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PROGRESSIVE COLLAPSE ANALYSIS OF 132KV TRANSMISSION TOWER IN DIFFERENT WIND ZONE

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Abstract

Power stations provide a connection between sources of electricity and user agencies. Tower, electrical wires, insulators, and neutral conductor make up the transmission line system. High-stress rate loadings, such as explosion or impact, cause the progressive failure of a structure in a short amount of time, with the failurebeing triggered by the loss of crucial structural components. The purpose of this study is to determine the behaviour of a 132kv double-circuit transmission system in changes in wind zones ii and wind zone iii considering progressive failure scenarios. There will be research done on ten distinct progressive collapse conditions. The impact of loading condition on the structure should be investigated in more depth. Need to evaluate a 132kv power lattice transmission tower structure's vulnerability to various progressive collapse conditions. By increasing the degree of elimination, the structureis rendered less susceptible. By comparing the values of capacity-to-demand ratio and deformation in situations of leg, brace and horizontal members removal at various elevations of tower, it can be determined that capacity-to-demand ratio can identify the real failure mechanism. The examined tower structure exhibits more resilience at higher heights than at lower altitudes, and the gradual collapse susceptibility reduces as the failure elevation rises.

Keywords: Transmission line tower, Progressive collapse, Local failure, Bracings.

1. Introduction

Towers are tall structures having height much more compared to their lateral dimensions. The main purpose of transmission line tower is to support conductors and earth wires. They are space frames or truss made up of steel havingfoundation under each leg. Transmission line towers constitute about 28 to 42 percent of thecost of the transmission line. The increasing demand for electrical energy can be met more economically by developing different light weight configurations of transmission line towers that is optimization of transmission tower. The selection of an optimum outline together with right type of bracing system, height, cross arm type, configuration and other parameters contributes toa large extent in developing an economical design of transmission line tower. As a goal of everydesigner are to design the best (optimum) systems.As transmission towers are tall structures, they are more susceptible to wind load compared toearthquake load. Generally, four legged lattice towers are most commonly used as a transmission line towers and three legged towers only used as telecommunication, microwaves, radio and guyed towers but not used in power sectors as a transmission line towers. Towers are often subjected to severeconditions, such as wild weather, earthquakes,and even explosions. As a result of such extreme external loads, towers could suffer loss of some of their critical structural members and consequent collapse may occur. The reasons causing the tower progressive collapse can be due to:

I. Unexpected events

II. Degradation of structural performance due tocorrosion of steel members.

III. Improper design or faulty construction methods

Progressive collapse initiated by the loss of criticalstructural components occurs over a short periodof time due to high strain rate loadings such as blast or impact. Since the collapse of Ronan Point apartment building in 1968, progressive collapse has been an important issue in structural design and a significant amount of research has been conducted on progressive collapse response of building structures subjected to extreme loading scenarios Apart from building structures, the dynamic behavior of the tower structures subject to extreme loading scenarios (e.g. blast loadings) and critical member loss are currently of high interest to structural engineers and researchers. Towers are often subjected to severe conditions, such as wild weather, earthquakes, and even explosions.

2. Literature review

Behrouz Asgarian et.al (2016) [1] evaluate the progressive collapse vulnerability of a lattice tower in a 400-kV power transmission line. The load increase factors (IF) after an instantaneous element removal are determined for application in static analyses and for design purpose. The capacity-to-demand ratios (C/D) are proposed to identify critical members after different removal scenarios. This proposed parameter is examined by comparison with Overload Factor (OF) from pushdown analysis. In addition, the pushdown analysis is used to determine the remaining capacity of the structure after removing an element. It is found that tower may resist progressive collapse because of the possible alternative load paths. It is also observed that the studied structure has less susceptibility to progressive collapse in scenarios of element removal at higher elevations.

Rambabu Dadi et. al. (2018) [2], studied the progressive collapse behavior of 220-kV transmission line tower with different bracing patterns namely K-bracing, X-bracing, (K-X) bracings. All the considered towers are analyzed for gravity and wind loads (IS: 875(Part-III)-2015). The tower is analyzed as space truss for different load combinations as per IS: 875(Part-V) and IS:456- 2000. Based on the analysis of obtained results, a comparison between towers with different bracing patterns namely K-bracing, X-bracing, (K-X) bracings with different Progressive collapse conditions is made.

Sudam Punse et. al . (2014) [3], observed that narrow based steel lattice transmission tower structures have enhanced performance especially while considering eccentric loading conditions for high altitude when compared to other normal tower. The bottom tie 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 to have larger influence on the behavior of the tower structure 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.

