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Analysis of Transmission Tower Using STAAD Pro- Seismic Analysis

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Abstract The main objective of the present analysis is to analyze the transmission tower. The analysis is carried out for modal and seismic conditions. Three types of towers are considered in this study; Double warren bracing tower (DWT), Diamond bracing tower (DT), K and Double warren bracing tower (KDWT). Load calculation of transmission line towers for normal load condition as per IS 802(part1:sec1):1995 and seismic load as per IS 1893(part1):2002 are considered. Typical electrical transmission line tower is considered from for validation. Finite element analysis includes the modal analysis and seismic analysis. Results obtained from the modal and seismic induced loads are compared and conclusion are drawn.

Keywords — Diamond bracing tower (DT), Double warren bracing tower (DWT), K and Double warren bracing tower (KDWT, modal analysis and seismic analysis, transmission line tower.

I. Introduction

The requirement of an outsized transmission and distribution system in a country like India which features a large population residing everywhere the country is because of need of the electricity supply for this population. Transmission line is an integrated system consisting of conductor subsystem, ground wire subsystem and one subsystem for every category of support structure. Mechanical supports of cable represent a big portion of the value of the road and that they play a crucial role within the reliable power transmission. They are designed and constructed in big variety of shapes, types, sizes, configurations and materials. The structure types utilized in transmission lines generally fall under one among the three categories: lattice, pole and guyed.

The main supporting unit of electric tower line is electric tower. And the electric towers are usually called as transmission towers. Transmission towers have to carry the heavy transmission conductor at enough safe height from the ground. In extend to that all towers have to sustain all kinds of natural calamities. So transmission tower designing is an important engineering job where all three basic engineering concepts, civil, mechanical and electrical engineering concepts are equally applicable.

A high-voltage power transmission tower line structure is an intricate structure in that its plan is described by the uncommon necessities to be met from both electrical and auxiliary perspectives. The state of the pinnacle is made by its tallness, length of its cross arms that convey the electrical conveyors, bracings and so forth.

One of the various accessible investigative and numerical procedures, the Finite Element (FE) technique has been the most well known strategy utilized in the examination of transmission tower. For the most part, the firmness framework technique is utilized in the model of the transmission tower. Notwithstanding, regardless of that fast advancement in highspeed calculation, because of the enormous number of degrees of opportunity required for exact demonstrating, itemized three-dimensional limited component examination of transmission tower is still tedious. Since it needs broad information info and it produces huge yield with tackling huge measurement grids, which frequently shows the physical conduct of the transmission tower.

II. SELECTION OF TRANSMISSION LINE AND ITS COMPONENTS

The transmission line is a component of the line voltage. The general execution of an overhead transmission line is an element of the presentation of different segments establishing the transmission line. The transmission line is considered as a coordinated framework comprising of following subsystems (alongside their three parts):

- Conductor subsystem comprising of conductor and its holding cinches.
- Ground wire subsystem comprising of ground wire and its holding cinches.
- One subsystem for every classification of help structure for example for a specific cross section structure, the segments are edge part, jolts, establishments.

The right selection of above mentioned components are highly interrelated to each other. The selection of conductor and ground wire is dependent on the sag characteristics of both and also dependent on the span of the transmission line

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which in turns relates to the spotting of the towers along the line. Tower spotting is itself a function of tower type. Tower spotting along the line further depend on the angle of line deviation. The span of transmission line and angle of line deviation can further be optimizing for getting the best results. Even the footing type is also a function of these two parameters. The judicious selection in the conductors, insulators and ground wire and design of towers with their spotting and erection can bring the cost effectiveness of the transmission line.

III. TOWER DESIGN

When the outer burdens following up on the pinnacle are resolved, one continues with an investigation of the powers in different individuals with the end goal of repairing their sizes. Since pivotal power is the main power for a bracket component, the part must be intended for either pressure or strain. When there are numerous heap conditions, certain individuals might be exposed to both compressive and pliable powers under various stacking conditions. Inversion of burdens may likewise instigate exchange nature of powers. Consequently these individuals are to be intended for both pressure and strain. The complete power following up on any individual part under the ordinary condition and furthermore under the wrecked wire condition is duplicated by the comparing element of wellbeing, and it is guaranteed that the qualities are inside the passable extreme quality of the specific steel utilized.

BRACING SYSTEMS

Once the width of the tower at the top and also the level at which the batter should start are determined, the next step is to select the system of bracings. The following bracing systems are usually adopted for transmission line towers.

Single web system: It comprises either diagonals and struts or all diagonals. This system is particularly used for narrow-based towers, in cross-arm girders and for portal type of towers. Except for 66 kV single circuit towers, this system has little application for wide-based towers at higher voltages as shown in figure 1.2(a).

Double web or Warren system: This framework is comprised of corner to corner cross bracings. Shear is similarly appropriated between the two diagonals, one in pressure and the other in strain. Both the diagonals are intended for pressure and strain so as to allow inversion of remotely applied shear. The inclining supports are associated at their cross focuses. Since the shear prelude is conveyed by two individuals and basic length is roughly a large portion of that of a comparing single web framework. This framework is utilized for both enormous and little towers and can be monetarily embraced all through the pole with the exception of in the lower a couple of boards, where jewel or gateway arrangement of bracings is increasingly appropriate. As shown in figure 1.2(b).

Pratt system: This framework likewise contains corner to corner cross bracings and, furthermore, it has flat swaggers. These swaggers are exposed to pressure and the shear is taken altogether by one corner to corner in strain, the other askew acting like a repetitive part. It is often economical to use the Pratt bracings for the bottom two or three panels and Warren bracings for the rest of the tower as shown in figure 1.2(c).

Portal system

The diagonals are necessarily designed for both tension and compression and, therefore, this arrangement provides more stiffness than the Pratt system. The advantage of this system is that the horizontal struts are supported at the mid length by the diagonals as shown in figure 1.2(d).

