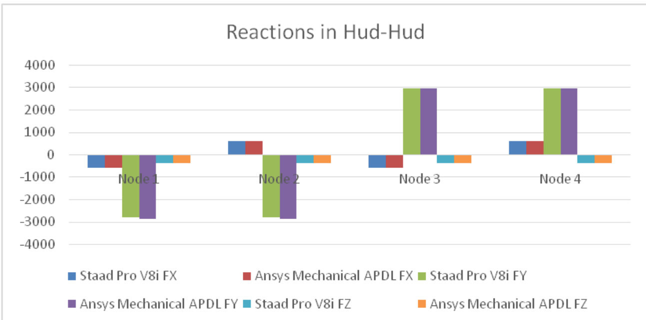

Figure 11 Reactions Fx, Fy and Fz for Hud-Hud using Staad Pro and Ansys

4.4 Stresses induced:

Stressesinduced in the members of the tower obtained from STAAD Pro and Ansys Mechanical APDL are presented in

Table 4,5,6,7 & 8and shown graphically in Figures 12,13,14,15 & 16.

It has been observed from the results obtained after the analysis using STAAD Pro V8i and Ansys Mechanical APDL for the two different wind speeds 50 m/s and 76m/s(HudHud), stresses induced in the Tower membersfor the windspeed 76m/s is almost double than for windspeed 50m/s.

While comparing the two Software's STAAD Pro V8i and Ansys Mechanical APDL, the difference in the results are only 4%. It is clearly understood that STAAD Pro V8i results more than the results obtained from Ansys Mechanical APDL.

Table 4 represents Maximum stresses induced in the Tower members for wind speeds 50 m/s and 76 m/s panel wise. In Panel 6, Tower members are induced maximum stresses w.r.t windspeed 50 m/s and 76 m/s. Since Panel 6 supports Bottom Crossarm Tower members, the stresses induced in the members are more compared to other panels. The superstructure consists of 234 tower members are divided into the 12 panels depending on their location and level.

Table 5 represents Maximum stresses in Leg Members for Both wind speeds 50 m/s and 76 m/s using STAAD Pro V8i and Ansys Mechanical APDL. It is observed from the table that Panel 6 members of the tower is having the more values of the stresses compared with other panel members because of the leg members supports the bottom crossarm members.

Table 6 represents Maximum stresses induced in Diagonal Members for two wind speeds 50 m/s and 76 m/s panel wise. Panel 9 Members were observed to be more stressed than other panel numbers.

Table 7 represents Maximum Stresses induced in Horizontal Members for the Two wind speeds 50 m/s and 76 m/s panel wise. Panel 8 members were observed to be more stressed than other panel members.

Table 8 represents Maximum Stresses induced for the tower Crossarm members with wind speed of Zone – V and Hud-Hud 76m/s for Staad Pro V8i and Ansys Mechanical APDL. Bottom crossarm members are subjected to be more stressed than other two crossarm members Top and Middle Crossarm members.

Table 4: Maximum Stresses Induced For The Tower Members For Wind Speed Of Zone – V And Hud-Hud 76m/S Using Staad Pro V8i And Ansys Mechanical APDL

	Wind Zone V (50 m/s)		Hud-Hud (76 m/s)	
Node	Staad Pro V8i	Ansys Mechanical APDL	Staad Pro V8i	Ansys Mechanical APDL
panel 1	133.282	127.67	247.48	243.78
panel 2	132.403	127.83	245.66	243.67
panel 3	174.486	166.92	323.18	318.35
panel 4	190.145	180.04	351.98	343.6
panel 5	218.732	204.96	404.16	395.19
panel 6	226.145	215.86	419.63	414.26
panel 7	134.424	128.48	250.58	245.39
panel 8	164.946	145.73	307.39	289.75
panel 9	167.332	155.67	313.3	291.05
panel 10	93.899	78.98	169.78	158.77
panel 11	87.097	81.204	157.83	136.37
panel 12	39.286	28.809	77.755	56.48

Table 5: Maximum Stresses Induced For The Tower Leg Members With Wind Speed Of Zone – V And Hud-Hud 76m/S For Staad Pro V8i And Ansys Mechanical APDL

