



ADVANTAGES OF MONOPOLE TRANSMISSION TOWER WITH NEW GENERATION CONDUCTORS

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ABSTRACT

This paper made an attempt to enlighten the safety parameter of monopole with the Lattice tower transmission line design in urban areas, where required right of way is constraint. Pipe section for monopole and a four-legged section for lattice tower have been chosen as tower profiles. The new generation composite conductors and Steel Reinforced conductors' properties have been examined for an integral approach. The analysis is carried out with IS 802 (Part-1/Sec-1): 2015 and IS 875(Part3)-2015 revised code versions for 60 m height and 250 m span. It is concluded that the Monopole pipe sections are 6.7% less in weight than the four-legged lattice tower with composite conductors. While comparing the design philosophy of IS 802:2015 code and IS 875-2015 versions, former code contributed an economic design when compared to IS 875-2015 loading procedure. It is further extended that in terms of weight comparison, monopole and four-legged towers have illustrated as 30% & 9.18% less in comparison with IS 875 Code procedure.

Keywords: Tower anatomy, Monopole, Four-legged tower, Composite conductor, IS: 802 (Part-1/Sec-1): 2015, IS (875(part3)-2015

Cite this Article: Ramesh Bantupalli, Sharon Potireddy, Baljai K.V.G.D, Santhosh Kumar B, Advantages of Monopole Transmission Tower with New Generation Conductors, *International Journal of Advanced Research in Engineering and Technology (IJARET)*, 11 (3), 2020, pp 79-90.

<http://www.iaeme.com/IJARET/issues.asp?JType=IJARET&VType=11&IType=3>

1. INTRODUCTION

Historically, lattice and Compact towers have been used to support transmission and distribution lines in India. As India's population increases and area available to accommodate transmission lines become scarce and more expensive, steel pipe poles would provide a viable alternative in India. However, recently tubular poles made from stronger materials such as steel, have gained utility market share in India, as well. Transmission poles can be installed in locations where limited space is available due to smaller footprint compared to lattice towers. Moreover, Transmission poles are installed in places with existing corridors already used by other projects such as highways, roads, rail tracks, rivers and etc., Usage of restricted space allows monopole a more direct line design which results in optimizing the total line cost, Remove “visual” pollution, Pole structures are compatible with the environment i.e. poles are environment-friendly structures. The pole structure has i) Less right-of-way (ii) Better Visual Appearance (iii) Less components, faster installation, and less Installation Cost (iv) Better reliability under extreme conditions (v) Design Flexibility (vi) Future maintenance and repairs (vii) Safety (viii) Vandalism, Conical/Pipe Poles. To capture the latest developments and innovations of monopole towers with New Generation Conductors, with Environmental and Ecological Awakening is explained [1, 2]. Historically the steel pipe poles specification was hinted briefly in 1985 Indian standard code for 11kV overhead power lines and simple, in case ROW costs are high or if the width of ROW is limited the vertical configuration is may give a lower line cost.

The weight of the tower supporting the conductor and consequently its cost depends on tower height which is maximum sag at design span and minimum ground clearance between the charged line and ground as per Indian electricity rules. For the safety of electrical installations, the IEC technical guidelines demand the minimum Factor of Safety be maintained in tensioning the conductor. Hence the applied tension is at half of the rated ultimate strength. If the supports for the conductor at each end of a span are at the same elevation, the low point of the conductor is in the middle of the span and each structure will support one-half of the conductor weight. In this case, the effective span is equal to the actual span. Generally, transmission tower cost varies from 28 % to 42% of the total cost [1, 3-6].

With the evolutionary generation conductors, design flexibility and environmental and ecological awakenings this paper examine the variation of internal parameters of 60 m high pipe monopole and four-legged lattice tower geometrics along with the Steel reinforced conductor and composite conductor with IS 802(part1/section 1)2015[7] code provisions for the mechanical sag and temperature stringing procedure. The serviceability parameters investigated are sag and tension, deflections, tilt, and the overall economy is examined with weight consideration.