Diamond bracing system

Somewhat similar enough to the warren system, this bracing arrangement can also be derived from the portal system by inverting every second panel.as for each of these systems all diagonals are designed for tension and compression. Applicable to panel of approximately the same size as the pratt and portal systems, this arrangement has the advantage that the horizontal members carry no primary loads and are designed as redundant supports as shown in figure 1.2(e). Like the Pratt system, this arrangement is also used for the bottom two or three panels in conjunction with the Warren system for the other panels. It is especially useful for heavy river-crossing towers.

TRANSMISSION LINE TOWER COMPONENTS

A transmission line tower is constituted of the following components are as shown in figure 1.3

- Peak
- Cross arm
- Cage
- Transmission Tower Body

Peak

It is the portion of tower above the top cross arm in case of vertical configuration tower and above the boom in case of horizontal configuration tower. The function of the peak is to support the ground wire in suspension clamp and tension clamp at suspension and angle of tower location respectively. The height of the peak depends upon specified angle of shield and mid span clearance.

Cross Arm

Cross arms of transmission tower hold the transmission conductor. The quantity of cross arm relies on number of circuits, tower setup and conveyors/ground wire game plan. The cross arm for ground wire consists of fabricated steel work and that for conductor may be insulated type or consist of fabricated steel work. The dimension of a cross arm depend upon the line voltage, type and configuration of

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insulator string, minimum framing angle from the requirement of mechanical stress distribution.

Cage

The portion between peak and tower body in vertical configuration tower is called Cage. The cross section of cage is generally square and it may be uniform or tapered throughout its height depending upon loads

Transmission Tower Body

Tower body is the main portion of the tower for connecting cage/boom to the tower foundation or body extension or leg extension. It comprises tower legs inter connected by bracings and redundant members. It is generally square in shape. In another arrangement, a tower body comprises two columns connected at one of their ends to the foundations and at the other to the boom to which conductors are attached through insulator string.

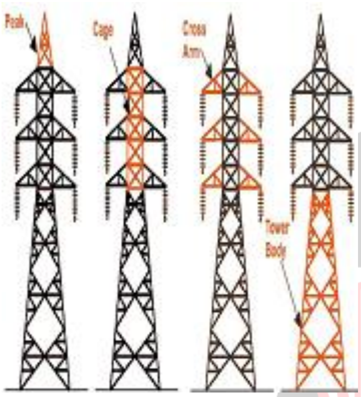

Fig 1

DESIGN OF TRANSMISSION TOWER

During design of transmission tower the following points to be considered.

- The minimum ground clearance of the lowest conductor point above the ground level. The length of the insulator string
- The minimum clearance to be maintained between conductors and between conductor and tower
- The location of ground wire with respect to outer most conductors
- The mid span clearance required from considerations of the dynamic behaviour of conductor and lightening protection of the line

To determine the actual transmission tower height by considering the above points, the total height of tower is divided in to four parts as shown in figure 1.4.

- Minimum permissible ground clearance (H1)
- Maximum sag of the conductor (H2)
- Vertical spacing between top and bottom conductors (H3)
- Vertical clearance between ground wire and top conductor (H4)

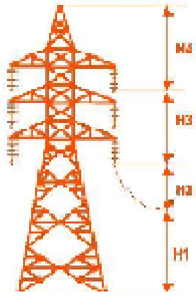

Fig 2

III. OBJECTIVES

The main objectives of the thesis are summarized in the following:

1 Three types of towers are considered in this study as given below

- Double warren bracing tower (DWT)
- Diamond bracing tower. (DT)
- K and Double warren bracing tower.(KDWT)

2 Load calculation of transmission line towers for normal load condition as per IS 802(part1:sec1):1995, IS 875(part3):1987 and seismic load as per IS 1893(part1):2002 are considered.

3 Typical electrical transmission line tower is considered from for validation.

4 Finite element analysis includes the modal analysis, wind analysis and seismic analysis.

5 Results obtained from the seismic and wind induced loads are compared and conclusion are drawn.

METHODOLOGY

- This involves the detailed discussion on previous journal papers related to the dynamic analysis of transmission line towers.
- The load calculation of transmission line tower system is done for wind load as per IS 802 (part 1/sec 1)-1995, IS 875 (part 3): 1987 and seismic load as per IS 1893(part 1): 2002.
- Typical electrical transmission line tower is considered from the literature and these results of maximum axial force and displacement are compared with literature and validated.
- Parametric studies are implemented in order to assess the dynamic analysis of three different types of towers with varying heights of 30m, 40m and 50m with respective base widths.
- Modal analysis is carried out for all three towers to get the natural frequency and mode shapes.

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- Seismic analysis is carried out by equivalent static, response spectrum and time history analyses to obtain the stress and displacement for all the zones as per IS: 1893 (Part 1):2002.
- Results obtained from above analyses are tabulated, discussed and conclusions are drawn

IV. TRANSMISSION LINE TOWERS

INTRODUCTION: Transmission line towers comprise around 28 to 42 percent of the expense of the transmission line. The expanding interest for electrical vitality can be met all the more monetarily by creating diverse light-weight arrangements of transmission line towers.

The transmission tower-line framework, comprising of grid bolster towers and conveyor links, is a significant help venture as a high-voltage electric force transporter and assume a significant job in the foundation framework in numerous nations all through the world Along with fast improvement of the force business and national economy, planning and building a lot taller and longer range high-voltage transmission towers is clear flow pattern, which has proposed new prerequisites for auxiliary designing. This basic framework has some specific attributes, for example, tall building tower, enormous range and intersection hypsography, the adaptability of whole structure expanding nonlinearly as its tallness, and force transmission tower coupling with transmission line tower with various sufficiency of dynamic properties Due to their specific auxiliary qualities, numerous transmission tower-line frameworks regularly breakdown in light of dynamic loadings.

CONFIGURATION OF TOWER

A transmission line tower is like exposed structure. Its super structure suitably shaped, dimensioned and designed to sustain the external loads acting on the cables (conductors and ground wires) of the super structure itself. The super structure has a trunk and a hamper (cage) to which cables are attached either through insulators or directly.