	Wind Zone V(50 m/s)		Hud-Hud (76 m/s)	
Node	Staad Pro V8i	Ansys Mechanical APDL	Staad Pro V8i	Ansys Mechanical APDL
panel 1	133.28	127.67	247.48	243.78
panel 2	132.40	127.83	245.66	243.67
panel 3	174.49	166.92	323.18	318.35
panel 4	190.15	180.04	351.98	343.6
panel 5	218.73	204.96	404.16	395.19
panel 6	226.15	215.86	419.63	414.26
panel 7	134.42	128.48	250.58	245.39
panel 8	164.95	145.73	307.39	274.98
panel 9	167.33	155.67	313.3	291.05
panel 10	53.36	50.043	100.86	98.374
panel 11	55.87	50.565	109.71	103.98
panel 12	39.29	28.809	77.76	56.48

Table 6: Maximum Stresses Induced For The Tower Diagonal Members With Wind Speed Of Zone – V And Hud-Hud 76m/S For Staad Pro V8i And Ansys Mechanical APDL

	Wind Zone V (50 m/s)		Hud-Hud (76 m/s)	
Node	Staad Pro V8i	Ansys Mechanical APDL	Staad Pro V8i	Ansys Mechanical APDL
panel 1	51.608	48.767	94.737	93.13
panel 2	59.956	50.303	111.424	95.88
panel 3	63.896	54.831	122.072	104.7
panel 4	72.121	61.923	141.008	129.78
panel 5	127.668	114.589	242.854	228.98
panel 6	134.831	118.32	277.597	259.23
panel 7	86.117	74.123	162.721	149.45
panel 8	112.641	99.59	219.773	202.54
panel 9	138.589	112.78	271.782	262.33
panel 10	78.995	66.803	153.581	148.24
panel 11	74.558	71.564	139.216	136.37

Table 7: Maximum Stresses induced for the tower Horizontal members with wind speed of Zone – V and Hud-Hud 76m/s for Staad Pro V8i and Ansys Mechanical APDL

	Wind Zone V (50 m/s)		Hud-Hud (76 m/s)	
Node	Staad Pro V8i	Ansys Mechanical APDL	Staad Pro V8i	Ansys Mechanical APDL
panel 1	92.05	95.37	175.65	180.4
panel 2	66.47	68.43	126.39	129.14
panel 3	88.10	96.09	168.81	179.91
panel 4	52.703	32.29	92.46	68.695
panel 5	146.408	135.58	270.64	262.44
panel 6	71.31	81.53	138.02	136.88
panel 7	63.42	54.75	125.70	110.72
panel 8	140.163	133.22	288.88	279.78
panel 9	59.901	49.78	116.99	100.74
panel 10	93.899	80.98	169.78	152.46
panel 11	66.78	59.78	133.01	126.78

Table 8: Maximum Stresses Induced For The Tower Crossarm Members With Wind Speed Of Zone – V And Hud-Hud 76m/S For Staad Pro V8i And Ansys Mechanical APDL

	Wind Zone V (50 m/s)		Hud-Hud (76 m/s)	
Node	Staad Pro V8i	Ansys Mechanical APDL	Staad Pro V8i	Ansys Mechanical APDL
Bottom Crossarm	92.05	95.37	175.66	178.98
Middle Crossarm	66.47	68.43	126.39	129.26
Top Crossarm	88.09	96.09	168.81	176.98

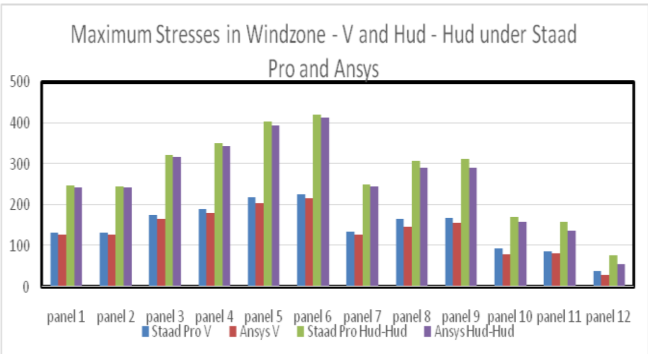

Figure 12 Maximum Stresses in Tower Members for Windzone – V and Hud-Hud under Staad Pro and Ansys

