Parametric Study of Guyed Transmission Tower Based on the Pre-Tension of Guy wire, Configuration and Base width

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Abstract— A single transmission line consist of many transmission tower. So, material saving in a single tower will lead to a considerable effect to the final cost of the project. The transmission line tower constitute about 28% to 42% of the cost of a transmission line. Therefore optimization in design of towers can bring about significant economy in the cost of transmission lines. Moreover, the increasing demand in electrical energy can also be met economically by developing different light weight configuration of transmission line towers. In this work, a parametric study on the effect of the guy pre- load, configurations and distance between guy base and tower base is carried out. A 220 KV guyed tower is analyzed in STAAD Pro. V8i. The wind load is calculated from the design code. Each of these tower member are design as an angle section. Various values of pre- loads are considered for the guys. Then analysis and compare the result.

Key words: Guyed Transmission Tower, Pre- Load, Wind Force

I. INTRODUCTION

An attempt has been made to make the transmission line more cost effective by changing the pre- load of guys of guyed transmission tower. A 220 KV single circuit tower is selected. The other parameter except pre- load of guys, configurations and distance between guys base and tower base is kept constant. The value of pre- load is taken 5%, 10%, 15%, 20% of ultimate breaking strength of guys wire and distance between guys base and tower base is taken 12m, 14m and 16m.

The following work has been done:-

1) The sag tension calculation for conductor and ground wire using parabolic equation.
2) Loading format including reliability, security and safety pattern is evaluated. Then, all the towers of different Pre-load are modelled using STAAD.Pro.V8i.
3) The wind loading is calculated on the longitudinal face of all the towers.
4) Then, all the towers are analyzed as a three dimensional Structure using STAAD.Pro.V8i.
5) Finally, tower members are designed as angle sections.

II. INPUT PARAMETER

The following parameters for transmission line and its component are assumed from I.S. 802 Part1/Sec 1:1995, I.S.5613 Part 2/Sec 1:1989.

- Transmission Line Voltage: 220 kV
- Terrain Category: 1
- Return Period: 150 years
- Wind Zone: 2
- Basic Wind Speed: 39 m/s
- Basic Wind Pressure: 68.10 kg/sq.m
- Tower Type: Guyed Tower, Suspension Type Tower
- No. of Circuits: Single Circuit
- Cross Arm: Pointed
- Body Extension: Not Considered
- Steel Used: Mild Steel & High Tensile Steel
- Shielding angle: 30 degree
- Conductor Material: ACSR (Aluminium Conductor)
- Maximum Temperature: 75°C (ACSR)
- Number of Ground Wires: Double
- Peak Type: Triangular
- G.W. Type: Earth wire – One GSW and One OPGW
- Diameter of earth wire – 1.23cm (OPGW)& 1.24cm (GSW)
- Insulator Type: Single Tension String
- Size of Insulator Disc: 0.255*0.145 m
- Number of Insulator Discs: 10
- Length of Insulator String: 1.82 m
- Minimum Ground Clearance: 7 m
- Creep Effect: Not Considered
- Minimum Thickness of Member:
- Leg Member, main compression chord in cross & peak: 6mm
- Redundant member: 3mm
- Other member: 4mm
- Permissible Weight Span:
- Normal Condition:
- Maximum: 550 m
- Minimum: 100 m
- Broken Wire Condition:
- Maximum: 440 m
- Minimum: 80 m
- Normal Span: 350 m

III. SAG TENSION FOR GROUND- WIRE AND CONDUCTOR

Indian standard codes of practice for use of structural steel in over- head transmission line towers (i.e. IS802(Part 1/Sec 1):1995) have prescribed following conditions for the sag tension calculations for the conductor and the ground wire:

1) Maximum temperature (75ºC for ASCR and 53ºC for ground wire) with design wind pressure (0% and 36%).
2) Every day temperature (32ºC) and design wind pressure (100%, 75% and 0%).
3) Minimum temperature (0ºC) with design wind pressure (0% and 36%).