STRUCTURAL COMPONENTS OF TOWER

he principle auxiliary segments of transmission line are the conduits, the shield wires, protector strings, equipment, suspension and impasse structures. The reaction of a line area to link crack relies upon the connection between every one of these parts. The conductors are the abandoned links made out of aluminum, aroused steel or a blend of the over two. Shield wires are grounded steel wires set over the conduits for lightning assurance. Conductors are joined to suspension structures by means of encasings strings that are vertical under the typical activity conditions and are allowed to swing along the line at whatever point there is longitudinal unequal burden.

PARAMETERS OF TOWER

Three types of Transmission line towers are considered in this dissertation as given in table 3.1, typical 30m height towers with different bracing system are shown in figure 3.1(a-c) and table 3.2 lists the parameters such as height and base width considered for the analysis.

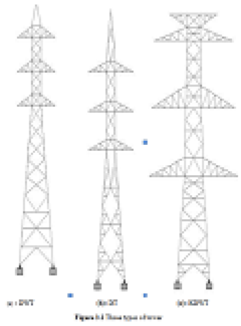

Fig 3

Table 3.1: Three types of tower with different parameters

Sl no	Different types of towers	Parameters of tower
1	Double Warren (DWT)	A typical tower is a 132-KV double-circuit tower with angle of inclination is 2°, wind zone 4 (47m/s) is considered, the basic tower is 6.0 m base width & 30 m height it changes the parameter of 8.0 m base width of 40 m height and 10.0 m base width of 50 m height of tower
2	Daimond (DT)	A typical tower basic tower is 5.4 m base width & 28.58 m height it changes the parameter of 5.4m base width of 30m height, 6.43 m base width of 40 m height and 8.04 m base width of 50 m height of tower
3	K and Double Warren (KDWT)	A typical tower is 400-KV double circuit tower with angle of inclination is 2°, the basic tower is 8.83 m base width & 44.34 m height and it changes the parameter of 5.975m base width of 30m height, 7.965m base width of 40 m height and 9.957 m base width of 50 m height of tower.

Table 3.2 Different parameters for all towers

Different bracing of Towers	Height (Meter)	Base width (Meter)
Double Warren (DWT)	30	6
	40	8
	50	10
Daimond DT	30	5.4
	40	6.43
	50	8.04
K and Double Warren KDWT	30	5.975
	40	7.965
	50	9.957

SUPPORT CONDITION: The support conditions are considered to be fixed.

MATERIAL PROPERTIES: The general practice is to use the steel for tower members having the modulus of elasticity of material as 2.1 x 10^5 N/mm^2 and density of the material as 7850 kg/m^3. The following sectional properties are considered in this thesis are given in table 3.2.

Table 3.3 Sectional Properties

Serial No	Different Components	Angle Section
1	Leg members	200x200x25
2	Main members	150x150x12
3	Secondary members	200x200x12
4	Cross arms	150x150x15
5	Diaphragm	80x80x6

TYPES OF LOADS

Dead load

Dead loads on the transmission towers consist of cross arms, insulators and self-weight of the transmission towers in addition to its weight of bracings etc. Further additional special dead loads such as main members, leg members, secondary members and diaphragm.

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Live load

The live load on transmission towers consist of the gravitational load servicing as well as lineman tools and its intensity is taken as per IS: 802-1995. In addition to that special live loads are to be taken.

Earthquake load

Since earthquake load on a building depends on the mass of the building, earthquake loads usually do not govern the design of light industrial steel buildings. Wind loads usually govern. However, in the case of transmission towers with a large mass located at the too high structure, the earthquake load may govern the design. These loads are calculated as per IS: 1893(part1)-2002.

LOAD CONSIDERED ON TRANSMISSION LINE TOWERS

INTRODUCTION

CBIP manual "Transmission Line Manual" states that tower loading is most important part of tower design. Any mistake or error in the load assessment will make the tower design erroneous. Various types of loads are

to be calculated accurately depending on the tower design parameters. In the load calculation the wind plays a vital role. The correct assessment of wind will lead to proper load assessment and reliable design of tower structure.

The following load cases are considered in this thesis.

- Dead load is the self-weight of tower members, ground wire, conductor and insulators.
- Live load on the tower is lineman with tools and accessories as per IS 802 (part 1: sec 1)-1995.
- Wind load on the tower members is taken for normal load condition as per IS 802 (part 1: sec 1)1995 and IS 875(part3)-1987.
- Earthquake load on the tower is considered as per IS 1893(part1): 2002.

The loading criteria for the transmission line tower as given by CBIP "Transmission Line Manual" are as follows.

- Reliability
- Security
- Safety

Reliability

Reliability of a transmission system is the probability that the system would perform its function task under the designed load criteria for a specified period. Thus, this covers climatic loads such as wind loads and/or ice loads.

Security

Security of a transmission system is the capacity of the system to protect itself from any major failure arising out of the failure of its components. Thus, this covers unbalanced longitudinal loads and torsional loads due to broken wires

Safety

Safety of a transmission system is the ability of the system to provide protection against any injuries or loss of lives to human beings out of the failure of any of its components. Thus, this covers loads imposed on tower during the construction of transmission line and loads imposed on tower during the maintenance of transmission line.

Nature of Loads as given by CBIP in "Transmission Line Manual" is as follows:

Transverse loads

This type of load includes

- Wind load on tower structure, conductor, ground wire and insulator strings.
- Component of mechanical tension of conductor and ground wire.

Vertical loads: This type of load includes

- Loads due to weight of each conductor, ground wire based on appropriate weight span, weight of insulator strings and fittings.
- Self-weight of the structure.
- Loads during construction and maintenance.

Longitudinal loads: This type of load includes enbalanced horizontal loads in longitudinal direction due to mechanical tension of conductor and or ground wire during broken wire condition.