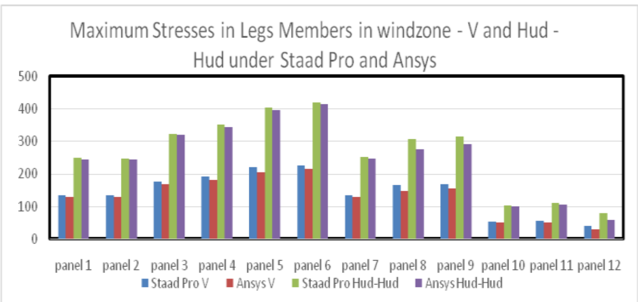

Figure 13 Maximum Stresses in Leg Members for Windzone – V and Hud-Hud under Staad Pro and Ansys

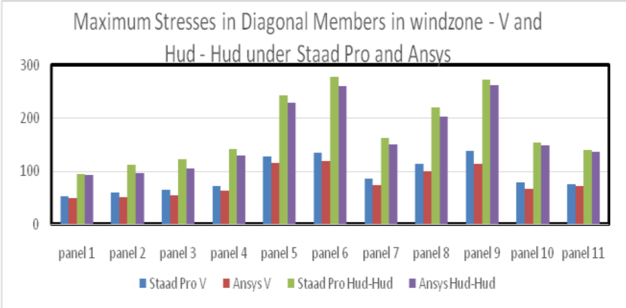

Figure 14 Maximum Stresses in Diagonal Members for Windzone – V and Hud-Hud under Staad Pro and Ansys

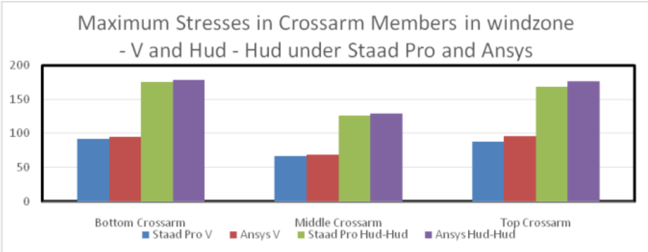

Figure 15 Maximum Stresses in Crossarm Members for Windzone – V and Hud-Hud under Staad Pro and Ansys

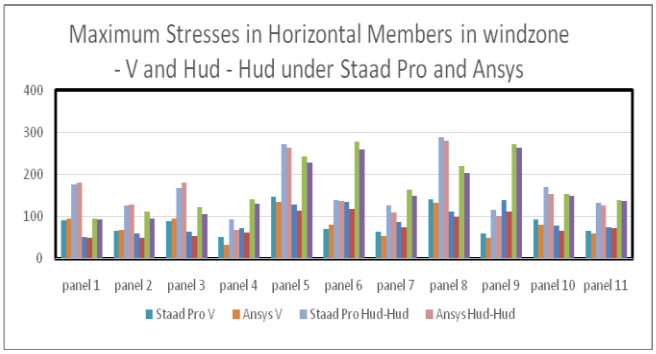

Figure 16 Maximum Stresses in Horizontal Members for Windzone – V and Hud-Hud under Staad Pro and Ansys

From the comparison of results, it is found that, maximum stresses induced in the members of tower for HUD-HUD wind intensity are found to be more when compared to wind intensity of 50m/s.

V. CONCLUSIONS

1. The sensitivity behaviour of Transmission line tower under the influence of Natural disaster HUD – HUD was stuided.
2. From the IS 875 part –III, the regular wind speed to be followed in the design of structures in the area Visakhapatnam is 50 m/s. At the time of very severe Cyclonic (Hud – Hud), wind speed was considered at 76 m/s. The percentage of increase in wind speed is observed to be 52%.

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3. The maximum deflections under HUD – HUD (76m/s) intensity in three mutually perpendicular directions is observed and found to be approximately 50% more than that under the normal intensity of 50m/s.
4. The maximum Support Reactions in three perpendicular directions at the time of HUD – HUD (76 m/s) is found to be more than 50% than that under the intensity of 50m/s.
5. The maximum compressive and tensile stresses are observed and is increased by 51.90%.
6. After the analysis of the tower w.r.t. Two wind speeds, it is clear that all parameters considered, i.e., displacements, stresses and reactions, increased by 51% (Average). Hence, while designing the tower, this must be kept in mind and should be designed for severe wind speed conditions.

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