Rajasekharan et. al. (2014) [4], conducted wind analysis and observed that the increase in joint displacement is nearly 68% when tower height increases from 30m to 40m. When tower height increases from 40m to 50m the displacement is likely to increase by 60%. The change in stress when height increases from 30 to 40m is about 45% and for 40 to 50m is 39% on both cases of wind speeds. For an increase in wind speed from 50 to 55 m/s with no change in direction the displacement, the member stresses increase by 15% to 17%. In wind analysis the joint displacement is more for the tower with Y bracings whereas the member stress at bottom leg is more for the tower with XX bracing due to the absence of horizontal bracing.

Until date, just a few studies have been conducted on progressive collapse study of transmission tower structure. From literature review it is observed that many studies carried out on design and analysis of 220kV and 400kV transmission line towers. Various types of bracing used in previous study for study purpose and conclusion were obtained. Susceptibility of different types of towers were studied for different progressive collapse conditions.

3. Tower data considered

For this study, a 21 m tall latticed self-supporting tower having the 6m x 6m square base is considered having wind span 330m and the same was modeled in the relevant design software. The properties of the transmission tower, transmission line, conductors, and earth-wire are given below:

Table -1: Characteristics of Transmission Tower Line

Line Parameters	Description
Line Voltage	132 KV
No. of Circuit	Double Circuit Tower
Geometry	Square-based (6 x 6 m)
Cross Arm	Pointed
Tower Type	Self-Supporting latticed tower

Table -2: Conductor Specifications: ACSR "Panther" (30/3+ 7/3 mm)

Ultimate Tensile Strength of Conductor UTS	9164.19 kg
Overall diameter of the Conductor d	2.10 cm
Weight of the Conductor w	0.974 kg/m

Table – 3: Earthwire Specifications

Coefficient of linear Expansion a	17.80 x 10^{-6} deg c
Young's Modulus of elasticity	8155 kg/mm
Maximum temperature	75^0 c
Minimum Temperature	-5^0 c
Every day Temperature	32^0 c

Material	Galvanized Steel
Stranding/Wire Size	7/3.15 mm
Total Wire Area	0.5401 cm^2
Overall diameter (d)	9.45 mm
Weight of Wire (w)	0.428 kg/m
Minimum UTS	5710 kg
Modulus of elasticity Final (E)	19361 kg/mm^2

The above-mentioned values were used for further investigation and Evaluation of loading on the transmission tower.

4. Modelling and analysis

Determination of Height and Top hamper width:

1. Minimum permissible ground clearance (h1)

2. Maximum sag (h2)

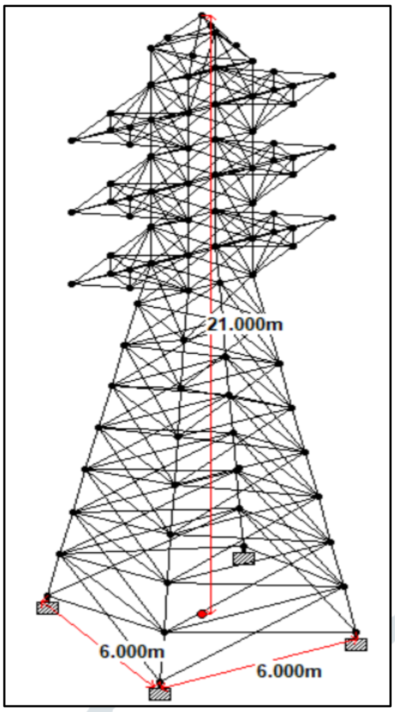
3. Vertical spacing between conductors (h3)

4. Vertical clearance between ground wire and top conductor (h4)

Thus the total height of the tower is given by H = h1 + h2 + h3 + h4 (m)

- For 132KV DC tower clearance above the lowest point of the conductor as 6.10m = h1.
- The conductors are subjected to sagging during hot climate. The tower height should be determined by considering the maximum sag (sag at peak hot climate). By considering the temperature and the external forces acting on the conductor (horizontal force due to wind, vertical force due to weight of conductor and ice formation) the amount of sag is calculated by catenary method. For a maximum temperature of 60 deg c, sag can be assumed as 6m = h2.
- Based upon the value of sag the vertical spacing required between the conductors is calculated by Swedish Empirical Formula Vertical Spacing between the top most and lowest conductors is $6.5\sqrt{S} + 0.7E$. Where S = Sag in cm E = Line Voltage in KV. From the formula h3 = 5.9m.
- Considering the shielding angle (angle which the line joining the ground wire and the outer most conductor makes with the vertical) required for interruption of direct lightning strikes at the ground and the minimum mid span clearance between the ground wire and the top power conductor h4= 3m. H = 21m.
- The top hammer width of the tower is one-third (1/3) times the base width based upon the condition that "The intersection of the tower legs should be above the CG (resultant) of the entire loads so that the resultant load is carried both braces and leg members. Hence top hamper width = (1/3) *6 = 2m.