Anti-Cascading checks:

- In order to prevent the cascading failure in line, angle towers are checked for anti-cascading loads for all conductors and g. wires broken in the same span.

Loading Combinations given by the IS 802: Part 1: Sec: 1:1995 are as follows:

Reliability Condition (Normal Condition):

- Transverse loads
- Vertical loads
- Longitudinal loads

Security Condition (Broken Wire Condition)

- Transverse loads
- Vertical loads
- Longitudinal loads

Safety Condition (Construction and Maintenance):

Normal Condition:

- Transverse loads

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- Vertical loads
- Longitudinal loads

Broken Wire Condition:

- Transverse loads
- Vertical loads
- Longitudinal loads

Anti-Cascading loads:

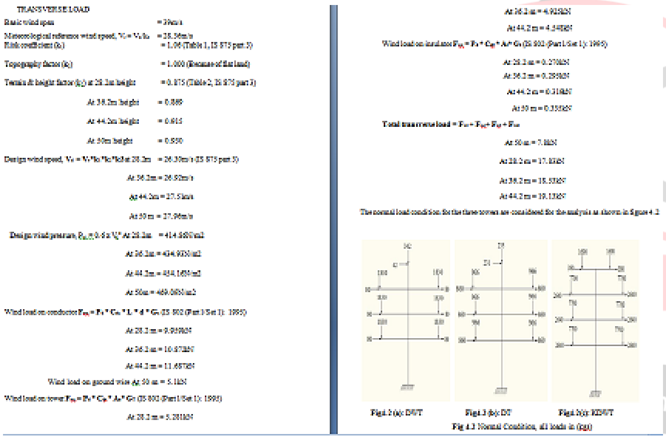
Broken Wire Condition:

- Transverse loads
- Vertical loads
- Longitudinal loads

Out of all these above load cases, normal load condition is considered in this thesis

PARAMETERS FOR THE TRANSMISSION LINE AND ITS COMPONENTS

The following parameters for validation model are Basic wind speed 39m/s, 400kV double circuit the span between two towers (L) is 400 m; the diameter (d) for ground wire, conductor wire and insulator is considered as 11.0 mm, 31.77 mm and 255 mm, respectively angle of deviation (Φ) is taken as 2, unit weight (w) for ground wire and conductor wire are 0.7363kg/m and 2 kg/m respectively.



TRANSVERSE LOAD

Basic wind speed = 39m/s

Meteorological reference wind speed, $V_R = V_b/k_0$ = 35.36m/s

Risk coefficient (k_1) = 1.06 (Table 1, IS 875 part 3)

Topography factor (k_3) = 1.000 (Because of flat land)

Terrain & height factor (k_2) at 28.2m height = 0.875 (Table 2, IS 875 part 3)

At 38.2m height = 0.889

At 44.2m height = 0.915

At 50m height = 0.930

Design wind speed, $V_d = V_R*k_1*k_2*k_3$ at 28.2m = 26.30m/s (IS 875 part 3)

At 38.2m = 26.92m/s

At 44.2m = 27.5km/s

At 50 m = 27.96m/s

Design wind pressure, $P_d = 0.6 \times V_d^2$ At 28.2m = 414.88N/m2

At 38.2m = 434.93N/m2

At 44.2m = 454.16N/m2

At 50m = 469.08N/m2

Wind load on conductor $F_{wc} = P_d * C_{dc} * L * d * G_c$ (IS 802 (Part I/Sec 1): 1995)

At 28.2 m = 9.95kN

At 38.2 m = 10.87kN

At 44.2 m = 11.68kN

Wind load on ground wire At 50 m = 5.1kN

Wind load on tower $F_{wt} = P_d * C_{dt} * A_e * G_t$ (IS 802 (Part I/Sec 1): 1995)

At 28.2 m = 5.28kN

At 38.2 m = 4.92kN

At 44.2 m = 4.54kN

Wind load on insulator $F_{wi} = P_d * C_{di} * A_i * G_i$ (IS 802 (Part I/Sec 1): 1995)

At 28.2 m = 0.27kN

At 38.2 m = 0.29kN

At 44.2 m = 0.31kN

At 50 m = 0.33kN

Total transverse load = $F_{wc} + F_{wt} + F_{wi} + F_{wg}$

At 50 m = 7.1kN

At 28.2 m = 17.8kN

At 38.2 m = 15.5kN

At 44.2 m = 19.13kN

The normal load condition for the three towers are considered for the analysis as shown in figure 4.2

Fig 4.2 (a): DWT Fig 4.3 (b): DT Fig 4.3(c): KDWT

Fig 4.3 Normal Condition, all loads in (kg)

EARTHQUAKE LOAD

Introduction

Ground vibrations during an earthquake can cause severe damage to structures leading to loss of human lives and property. The ground vibrations at a site are influenced by various factors, the most important of which are

- Earthquake mechanism,
- Properties of the medium of the path of propagation of the seismic waves
- Local site conditions.

It has long been realized that the presence of soft soil layers near the earth's surface causes an increase in the amplitudes of seismic waves. This phenomenon is known as site amplification, and is mainly caused due to the low impedance of soil layers near the earth's surface. The magnitude of site amplification depends upon the depth to the bed rock as well as the type, thickness and properties of the soil layers above the bed rock. Hence, these factors need to be taken into consideration while determining the earthquake ground motions at a given site.

In this dissertation the earthquake loads are considered is equivalent static analysis, response spectrum and time history as per IS 1893 (part 1): 2002.

Generation of Response Spectra as per IS 1893-2002

The parameters considered are type of soil, type of construction, the dynamic behaviour of the structure and the appropriate seismic zone. The earthquake spectrum is an average smoothened plot of maximum acceleration as function of frequency or time period of vibration for a specified damping and for a sitespecific condition.

According to the code, India is classified into four seismic zones i.e. Zone II, Zone III, Zone IV and Zone V as in Figure 4.3. The code specifies forces for analytical design of structures for the structures standing on rocks or soil for above four zones and different value of damping of the structure. For the purpose of analysis, the acceleration spectrum has been prepared for all the four zones assuming damping as 5% and the soft soil condition.