2. LITERATURE REVIEW

(CEI/IEC/826-1994-04, 1991)[8] recommended the probabilistic climatic loads to avoid the cascading effects due not to fail for the first 90% failure of the primary member strengths, this report considers the strength of the tower is the primary factor in the tower system, while the strength of the conductors are more reliable because the maximum strength used is far less than the damage limits. [9]. This report recommended the non-linear analysis (P- Δ) for Narrow

base tower design if the tower deflection obtained from analysis exceeds 2.5% of tower height. While detailed information regarding the $P-\Delta$ is made for pole structures and suggested the 2% of pole height of deflection for the preliminary design of poles. [6]. Wind load on tower and conductor are transverse load in reliability and failure loads are security condition loads. Sag is inversely proportional to tension in the conductor at null points.

This technical report [10] focused on local weather and climatic conditions, as local conditions may indicate the use of heavier loading conditions than those prescribed by NESC for that general area while designing a particular transmission line. The maximum span is attainable with a given structure height and a given conductor clearance above level ground.

ACSR (Aluminium conductor, steel-reinforced) conductor has been used dated back 1945, because of its lower price, which has proved more economical than other conductors, such as copper or Copper weld-copper [1, 11]. The physical and electrical properties are also described in these references. The useful properties of these conductors are explained [12]

The transmission line manual of CBIP Publication [1] established the design guidelines for the lattice tower geometry only. But the ASCE /SEI 48-2011(13) is a specific design code for steel transmission pole structures even for extra-high voltage systems also. Provision for monopole tower materials has been incorporated in the revised version of IS 802(Part 1/Sec1)2015 Code [7]. The IS 5613 (Part2/sec 1) [11] has recommended the different configurations of pole geometry for 220 kV power lines.

Balagopal et al (2018)[14] derived a simplified analytical solution to find the primary and secondary deflections for tapered poles with 8 and 30 m heights for lighting masts and 132 kV and 400 kV transmission line towers since the functional requirement of steel poles is greatly effected on the deflection by the combination of transverse and vertical loads.

Asharaf, et al (2005), [15]proposed the tapered model including shell elements technique with geometric nonlinearity to find the deflection of taped poles in transmission towers, since it was inevitable of large deflections in steel poles, and also concluded the overturning moments are more for poles and suggested the deep foundations for transfers loads

Neftalí Rodríguez (2009),[16] the transverse tower loading was applied as static loading while designing the towers, the author developed the analytical model for line cable rupture to predict the tower behavior in linear and nonlinear analysis. There is 7% of the little variation of total stress were found in the non-linear analysis. But strongly suggested this method since geometrical effects produced by the $P-\delta$ effect, may be quite important, as compared with a linear approach.

Sag and tension parameters are interdependent. Sag depends on the span length, tension, loading condition, mechanical properties of the conductor. The tension is, in turn, depends on the wire temperature relative to the weather conditions. The parabola and the catenary curves are generally used in the calculations for conductor sags on transmission lines. Generally, the parabola calculation is accurate when the sag is $\frac{1}{2}$ % of the span. It is reported that the parabola equation has a similar calculation as catenary. (IS 15613 Part1/sec1 -1985).

The simplified and generalized catenary curve calculation was derived, avoiding the errors in approximations [17]. Practical sag correction for tapes in traverse surveying with example is illustrated by Rainsford (1942) [18]. Derivation of a simplified formula for cable length variation for the sag variation rate with sag –span ratio is illustrated with numerical examples. [19].

The strength and serviceability of the towers are the measured parameters for the design of towers. Larger span shows a higher sag of conductor [19]. The calculation of the sag-tension of the conductor at different temperatures with different load cases of wind and ice is simulated [20]. The conductor presently using in the transmission line system is ACSR

conductor, which provides equal, identical and better thermal properties when compared with Alloyed Aluminum Conductors (ACCR). ACSR conductor has steel which offers much lesser elongation which means that much lesser sag at a given tension [14].

The composite core has further decreased thermal elongation and identical or more power than galvanized steel [6]. ACCR conductor has been designed in replacement of ACSR (Aluminum conductor steel reinforced) and ACSS (Aluminum conductor steel supported) conductor with respect to existing structures of same tension and clearances, also which gives twice the ampacity without risks [22]. The conductor choice is based on the conductivity to weight ratio, the power to weight ratio, the mechanical and electrical properties of the conductor's length and sort for a given vicinity and environmental situations.

