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"Comparative Study of Transmission Line Tower with Different Bracing Patterns Using Response Spectrum Method"

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Abstract—*Electricity consumption is day by day increase for each and every application. Transmission line towers constitute about 28 to 42 percent of the cost 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. The main objective of this study is to determine the most economical section of tower and its configuration as per Indian Standard IS-800. In this project the studies will be carried on transmission line tower in SAP2000 software. There will be comparative study of analysis of transmission line tower with different bracing patterns and study their progressive collapse behavior of transmission line tower in both software's. A standard kind of transmission line tower will be selecting as case examine will analyzed and modeled by using SAP2000 software. The present work describes the analysis and design of four legged self-supporting 220 KV double circuit power. The transmission tower has a height of 40 m and square base width of 11.5 m. The members are also grouped for better fabrication. Steel optimization has been carrying out to find the most suitable and economical section for the design. Loads acting on the tower are wind load; earthquake load dead load of the structure. All the considered towers will be analyzed for gravity and lateral loads (IS: 875(part-III)). The comparative study will be presented with respective to base shear, self-weight, modal time period, modal mass participation and weight of tower.*
Keywords: *Transmission Line Tower, Response Spectrum, time history Earthquake Loading, Loading, Wind Loading.*

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I. INTRODUCTION

General Introduction

The increasing demand for electrical energy can be met more economically by developing different light weight configurations of transmission line towers. The selection of an optimum outline together with right type of bracing system, height, cross arm type and other parameters contributes to a large extent in developing an economical design of transmission line tower.

Transmission tower lines are one of most important life-line structures. Transmission towers are necessary for the purpose of supplying electricity to various regions of the nation. This has led to the increase in the building of power stations and consequent increase in power transmission lines from the generating stations to the different corners where it is needed. Transmission line should be stable and carefully designed so that they do not fail during natural disaster. It should also conform to the national and international standard. In the planning and design of a transmission line, a number of requirements have to be met from both structural and electrical point of view. From the electrical point of view, the most important requirement is insulation and safe clearances of the power carrying conductors from the ground. The cross-section of conductors, the spacing between conductors, and the location of ground wires with respect to the conductors will decide the design of towers and foundations.

Transmission tower are modeled by using different bracing patterns. Axial forces, deflections and weight of tower vary with bracing pattern. Certain bracing pattern reduce weight of tower. The major components of a transmission line consist of the conductors, ground wires, insulation, towers and foundations. Most of the time transmission lines are designed for wind and ice in the transverse direction.

Types of Transmission Towers

The electric transmission tower can be classified several ways. The most obvious and visible type towers are

1. Lattice structure
2. Tubular pole structure

A. Lattice structure

Lattice steel towers are made up of many different steel structural components connected together with bolts or welded. These towers are also called self-supporting transmission towers or free-standing towers, due to their ability to support themselves. These towers are not always Made of steel, they can also be made of aluminum or galvanized steel.

B. Tubular pole structure

Tubular steel poles are another of the major types of transmission towers. They are made up of hollow steel poles. Tubular steel poles can be manufactured as one large piece, or as several small pieces which fit together.

Components of transmission tower

Transmission tower consists of following parts

A. Boom of transmission tower
B. Cage of transmission tower
C. Cross arm of transmission tower
D. Peak of transmission tower
E. Transmission tower body's