Sag tension are calculated by using the parabolic equations are discussed in the I.S. 5613: Part 2: Sec: 1: 1989 for both the conductor and ground wire.

Parabolic Equation

$F_2^2*(F_2-(K-\alpha*t*E)) = (L^2\delta^2q_2^2E)/24$

Take $K = F1 - (L^2\delta^2q_2^2E)/24F_1^2$

Temperature variation °C	0		32			53
Wind Variation %	0	36	0	75	100	0
Tension = F x A (kg)	3286	3476.06	2482	3393.8	4018	1822.84
Sag = $wL^2/8T$ (m)	4.48	4.23	5.93	4.34	3.66	8.08

Table 1: Sag Tension for Conductor

Temperature variation °C	0		32			53
Wind Variation %	0	36	0	75	100	0
Tension = F x A (kg)	3031	3088.23	2576.9	2875	3103.7	2077
Sag = $wL^2/8T$ (m)	3.64	3.57	4.28	3.83	3.55	5.3

Table 2: Sag Tension for Ground Wire (gsw)

Temperature variation °C	0		32			53
Wind Variation %	0	36	0	75	100	0
Tension = F x A (kg)	2936.9	2998.5	2462	2788.9	3035.4	1944
Sag = $wL^2/8T$ (m)	3.41	3.34	4.06	3.6	3.3	5.15

Table 3: Sag Tension for Ground Wire (opgw)

IV. CONFIGURATION OF TOWER

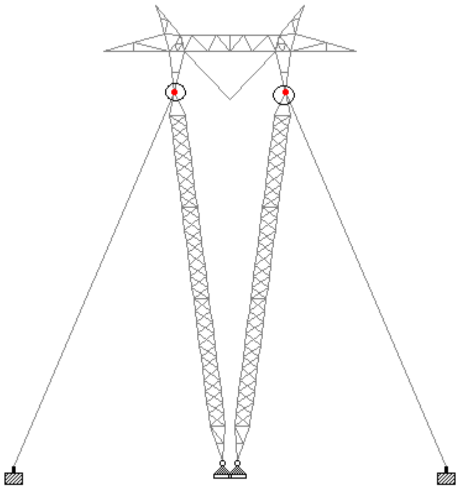

Fig. 1: Configuration of Type 1 Tower

Configurations of all the towers are done by first fixing the outline of the towers as per the Indian Standard requirements.

The height of tower is taken 30m after accounting shield angle.

For the study, five different type of tower taken based on the position of guys attached on the tower body is as below.