The general theory of sag and tension calculations for ACSR Conductors were made in (IS 5613-Part1/Sec-1). A similar calculation was made with ACCR conductors with associated specifications. Up-gradation of towers with Re conducting for the restricted right of way with the composite conductors' suitability in sag ampacity for 275 KV overhead transmission line is pursued and highlighted the sag temperature characteristics of ACCR conductors[23],

2.1. Objectives of the Paper

Optimization of the towers is the main purpose of the analytical study in urban areas where the needy Right way is restricted due to the non-availability of land. Monopoles and four-legged towers are selected for strength and serviceability conditions are compared with IS 802-2015 version and Wind loading codes IS 875-2015 codal Provisions. Further examination has been done for weight consideration for sag tension relationships of ACSR and ACCR Conductors.

3. METHODOLOGY

The structural support system is certainly an essential element of a line, but much of the unusual behavior and most of the problems of a line start on or are generated by the wiring system. The wire system consists of the conductors and ground wires and includes all components. The major loads of a transmission line are generated on or by the wiring system. Although the support system can support very heavy vertical loads at relatively low cost, this same support system can prove to be inadequate when unusual or unexpected things happen to the wiring system.

In the first instance IS 802-2015(Part-1/Sec-1)[7] and IS 875-2015(Part-3)[24] codal provisions have suggested design of Monopole and Four-legged transmission tower for climatic loads and safety and security load combinations. Secondly, the sag-tensions calculations of the conductor are calculated for ACSR (Aluminum conductor steel reinforced) conductor and new generation composite ACCR (Aluminum composite conductor reinforced) conductor for temperature, wind loading cases. The transverse wind loads on conductors, insulators and on the towers are computed according to relevant provisions of IS 802-2015 code and IS 875-2015 codal recommendations, Gust factor method was adopted for calculating the transverse wind forces. Tower height of 60 m with 250 m basic span are considered in the paper. The geometric properties are prescribed from IS 1161-2014 [25]. The reference wind speed is recommended as 10 minutes in IS 802-2015(Part-1/Sec-1) [7] and one hour mean wind speed in IS 875-2015(Part-3)[24] codal provisions

The methodology adopted for design wind loading factors such as Risk factor, terrain factor specified in IS 802-2015(Part-1/Sec-1) [7] are different from [25] code provisions. Moreover, the procedure for calculating the Gust loading factor in both the codes are varied. The impact of 875 (2015) provisions in cyclonic region was explored in [26-32]

STTAD Pro software application[33] was adopted for computation of internal parameters, the nodal forces are computed with relevant panel heights and drag coefficients, the Reliability level 1 is adopted since there is higher safety is required for the narrowly-based tower have larger overturning moments in comparison with largely based towers. The geometric properties of the monopole tower pipe and Four-legged lattice tower are depicted in table 1. The elevation of towers are produced in figure 1. Mechanical properties of ACCR and ACSR Conductors are also shown in table 2. The monopole tower constructed recently in Andhra Pradesh is depicted in the figure 2. The variation of gust factors for Monopole, lattice tower is depicted in the figures 4 and 5. The variation of force coefficient is also shown in the figure 6.