ASSUMPTIONS IN EARTHQUAKE RESISTANT DESIGN

The following assumptions are made in the earthquake resistant design of structures

- Earthquake causes impulsive ground motions, which are complex and irregular in character, changing in period and amplitude each lasting for a small duration. Therefore, resonance of the type as visualized under steady-state sinusoidal excitations will not occur, as it would need time to build up such amplitudes.

Earthquake is not likely to occur simultaneously with wind or maximum flood or maximum sea waves.

- The value of elastic modules of materials, wherever required, may be taken as for static analysis unless a more definite value is available for use in such condition

The Design response spectra for all the seismic zones are tabulated in table 4.3 and shown in Figure 4.5

Table 4.3: Design Response Spectrum in 'g' for Seismic Zone II, III, IV and V

Time (Sec)	Zone II	Zone III	Zone IV	Zone V
4	0.006	0.010	0.015	0.022
2	0.012	0.020	0.030	0.045
1.33	0.018	0.030	0.045	0.067
1	0.025	0.040	0.060	0.090
0.669	0.037	0.060	0.089	0.134
0.5	0.037	0.060	0.090	0.135
0.2	0.037	0.060	0.090	0.135
0.1	0.037	0.060	0.090	0.135
0.066	0.030	0.048	0.072	0.108
0.05	0.026	0.042	0.063	0.094
0.04	0.024	0.038	0.057	0.086
0.033	0.022	0.036	0.054	0.081
0.028	0.021	0.034	0.051	0.077
0.025	0.020	0.033	0.049	0.074
0.022	0.020	0.032	0.048	0.072
0.02	0.019	0.031	0.046	0.070

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V. GENERATION OF TIME HISTORY

Time history analysis is a type of dynamic analysis to obtain the response of the structure at each increment of time. The time history analysis is considered exact and yields accurate data. However, this analysis is quite involved with lot of computational effort. The design response spectra developed for zones II, III, IV and V are converted to time history data in terms of acceleration using Data Analysis Package (DAP) software as shown in Figure 4.6

MODEL

INTRODUCTION

The tower consider for validation from the journal paper by Y. M. Ghugal (2011).The structural system consists of a configuration is 400 kV double circuit transmission line tower.

CODE OF PRACTICE

IS: 802 (Part 1 / Sec 1): 1995, IS: 5613 (Part 2 / Sec 1): 1989. And IS1893-2002

MATERIAL PROPERTIES

The following parameters are Basic wind speed 39m/s, 400kV double circuit the span between two towers (L) is 400 m, the diameter (d) for ground wire, conductor wire and insulator is considered as 11.0 mm, 31.77 mm and 255 mm respectively. angle of deviation (Φ) is taken as 2° unit weight (w) for ground wire and conductor wire are 0.7363kg/m and 2 kg/m respectively.

STRUCTURAL ELEMENT DIMENSIONS

The following parameters are Base width is 8.5m x 8.5m, Hamper (Cage) width is 3.6m x 3.6m, Topmost Hamper width (Ground wire) is 2m x 2m and Total tower height is 50m.

LOADS AND LOAD COMBINATIONS

Load due to conductor in transverse direction wind load for Normal condition, Broken Wire Condition Left Bottom Conductor, Left Middle Conductor, Left Top Conductor, Left Ground Wire. Primary Normal Load cases are considered for the design and compare the results.

Dead loads (DL)

Self-weight of the structure is assigned to the transmission tower by using the software. However, the components not modelled such as insulators have been applied as super imposed load on the structure.

Live loads (LL)

Super imposed Live Load for Ground wire = 19.3kN Super imposed Live Load for Cross arm = 37.5kN

Earthquake load

Zone: Zone –II Zone factor: 0.10

Importance factor: 1.5

Response reduction factor: 5.0 for (Special Moment Resisting Frame) Soil Type: Soft

A Transmission line tower of validation model for normal loading conditions as shown in figure below

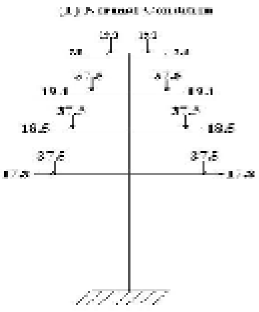

Fig 4

A typical four legged transmission line tower model is considered for validation as shown in figure below

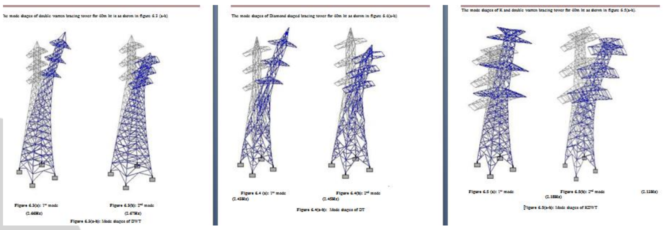

Fig 5

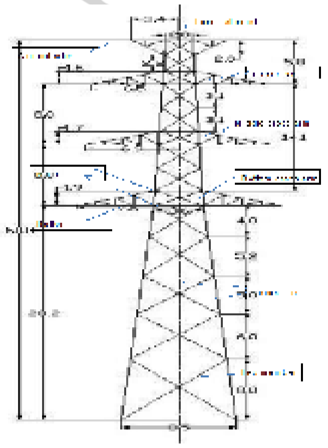

Fig 6

The analysis results obtained from the present work is compared with the journal paper results are tabulated in table 5.1 and 5.2

Table 5.1: Maximum axial force for normal loading condition

Sl no	Node Points	Maximum Axial Force for Four Legged Tower (kN)	
		Journal paper results	Present Results
1	Leg	613.1	618.5
2	Main Members	108.4	99.37
3	Secondary Members	6.9	7.79
4	Cross Arm	98.2	98.6
5	Diaphragm	24.8	25.7