The towers lie in wind zones II and III and material properties are applied as given in table 3:



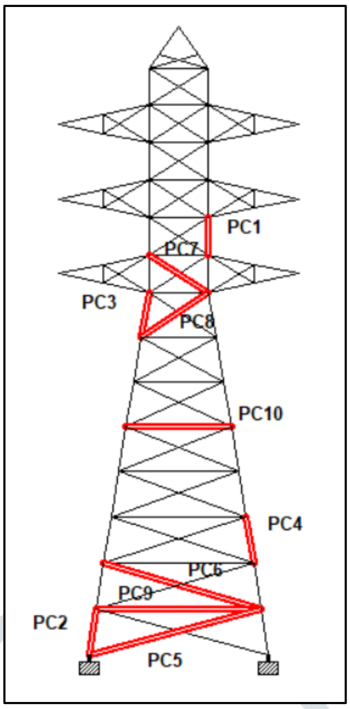


Fig. 1 Modelling of self supporting tower Fig. 2. Details of members considered for removal

Table 3: Material properties

I)Material Data			
Material		Steel	
Height		21m	
Panel	Height	Tower	Sections
1-4	Up to12m	Leg Members	ISA150X150X15
		Horizontal Members	ISA100X100X12
		Bracing Members	ISA80X80X10
5-8	12m–21m	Leg Members	ISA120X120X12
		Horizontal Members	ISA90X90X12
		Bracing Members	ISA70X70X10

The transmission tower was analyzed for 10 element removal scenarios (Fig. 2), they are:

Table 4: Defined failure scenarios

case (PC)	**Removed member type**	**Removed element ID**
1.	Leg	Front view- beam no 256
2.	Leg	Front view- beam no 42
3.	Leg	Back view- beam no 26
4.	Leg	Back view- beam no 43
5.	Bracing	Front view- beam no 476
6.	Bracing	Front view- beam no 263
7.	Bracing	Back view- beam no 178
8.	Bracing	Back view- beam no 344
9.	Horizontal	Front view- beam no 78
10.	Horizontal	Back view- beam no 84

5. Results and Discussion

The procedure was adopted to get the maximum displacements and demand-capacity ratio in the tower members. As we are designing any type structure, then now a days the structure must safe and also serviceable to the person whom using. Displacement is the phenomenon regarding the serviceability of the structure. Directly we can't say that the structure is failed if displacement is more, but we can say that the structure is not safe for us neither serviceable because it has displaced more from its original position. In analysis, we are finding only nodal displacement as it is rigid linked structure. Chart 1 shows the maximum displacement after members removal scenario, for wind zone II and wind zone III. Chart 2 shows maximum DCR ratio for the analyzed structure after different member removal conditions