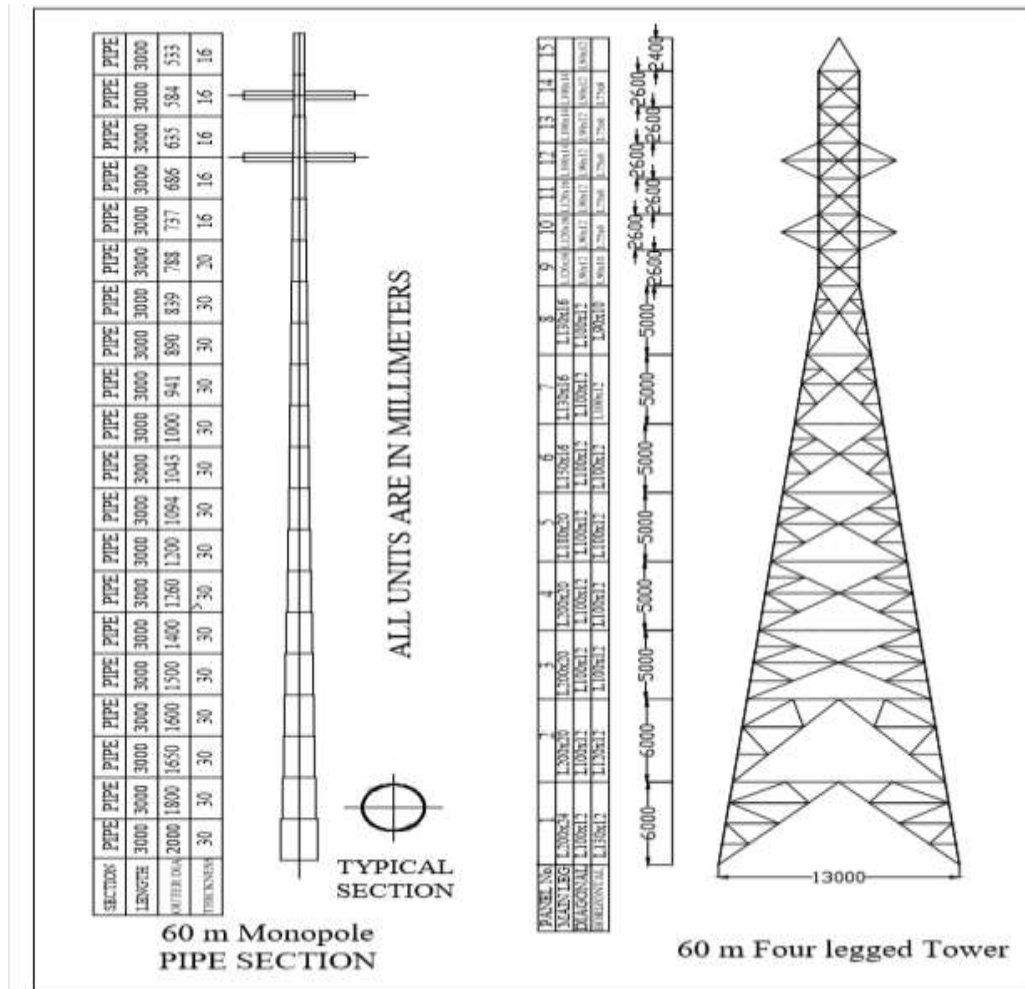


Figure 1 Geometric Properties of Monopole and Lattice towers

Table 1 Geometric properties of Monopole and Four-legged tower

Tower height	Monopole Pipe Section		Lattice Tower Four-legged Tower	
	Base Width (m)	Top Width (m)	Base Width (m)	Top width (m)
60	2.3	0.5	13.0	2.2

Table 2 Mechanical properties of ACSR and ACCR conductors

	ACSR-steel	ACCR Aluminum Matrix
Strength (M Pa)	1275	1378
Density(g/cm ³)	7.8	3.29
Strength /density	163	419
Coefficient of Thermal Expansion 10 ⁻⁶ /°c	12.1	6.3

4. RESULTS AND DISCUSSIONS

With the methodology in the previous part, the towers are analyzed with STAAD Pro software applications of wind loads on the tower and transverse wind loads on the conductors. The temperature and sag calculations are also determined with the codal recommendations of minimum temperature to the maximum prescribed temperature of 55°c are analyzed for ACSR and ACCR conductors. The variation of sag between the ACSR conductor and ACCR conductor is shown in Figure. It is clear from the table the ACCR conductor has less sag when compared to the ACSR conductor due to more mechanical strength and the variation is also depicted in the figure 7& 8. It is evident that more tensions are for ACCR conductors, since the sag and tensions are inversely proportional to each other. The mechanical tension and sag are depicted in the figure 7