Table 5.2: Maximum displacement for normal loading condition

Sl no	Node points	Maximum displacement for Four Legged Tower (mm)	
		Journal paper results	Present Results
1	Bottom Hamper Point	66.3	66.0
2	Bottom Cross arm Tip	85.3	84.5
3	Middle Cross arm Tip	126.2	125.2
4	Top Cross arm Tip	179.3	180.5
5	Ground Wire arm Tip	212.6	213.2
6	Topmost point of Leg	210.3	210.5

RESULTS

The results of maximum axial force and displacement obtained from the present work matches closely with

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VI. FE ANALYSIS FOR TRANSMISSION TOWERS

DESCRIPTION OF TOWERS

Towers under study are self-supporting towers with four legs, different heights and capacities, which are designed and installed, based on the wind load as the controlling design factor. The samples selected for this thesis are from three different towers with varying heights and different types of bracings with an angle section are generally being used in the members of the tower. The elastic modulus of the used for angle section is 210x103 N/mm2 and their unit weight is 7850 kg/m3. The connections are generally composed of nuts and bolts and plates are used as an interface member. The general shape of the towers can be seen in Figure 6.1

TOWER GEOMETRY

Tower geometry portrays life structures of tower and consider included deciding the blueprints of the towers. The determination of an ideal blueprint along with right sort of supporting framework adds to an enormous degree in building up a practical structure of transmission line towers. The geometry of a pinnacle has likewise bearing on stylish qualities.

The three types of transmission line towers consider in this thesis are shown in figure 6.1 and table 6.1 gives the details of base width, hamper width, nmber of nodes and number of members obtained from the FE analysis.

Table 6.2: Frequencies obtained frommodal analysis

Height of tower	Modes	Frequency(Hz)		
		DWT	DT	KDWT
30	1	3.97	3.81	3.06
	2	3.99	3.83	3.09
	3	12.32	6.65	5.16
40	1	2.66	2.43	2.13
	2	2.67	2.45	2.18
	3	9.44	4.16	4.72
50	1	2.12	1.88	1.74
	2	2.12	1.88	1.75
	3	6.51	3.64	4.61

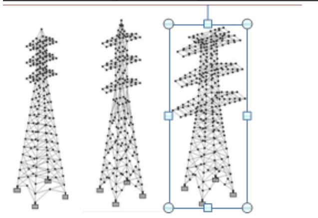
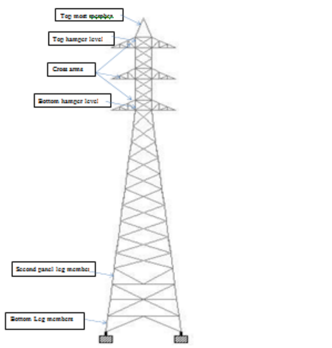


Figure 6.1(a-c): Geometry for three types of transmission line towers

Table 6.1: Geometry for all three tower towers

Towers	Height (Meter)	Base width (Meter)	Hamper width (Meter)	No of nodes	No of members
DWT	30	6	1.65	227	677
	40	8	1.65	237	684
	50	10	1.65	265	747
DT	30	5.4	1.65	263	709
	40	6.62	1.65	270	775
	50	8.06	1.65	327	972
KDWT	30	5.975	3.535	366	982
	40	7.965	3.535	436	1155
	50	9.957	3.535	379	1167

Typical transmission line tower with different member demensis as shown in figure 6.2. the main component considered in the analysis results are bottom leg , second panel, bottom hamper level, top hamper level, top most leg member top cross arms and bottom cross arm.



MODAL ANALYSIS

Mode shapes are intrinsic properties of a structure, and are dictated by the material properties (mass, damping, and firmness), and limit states of the structure. Following are the advantages of modular examination,

- It permits the plan to stay away from thunderous vibrations or to vibrate at a predefined recurrence
- It gives builds a thought of how the structure will react to various sorts of dynamic burdens.

Since a structure's vibration qualities decide how it reacts to the dynamic burden, it is consistently required to perform modular investigation first.

Figure 6.3(a-b) to 6.5(a-b) shows the first and second mode shapes for all types of tower and The modal frequencies for all towers with varying height are tabulated in table 6.2

RESPONSE SPECTRUM ANALYSIS

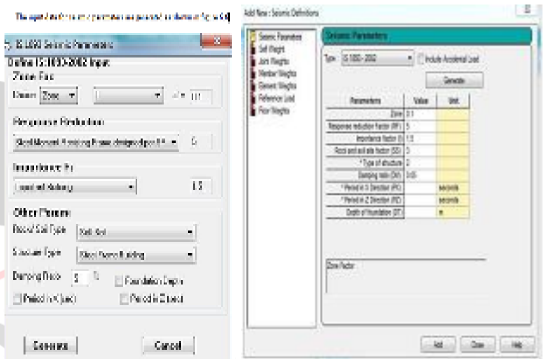


Figure 6.7: Response spectrum input data for generation

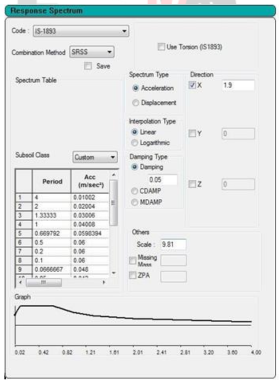


Figure 6.8: Response spectrum curve definitions and scale factor

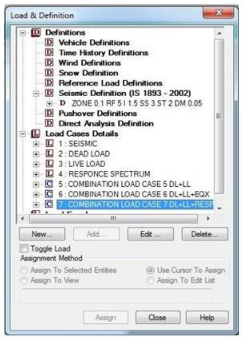
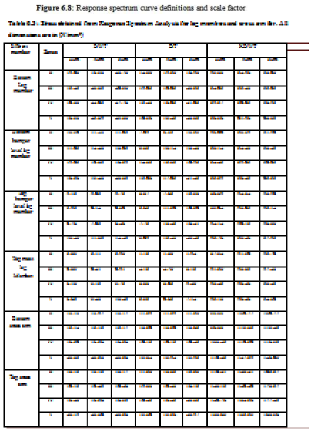
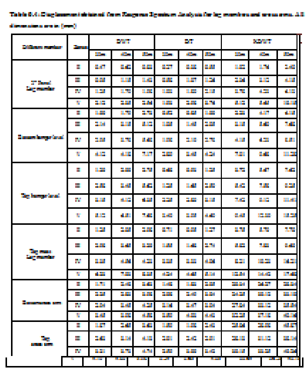