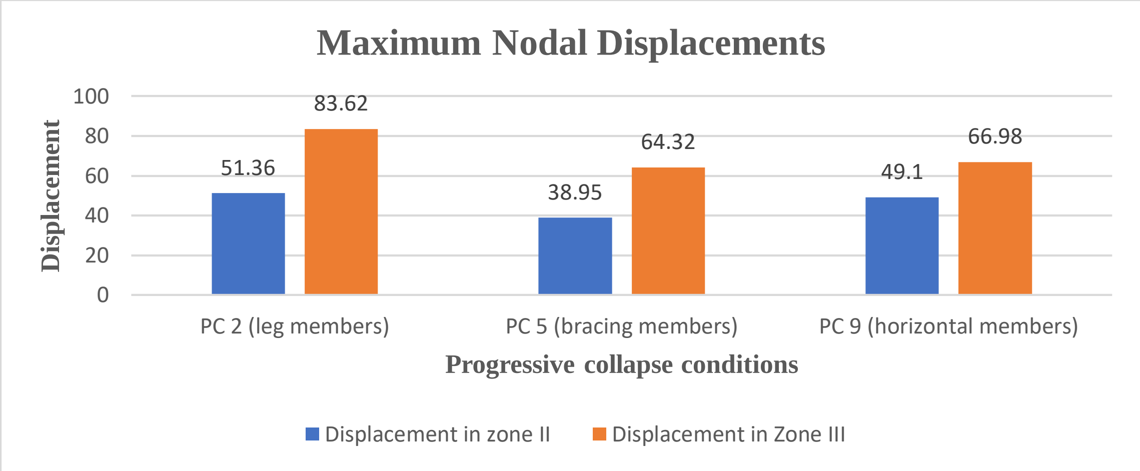


Chart 1: Maximum nodal displacements in the tower

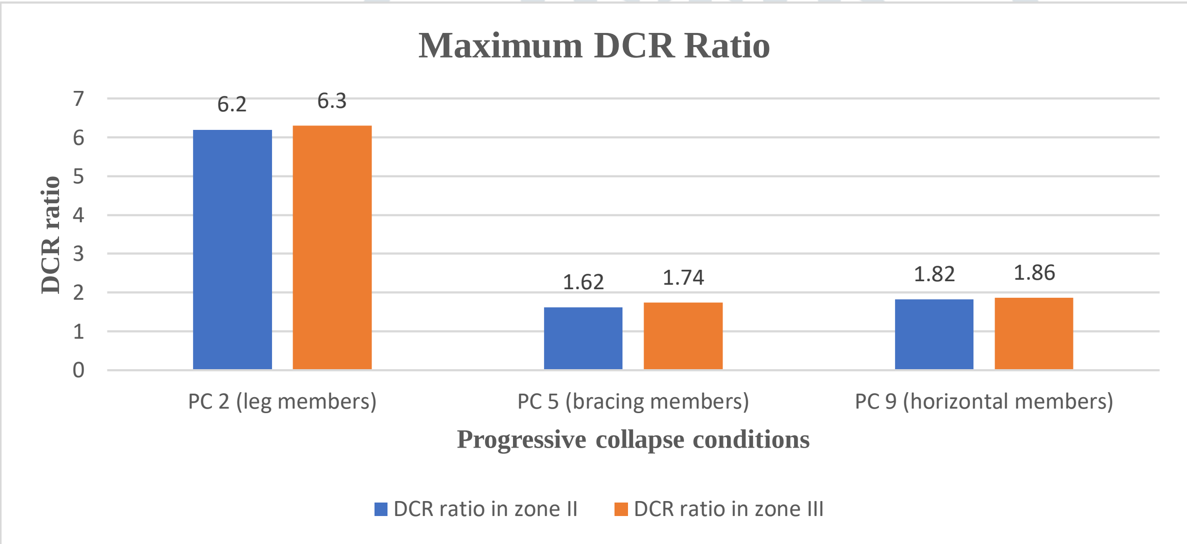


Chart 2: Maximum DCR ratio for the members of tower

6. Conclusion

Following conclusion was made in the review progressive collapse analysis of tower structure:

1. After analysis of structure, among considered scenarios of failure in this study; the most critical failure modes are related to the removing leg members at elevations between 9m and 19 m which in most cases lead to either large displacements or partial collapse of the tower because maximum DCR ratio is observed.
2. It can be concluded that the structure will be safe, if bracings members are termed as non-critical members are damaged by any reason or by sudden removal; as values of DCR ratios are observed below 2.
3. Horizontal members do not fall under critical members and does not responsible for collapse of structure because DCR ratio observed for all members for member removal conditions at different tower levels are observed as smaller than 2.
4. The greatest DCR ratio for leg members is 6 dues to lowermost leg removal condition.
5. There are not very many variations i.e. 10-15% in DCR ratio while comparing wind zones because there is not much difference in wind pressure in terms of loadings for wind zones II and III.
6. The studied tower structure shows more resilience in the scenarios of higher elevations comparing to the lower altitudes, and the progressive collapse susceptibility decreases as the elevation of failure increases.
7. Displacement of structure for different member removal conditions are compared; it can be found that tower with leg member removal condition will show increased deflection as compared to bracing members removal and horizontal members removal.
8. It can be concluded that, removal of leg members at lower elevations cases shows more impact on nodal displacement among all progressive collapse conditions i.e removal of leg members, bracing members and horizontal members.
9. Structure should be stiff enough at lower elevations to sustain the loads in different progressive collapse conditions. Wind zones does not show so much variations in displacement when we consider two zones as wind zone II and wind zone III.