Figure 2 Pipe Section Transmission Tower Profile

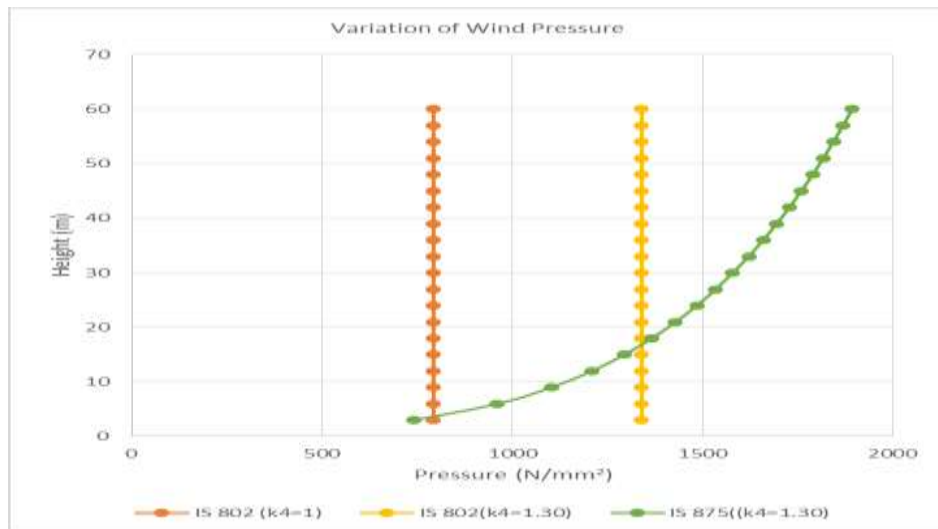


Figure 3 Variation of pressure as per IS 875 and 802

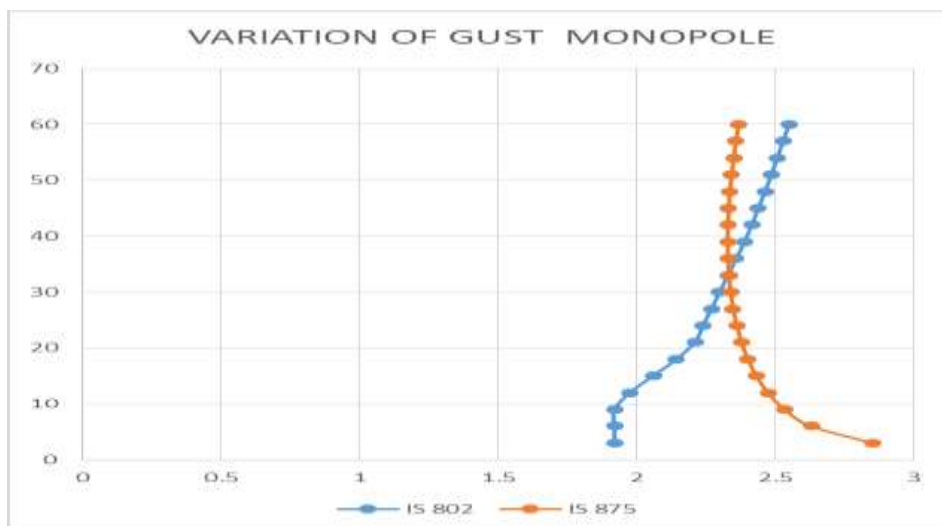


Figure 4 Variation of gust value for IS: 875-2015(Part-3) & IS 802-2015(Sec-1/ part-1) for monopole tower

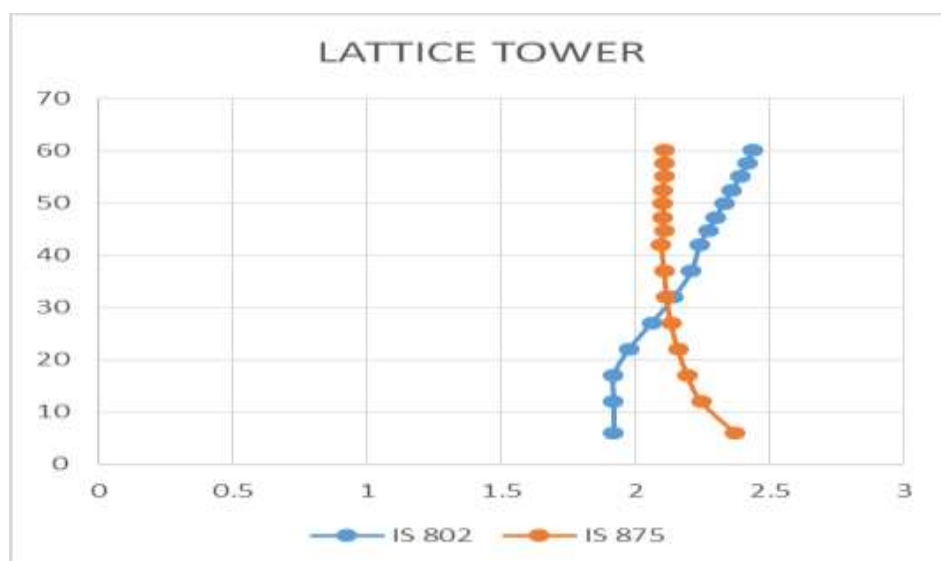


Figure 5 Variation of gust value for IS: 875-2015(Part-3) & IS 802-2015(Sec-1/ part-1) for 4-Legged tower