Figure 6.9: Load cases and load combination are considered for the analysis





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VII. RESULTS

Response spectrum analysis is carried out for all types of tower with different parameters to get the maximum stresses and maximum displacement. These results are tabulated for leg members and cross arms as given below in table 6.3 & 6.4

RESULTS AND DISCUSSIONS

RESPONSE SPECTRUM ANALYSIS

Response Spectrum analysis is performed on the all three types of transmission line towers for all the seismic zones as per IS 1893(part1)-2002. Maximum stresses and maximum displacements at pivotal points are tabulated in Table 7.4 and 7.5 for zone V respectively. Maximum stresses and displacements of three type towers for main leg members are shown in figure 7.1 to 7.6 respectively.

Table7.4: Maximum stresses for Zone V from response spectrum analysis (N/mm²)

Different member	DWT			DT			KWDT		
	30m	40m	50m	30m	40m	50m	30m	40m	50m
Bottom leg member (1)	18.92	25.34	29.30	16.98	19.25	23.05	58.98	62.48	69.05
Bottom hanger level (2)	18.58	19.23	20.35	15.68	17.65	21.25	55.54	58.25	65.55
Top hanger level (3)	10.20	11.05	12.25	9.64	15.23	20.25	45.78	50.28	57.45
Top most leg member (4)	8.85	9.23	10.25	5.95	6.85	7.12	45.13	48.25	52.36
Bottom cross arm	20.25	20.53	20.58	19.02	19.42	19.45	116.25	127.5	128.6
Top cross arm	20.14	20.36	20.58	19.36	19.58	20.47	130.89	135.5	180.9

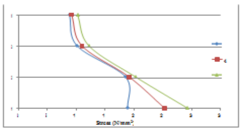


Figure 7.1: Maximum stress of DWT tower for main leg members

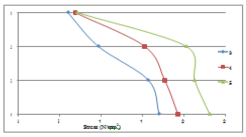


Figure 7.2: Maximum stress of DT tower for main leg members

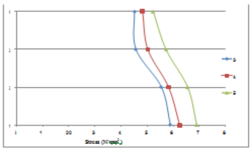


Figure 7.3: Maximum stress of KWDT tower for main leg members

Result clearly shows that as the height increases stresses increases. The towers DWT and DT are within the permissible limits whereas the cross arm of KWDT tower fails for zone V when the height is 40m and 50m. The increases of stresses in bottom leg member form 30m to 50m height for DWT is 37%, DT is 26% and KDWT is 20% respectively. Similarly the displacement increases as the height increases but the displacement for all the towers are within 5% of the tower height. The increase of displacement in top most member form 30m to 50m height for DWT is 68 %, DT is 70% and KDWT is 84% respectively

Different member	DWT			DT			KWDT		
	30m	40m	50m	30m	40m	50m	30m	40m	50m
2nd panel leg member (2)	2.12	2.35	2.56	1.93	2.98	3.76	5.12	5.65	10.15
Bottom hanger level (3)	4.12	4.18	7.17	2.89	3.45	4.24	7.01	9.68	11.28
Top hanger level (4)	5.12	6.51	7.68	3.60	3.95	4.60	9.45	12.30	15.25
Top most leg member (5)	6.23	7.03	8.35	4.24	4.65	5.14	12.54	14.62	17.68
Bottom cross arm	3.45	3.98	4.58	3.59	4.03	4.63	32.25	37.18	60.16
Top cross arm	4.10	4.80	5.98	3.24	3.65	4.05	33.64	36.25	63.15

Table 7.5: Maximum displacement for Zone V from response spectrum analysis (mm)

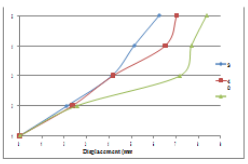


Figure 7.4: Maximum displacement of DWT tower for main leg members

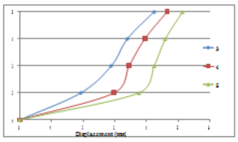
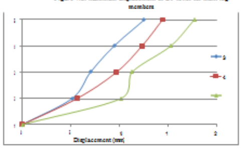


Figure 7.5: Maximum displacement of DT tower for main leg members



Result clearly shows that as the height increases stresses increases. The towers DWT and DT are within the permissible limits whereas the cross arm of KWDT tower fails for zone V when the height is 50m. The increases of stresses in bottom leg member form 30m to 50m height for DWT is 54%, DT is 35% and KDWT is 7% respectively.
Similarly the displacement increases as the height increases but the displacement for all the towers are within 5% of the tower height. The increases of displacement in top most member from 30m to 50m height for DWT is 35 %, DT is 21% and KDWT is 68% respectively

TIME HISTORY ANALYSIS

Time history analysis is performed on all three transmission line tower for all the seismic zones as per IS 1893(part1)-2002. Maximum stresses and maximum displacements at pivotal points are tabulated in Table and 7.7 for zone V respectively. Maximum stresses and displacements of three type towers for main leg members are shown in figure 7.7 to 7.12 respectively.