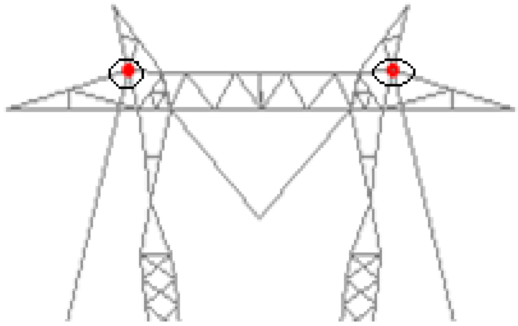

Fig. 2: Configuration of Type 2 Tower

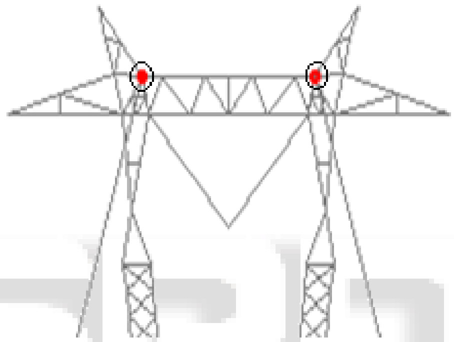

Fig. 3: Configuration of Type 3 Tower

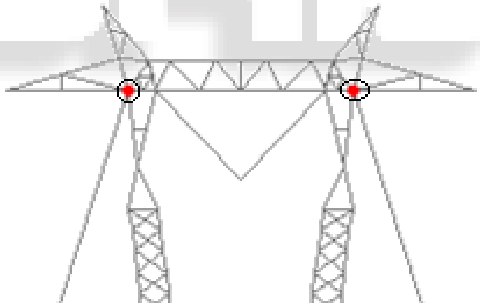

Fig. 4: Configuration of Type 4 Tower

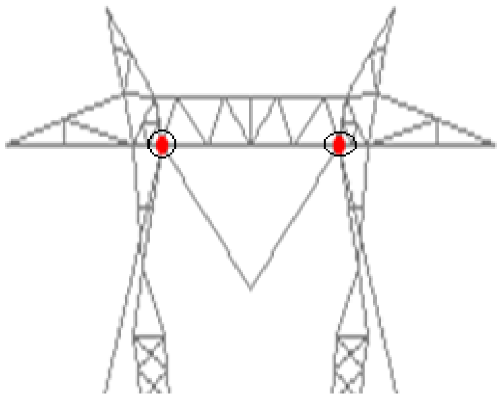

Fig. 5: Configuration of Type 5 Tower

V. WIND LOAD ON TOWER

Wind loads on both the towers are calculated as per I.S. 802 (Part 1/Sec 1):1995. For quick and easy calculations excel programs are separately developed according to Indian.

A. *Design Wind Pressure*

To calculate design wind pressure on conductor, ground wire, insulator and panels:

$P_d = 0.6 \times V_d^{\,2}$

where,

P = design wind pressure in N/m2

V_d = design wind speed in m/s

To calculate design wind pressure

$V_d = V_R \times K_1 \times K_2$

V_{R} = 10min wind speed (or) reduced wind speed

$V_R = V_b/K_o$

V_b = basic wind speed

K_O =1.375 [conversion factor]

K_1 = risk coefficient

K_2 = terrain roughness coefficient.

B. *Wind Loads on Conductor/Ground Wire*

To calculate wind loads on conductor and ground-wire

$F_{WC} = P_d \times C_{dc} \times L \times d \times G_c$

where,

F_{wc} = wind load on conductor

P_d = design wind pressure

C_{dc} = drag coefficient for ground wire=1.2 drag coefficient for conductor = 1.0

L = wind span

d = diameter of conductor/ground wire

G = gust response.

C. *Wind Load On Insulator*

To calculate wind load on insulator

$F_w = P_d \times C_{di} \times A_I \times G_i$

where,

A = 50% area of insulator projected parallel to the longitudinal axis of string

G_I = gust response factor for insulator

C_{dI} = drag coefficient, to be taken as 1.2

By using above formula the wind load on the tower due to conductor and ground wire is following:

	Reliability condition	Security condition		Safety condition		Anti-cascade condition
		NC	BWC	Stringing over condition	Under stringing condition	
Transverse load (kg)	2466	2251	1330	1333.8	666.901	666.9
Vertical load (max.) (kg)	796	796	716	1592	1933.6	716.8
Vertical load (min.) (kg)	-62	-62	-62	10	-124	-62
Longitudinal load (kg)	0	0	2998	1932.6	2576.9	2576.9

Table 4: Loading on Ground Wire

	Reliability condition	Security condition		Safety condition		Anti-cascade condition
		NC	BWC	Stringing over condition	Under stringing condition	
Transverse load (kg)	3374	3050	1827	1284	642.341	642.3
Vertical load(max.) (kg)	929.1	929	823	1858	2146.56	823.28
Vertical load(min.) (kg)	-86.2	-86.2	-86.2	10	-172.4	-86.20
Longitudinal load (kg)	0	0	3881	1861	2482	2482

Table 5: Loading On Conductor

VI. MODELING OF TOWER

Modeling of towers has been carried out in STAAD Pro.V8i software. Fig. 1 shows geometry of transmission towers.