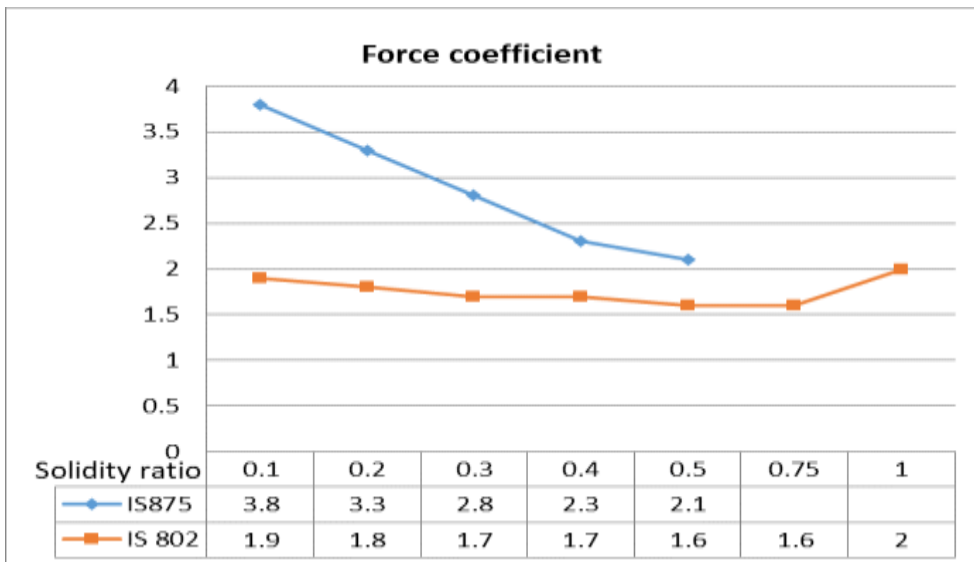


Figure 6 Variation of force coefficient

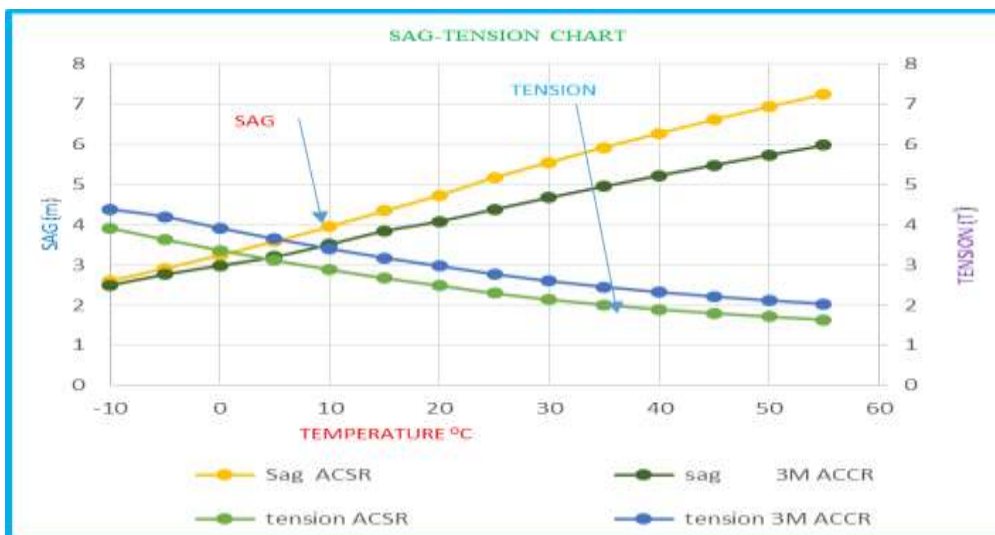


Figure 7 Sag and Tension graph for ACCR and ACSR Conductor

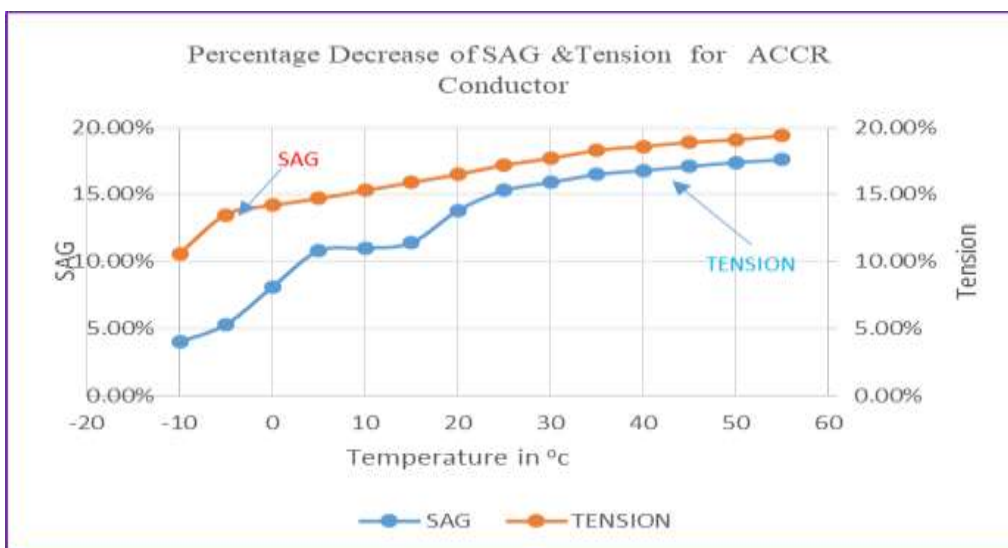


Figure 8 Decrease of sag and increase of Tension for ACSR Conductor

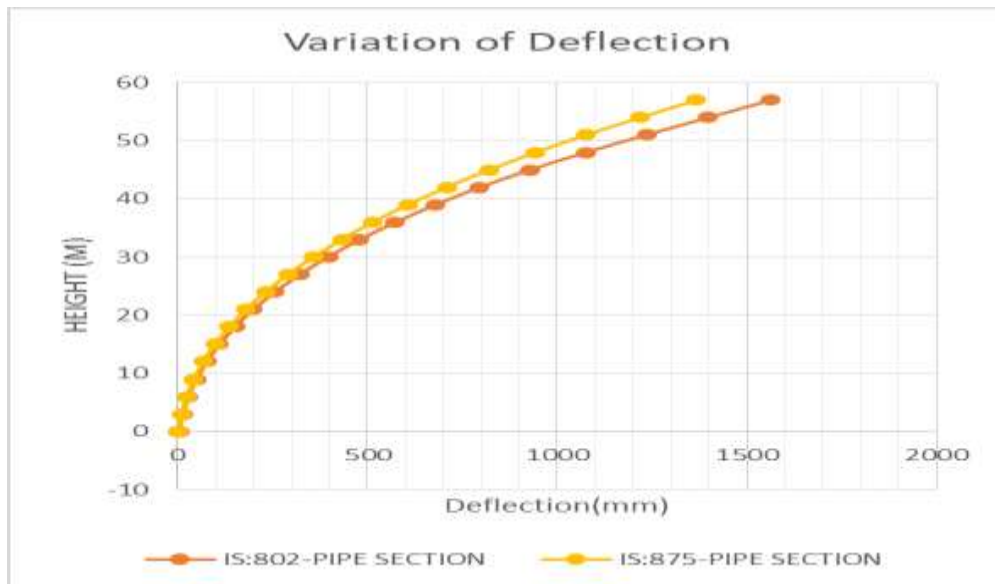


Figure 9 Variation of deflections of towers with conductors

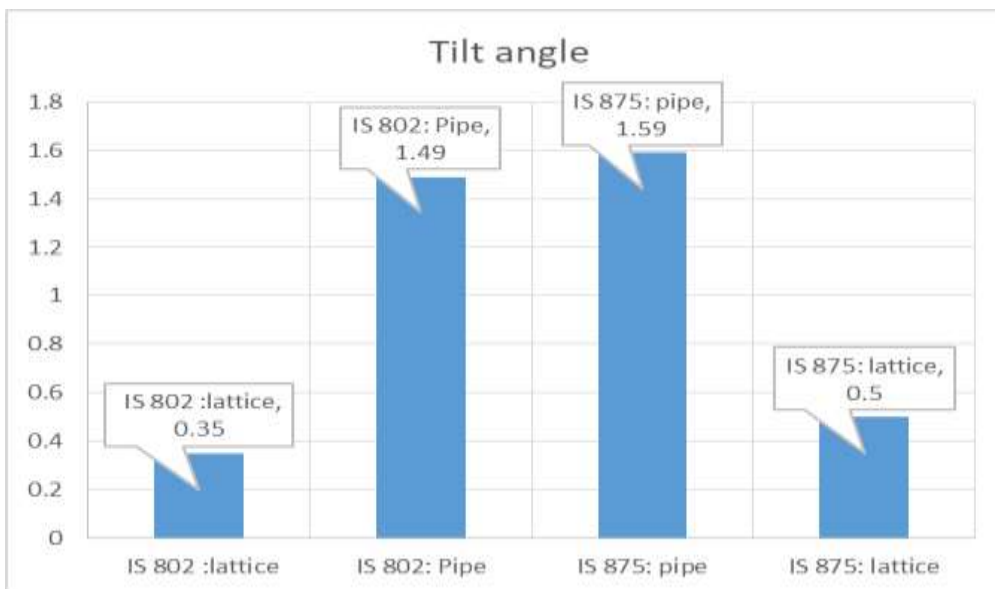


Figure 10 Variation of tilt angles for IS: 875-2015(Part-3) & IS 802-2015(Sec-1/ part-1)

5. DISCUSSIONS

With the above results shown in the tables and figures for analysis of Monopole tower and lattice tower the discussions are as follows

The analysis has been carried out with the gust factor method as per both the codes, the variation of gust values which are shown in the Figures 4 & 5 are different due to methodology involved. In the IS 802 code gust variation is with height, while in IS 875 it is closed form solution with background factor and resonance factor.

The string chart in the Fig 7. i.e., sag and tension variation shows they are interdependent and inversely proportional to one another. Table-3 depicts the variation of sag and tension for ACCR and ACSR conductors. Sag is decreased from 4% to 18% lesser than the ACSR conductor and its tension is increased in the range of 10% to 19% higher than the ACSR conductor.