Table 7.6: Maximum stress for Zone V from time history analysis (N/mm²)

Different member	DWT			DT			KWDT		
	30m	40m	50m	30m	40m	50m	30m	40m	50m
Bottom leg member (1)	42.31	48.80	58.17	40.25	45.0	50.94	107.86	126.63	129.45
Bottom hanger level (2)	32.26	35.82	38.94	36.92	42.51	42.78	93.90	106.86	110.90
Top hanger level (3)	7.23	7.96	9.0	8.39	9.10	10.21	43.95	53.13	67.95
Top most leg member (4)	6.74	7.24	8.40	5.23	5.95	6.25	22.86	23.79	55.06
Bottom cross arm	20.58	18.28	22.84	16.22	23.10	22.71	120.49	111.74	128.66
Top cross arm	17.56	14.09	14.03	15.01	17.92	26.93	148.24	160.68	219.05

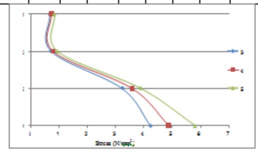


Figure 7.7: Maximum stress of DWT tower for main leg members

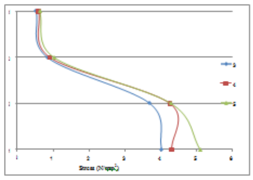


Figure 7.8: Maximum stress of DT tower for main leg members

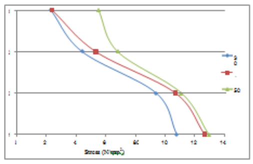


Figure 7.9: Maximum stress of KWDT tower for main leg members

Table 7.7: Maximum displacement for Zone V from time history analysis (mm)

Different member	DWT			DT			KWDT		
	30m	40m	50m	30m	40m	50m	30m	40m	50m
2nd panel leg member (2)	2.98	3.18	3.41	2.44	4.92	5.02	4.65	8.05	8.29
Bottom hanger level (3)	11.47	19.27	29.06	7.01	16.66	25.58	8.35	21.67	30.55
Top hanger level (4)	28.96	37.50	51.46	19.18	33.23	46.92	42.70	72.29	79.05
Top most leg member (5)	34.38	43.04	57.73	28.65	41.75	48.96	45.66	76.74	83.98
Bottom cross arm	13.36	21.24	31.41	8.69	18.13	27.08	38.22	53.20	57.21
Top cross arm	28.33	37.11	50.63	18.96	34.66	48.84	63.88	87.61	111.98

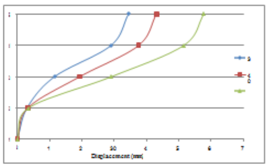


Figure 7.10: Maximum displacement of DWT tower for main leg members

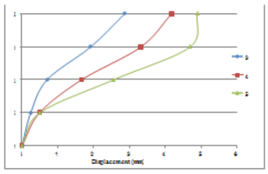


Figure 7.11: Maximum displacement of DT tower for main leg members

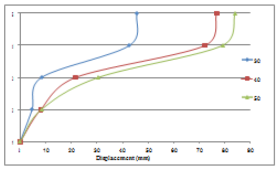


Figure 7.12: Maximum displacement of KWDT tower for main leg members

VIII. CONCLUSIONS AND FUTURE SCOPE

In this dissertation work efforts are made to understand the behaviour of transmission line tower under seismic and wind induced dynamic loads. Three types of towers are considered in the study by varying the parameters like height and base width of towers. Finite element analysis is carried out on the transmission line tower and the results are tabulated, discussed and conclusions are drawn. The following are the major conclusions from this dissertation work.

1 Response spectrum and time history graphs are generated as per IS 1893(part1):2002 which are adopted for seismic loads in finite element analysis.

2 Wind loads with gust factor are calculated for normal load condition as per IS 802(part1/sec1):1995 which is adopted for wind loads in finite element analyses.

3 A typical transmission line tower finite element model is validated by comparing the results with the literature.

4 Result from the modal analysis shows that as the height increases the natural frequencies reduces which shows the reduction in stiffness. The modal frequencies obtain for all the towers lies in the peak range of response spectrum, which needs to be further analysed under dynamic loads.

5 Response spectrum analysis result shows that as the height increases stresses increases. The stresses in DWT and DT towers are within the permissible limits whereas the cross arm of KWDT tower fails for zone V when the height is 50m. The increase of stresses in bottom leg member from

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30m to 50m height for DWT is 54%, DT is 35% and KDWT is 7% respectively.

6 Response spectrum analysis result shows that the displacement increases as the height increases and the displacement for all the towers are within 5% of tower height. The increase of displacement in top most members from 30m to 50m height for DWT is 35 %, DT is 21% and KDWT is 68% respectively.

7 Time history analysis result shows that as the height increases stresses increases. The stresses DWT and DT tower are within the permissible limits whereas in the cross arm of KWDT tower fails for zone V when the height is 40m and 50m. The increase of stresses in bottom leg member from 30m to 50m height for DWT is 37%, DT is 26% and KDWT is 20% respectively.

8 Time history analysis result shows that the displacement increases as the height increases but the displacement for all the towers are within 5% of the tower height. The increase of displacement in top most members from 30m to 50m height for DWT is 68 %, DT is 70% and KDWT is 84% respectively.

9 Wind analysis result shows that as the height increases stresses increases. The stresses in DWT and DT towers are within the permissible limits whereas the cross arm of KWDT tower fails for zone V when the height is 50m. The increase of stresses in bottom leg member from 30m to 50m height for DWT is 145%, DT is 34% and KDWT is 14% respectively.

10 Wind analysis result shows that displacement increases as the height increases and the displacement for all the towers are within 5% of the tower height. The increase of displacement in top most members from 30m to 50m height for DWT is 202 %, DT is 168% and KDWT is 155% respectively.

11 Out of the three bracing types K and Double Warren Bracing tower (KWDT) type is the most effective followed by DWT and DT respectively.

SCOPE FOR FUTURE WORK

1 Shake table tests on scale down models of Transmission line tower can be carried out to understand its dynamic behaviour experimentally.

2 K and double warren bracing tower can be replaced by X and diamond bracing and analysed on transmission line tower.

3 The aspect ratios of different height to base width and bracings can be varied and analysed, so that design graphs can be generated.

4 The analysis can be done for different real time history data available from different earthquakes.

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