7. References

1. Madisetti Pavan Kuma, Duba Vishalakshi, Ponnada Markandeya Raju and Dadi Rambabu (2018) Progressive collapse study of 220 KV transmission line tower with different bracing patterns, IJSER
2. Kumar, A. S. (2013). Analysis and Design of Four Legged Transmission Tower. International Journal of Science and Research, 5(May), 2319–7064. www.ijsr.net
3. Singh, M. A. A. Q. R., & Imtiaz Haque, C. U. (2014). International Journal of Modern Engineering. International Journal of Modern Engineering, 15(1), 23–35. http://ijme.us/issues/fall2014/Z__IJME fall 2014 v15 n1 (PDW-1).pdf#page=25
4. Nandhan, C., Chethan, K., & Tech, M. (2022). DYNAMIC ANALYSIS OF TELECOMMUNICATION TOWER WITH DIFFERENT BRACING SYSTEMS. 06, 1282–1293.
5. Access, O., & Gujjewar, P. P. (2022). STATIC AND DYNAMIC ANALYSIS OF TRANSMISSION TOWER TO WIND AND SEISMIC LOADS. 06, 3925–3933.
6. Italy, V. (2021). Telecommunication Tower on Residential Apartment at Jabalpur City with Building Improvement Analysis. International Journal for Research in Applied Science and Engineering Technology, 9(10), 1136–1147. https://doi.org/10.22214/ijraset.2021.38594
7. Pasnur, P. K., & Goral, S. S. (2018). A Study on Wind and Non-Linear Dynamic Analysis of Self-Supporting Telecommunication Tower. Journal of Advances and Scholarly Researches in Allied Education, 15(2), 617–622. https://doi.org/10.29070/15/56937
8. Balagam, V. (2019). COMPARITIVE STUDY OF FOUR LEGGED TRANSMISSION TOWER WITH International Journal of Technical Innovation in Modern Engineering & Science (IJTIMES) COMPARITIVE STUDY OF FOUR LEGGED TRANSMISSION TOWER. November.
9. Shah, D., & Jamani, A. R. (2020). Parametric Study on Behavior of Microwave Tower with Different Bracing Patterns under Lateral Loads. International Research Journal of Engineering and Technology, June, 5279–5286. www.irjet.net
10. Abdelwahed, B. (2019). A review on building progressive collapse, survey and discussion. Case Studies in Construction Materials, 11, e00264. https://doi.org/10.1016/j.cscm.2019.e00264
11. Asgarian, B., Dadras Eslamlou, S., E Zaghi, A., & Mehr, M. (2016). Progressive collapse analysis of power transmission towers. Journal of Constructional Steel Research, 123, 31–40. https://doi.org/10.1016/j.jcsr.2016.04.021
12. Song, B. I., Giriunas, K. A., & Sezen, H. (2014). Progressive collapse testing and analysis of a steel frame building. Journal of Constructional Steel Research, 94, 76–83. https://doi.org/10.1016/j.jcsr.2013.11.002
13. Naji, A., & Khodaverdi Zadeh, M. (2019). Progressive Collapse Analysis of Steel Braced Frames. Practice Periodical on Structural Design and Construction, 24(2). https://doi.org/10.1061/(asce)sc.1943-5576.0000414
14. Bhowmik, C., & Chakraborti, P. (2020). Analytical and Experimental Modal Analysis of Electrical Transmission Tower to Study the Dynamic Characteristics and Behaviors. KSCE Journal of Civil Engineering, 24(3), 931–942. https://doi.org/10.1007/s12205-020-1563-3
15. Malviya, S., & Jamle, S. (2019). Determination of Optimum Location of Rooftop Telecommunication Tower over Multistory Building under Seismic Loading. International Journal of Advanced Engineering Research and Science, 6(2), 65–73. https://doi.org/10.22161/ijaers.6.2.9
16. Fatema, K., Parikh, K. B., & Jamnu, M. A. (n.d.). "Optimization of Power Transmission Tower"–A Critical Review. Academia.Edu. https://www.academia.edu/download/37001940/63-64.pdf
17. Science, A. (n.d.). Parametric Studies on Transmission Line Tower Due to Dynamic Loading Parametric Studies on Transmission Line Tower Due to Dynamic Loading.
18. Salaam, S. E., Rao, N. P., & Raju, P. K. (2021). Failure analysis of transmission line tower subjected to combined wind and dust loads. Current Science, 121(4), 511–520. https://doi.org/10.18520/cs/v121/i4/511-520
19. Kr. Sharma, K., S.K, D., Kumar Singh, D., & A.K, S. (2015). Comparative Analysis of Steel Telecommunication Tower Subjected to Seismic & Wind Loading. Civil Engineering and Urban Planning: An International Journal (CiVEJ), 2(3), 15–33. https://doi.org/10.5121/civej.2015.2303
20. Kamarudin, et al. (2018). Review on analysis and design of lattice steel structure of overhead transmission tower. International Journal of ADVANCED AND APPLIED SCIENCES, 5(1), 73–80. https://doi.org/10.21833/ijaas.2018.01.010
21. Thakare, A. S. (2020). Comparative Structural Analysis and Design of Transmission Tower and Monopole by using STAAD. Pro Software. International Journal for Research in Applied Science and Engineering Technology, 8(5), 497–503.