In Figure 9, the deflections of towers with broken wire condition according to IS: 802-2015 and IS: 875-2015 have been plotted. The deflections of Pipe section tower as per IS 875:2015 are more compared to IS 802: 2015.

Maximum Tilt angles for 802-2015 code design guidelines with broken wire conductors is 1.49° and for lattice tower is 0.35° . and depicted in the Figure.10.

Similarly, Maximum Tilt angles for 875-2015 code design guidelines with broken wire conductors are 1.59° for the pipe section and for lattice tower is 0.5° .

Variation of weights between Monopole Transmission tower and 4- Legged Transmission tower has been given in tables 6. According to the table, Circular (pipe) Monopole Transmission tower has 28.4 T as per IS 875-2015 and 17.9 T as per 802-2015. Similarly, four-legged transmission towers have 30.5 Tone as per IS 875-2015 and 27.7 Tone as per 802-2015

6. CONCLUSION

The right of way in urban areas is more constraint. To comply with this criterion vertical profile of the tower is an alternative feasible point of comparison. Hence monopole transmission towers for transmission tower geometry internal parameters with composite conductors (ACCR) have been compared with conventional ACSR conductors. The internal parameters of four-legged tower profiles have also been compared. IS 802-2015 and 875-2015 codal provisions have been examined. The influencing internal parameters for transmission towers are Sag and conductor tension relations ships, deflections at top, tilt angle and variation of weights for tower anatomy have been examined in this paper. After detailed discussions in the previous part, the following conclusions have been drawn

- The monopole tower shows 6.7 % lesser weight when compared to the 4-legged tower.
- The above conclusion is with monopole tower base width of 2.3m and lattice tower base width is 13m. Hence the required right of way is 17.6% of the Lattice tower.
- Monopole with new generation conductors has shown 18% less sag when compared to conventional conductor Since the rated strength of the ACCR conductor is higher than the ACSR conductor,
- As the sag is less with new generation conductors the height of the tower is reduced without any effect with safety parameters, which in-turn weight of the tower can be reduced.
- The Overall cost minimization of the project is not limited to the tower material, but also cost of the land is an objective function of the system in urban areas [34].

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