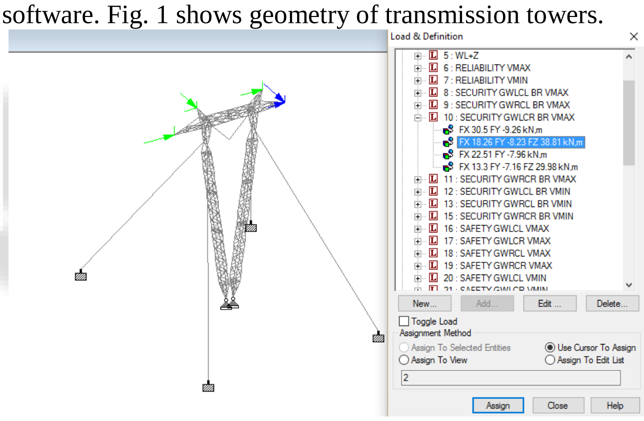

Fig. 6: Application of load on tower

Once modelling part is completed, application of loads is carried out. This include wind loads at angle member and also wind loads at conductor and ground-wire attachment points based on all three conditions viz. reliability, security and safety as shown in fig. 2. Then after 3D analysis of both the towers is carried out in STAAD Pro.V8i.

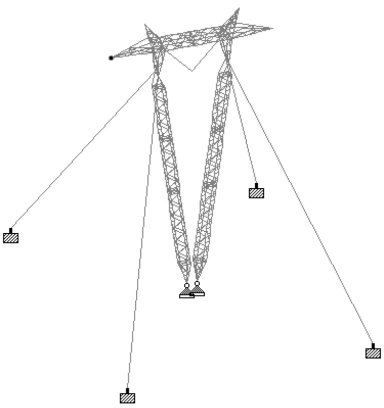

Fig. 7 : Modelling of guyed transmission tower in STAAD. Pro. V8i

VII. DESIGN OF TOWER

For the design of members of all the towers excel program has been developed based on the parameters of I.S. 802(Part 1/Sec 2):1995. Trial and error process is followed to get optimized sections.

VIII. RESULT AND CONCLUSION

As all the tower are design with enough factor of safety, weight of all the tower obtained as follow:

Type of tower	MATERIAL REQUIRED(KN)		
	12m_base width	14m_base width	16m_base width
Type 1	52.645	52.885	49.307
Type 2	51.436	51.332	48.62
Type 3	51.978	52.015	48.78
Type 4	50.842	48.96	47.938
Type 5	52.317	49.51	49.049

Table 6: Material take off for 5% pre tension in guy

Type of tower	MATERIAL REQUIRED(KN)		
	12m_base width	14m_base width	16m_base width
Type 1	53.683	50.762	50.132
Type 2	51.195	51.84	49.368
Type 3	51.658	51.223	49.724
Type 4	49.013	49.147	48.21
Type 5	51.489	50.253	49.493

Table 7: Material take off for 10% pre tension in guy

Type of tower	MATERIAL REQUIRED(KN)		
	12m_base width	14m_base width	16m_base width
Type 1	53.817	52.48	51.511
Type 2	52.126	50.96	49.903
Type 3	52.842	51.573	50.025
Type 4	50.466	49.134	47.746
Type 5	51.36	51.156	50.442

Table 8: Material take off for 15% pre tension in guy

Type of tower	MATERIAL REQUIRED(KN)		
	12m_base width	14m_base width	16m_base width
Type 1	54.545	53.928	53.598
Type 2	53.979	52.83	51.421
Type 3	54.731	52.705	51.659
Type 4	51.68	50.541	49.289
Type 5	54.825	53.408	52.213

Table 9: Material take off for 20% pre tension in guy

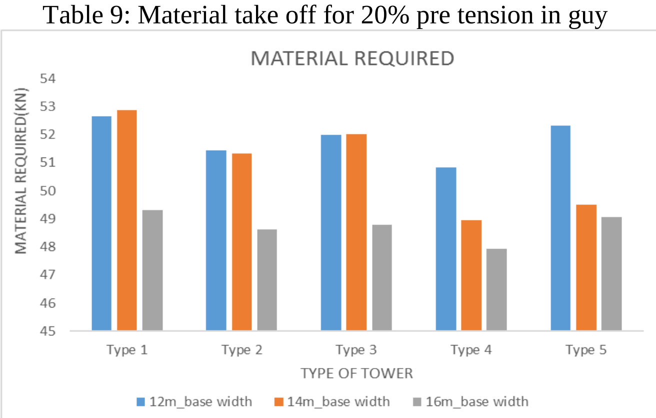

Fig. 8: Chart of Material Required for 5% Pre-Tension Tower

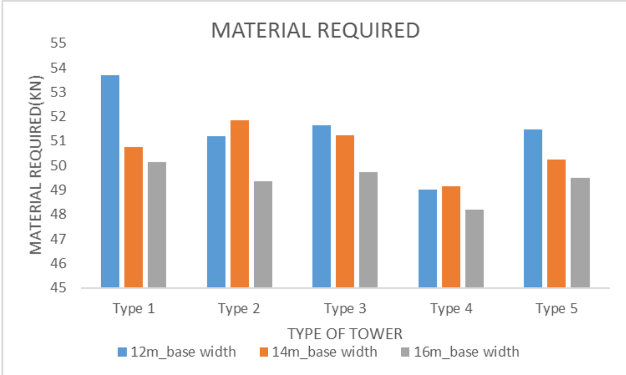

Fig. 9: Chart of Material Required for 10% Pre-Tension Tower

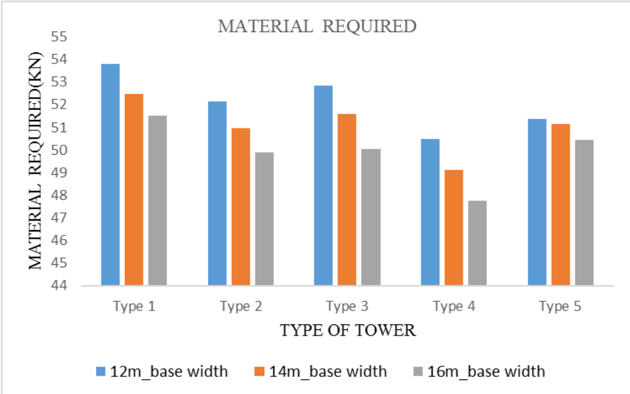

Fig. 10: Chart of Material Required for 5% Pre-Tension Tower

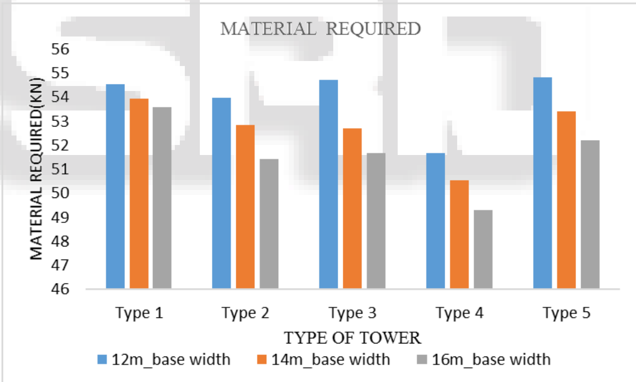

Fig. 11: Chart of Material Required for 5% Pre-Tension Tower

- The weight of the tower having 16m distance between guys base and tower base is minimum.
- As we increase the pre tension of the guys, the weight of tower is increases.
- The weight of tower with 15% pre tension in guys, type 4 tower and 16m distance between base of tower and guys is minimum i.e., 47.746 KN.
- The weight of tower with 20% pre tension in guys, type 5 tower and 12m distance between base of tower and guys is maximum i.e., 54.825 KN.
- It is observed that maximum saving in material is 12.9%.
- The weight of the tower having type 4 configuration is minimum.
- The weight of the tower having type 1 configuration is maximum.

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