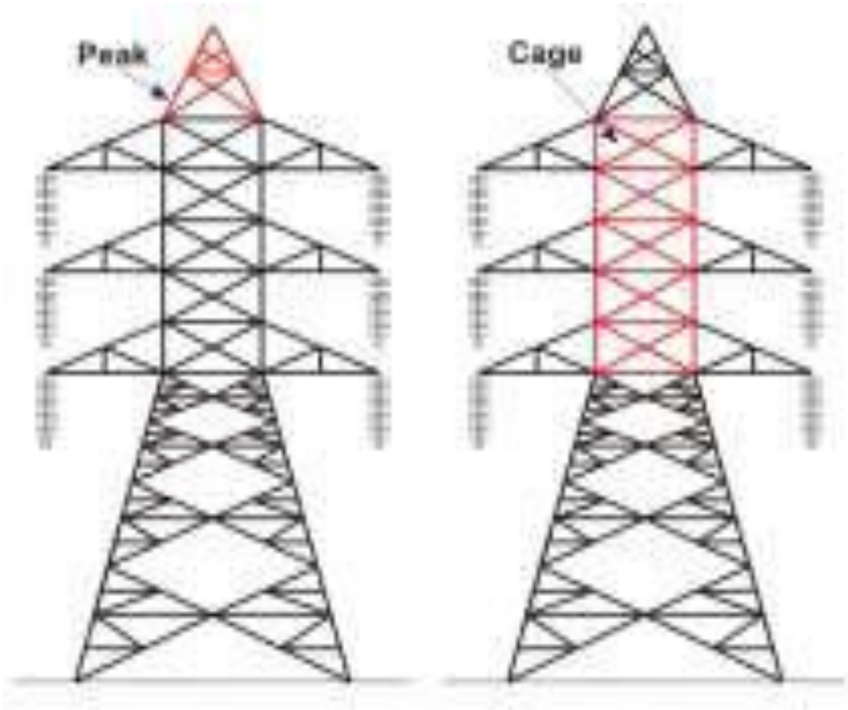


Fig.- 1 Transmission line Tower

II. RESEARCH OBJECTIVE

Based on the literature review presented in Chapter 2, the salient objectives of the Present study have been identified as follows,

1. The main objective of this study is analyzing the transmission line tower by using different bracing patterns to achieve the most economical and stable structure
2. To perform dynamic analysis of transmission line tower using response spectrum method.
3. Analysis of double bracing, knee bracing and single bracing tower with IS1893-2016 analysis of steel structure using SAP2000 software.
4. To analyze the transmission line tower system when subjected to dead load, live load, earthquake load and wind load by using SAP2000 software.
5. To determine the base shear force, time period, modal mass participations, self-weight of transmission line tower.
6. To study the effect of unsymmetrical configuration of wires on transmission line tower.

III. PROJECT STATEMENT

The study will give more knowledge which result into benefits for future implementation with the help of steel analysis and detailing of steel.

I. Response Spectrum Method

This method is applicable for those structures where modes apart from the elemental one affect significantly the response of the structure. during this method the response of multi degree of freedom system is expressed because the superposition of modal response, each modal response being determined from the spectral analysis of single degree of freedom system, which is then combined to match the entire response. Modal analysis of the response history of structure to specified ground motion; however, the strategy is sometimes utilized in conjunction with a response spectrum.

3.2 Seismic Base Shear

According to IS 1893 (Part-I): 2002, Clause 7.5.3 the total design lateral force or design seismic base shear (VB) along any principal direction is determined by,

$V_b = A_h * W$

Where,

A_h is the design horizontal acceleration spectrum

W is the seismic weight of building

3.2.1 Design Horizontal seismic coefficient

For the purpose of determining the design seismic forces, the country (India) is classified into four seismic zones (II, III, IV, and V). Previously, there were five zones, of which Zone I and II are merged into Zone II in fifth revision of code. According to IS 1893: 2016 (Part 1), Clause6.4.2 Design Horizontal Seismic Forces Coefficient Ah for a structure shall be determined by following expression.

Table 3.1 Seismic Zones of India

Seismic Intensity	Low	Moderate	Severe	Very Severe
Zone	II	III	IV	V
Z	0.10	0.16	0.24	0.36

India has been divided into four seismic zones. Zone II and Zone III are major zones covering more percentage of land area in India. Eastern India has higher seismic intensity. It fails under zone V. North-East India falls under zone IV. Geographical statistics of India show that almost 54 % of the land is vulnerable to earthquakes. Table 3.1 & Fig.3.2 shows various seismic zones of India with tentative percentage of land area.

I = Importance factor is used to obtain the design seismic force depending on the functional use of the structure, characterized by hazardous consequences of its failure, it's post-

Earthquake functional need, historic value, or economic importance (IS 1893-2016 cl.no.6.4.2/table6/pg.no.18)

R = Response reduction factor depending on the perceived seismic damage performance of the structure characterized by ductile or brittle deformations which is shown in Table 3.2 ((IS 1893-2016 cl.no.6.4.2/Table7/pg.no.23).

Sa/g = Average response acceleration coefficient (dimensionless value). The value of Sa/g is obtained from fig.3.3 from IS: 1893 (Part 1): 2016.

IV. PROBLEMFORMULATION

Proposed Work

After exclusive study of literature carried by various researchers, the unfocused area is identified as problem for proposed dissertation. carried out using following points

1. The main objective of this study is analyzing the transmission line tower by using different bracing patterns to achieve the most economical and stable structure.
2. To perform dynamic analysis of transmission line tower using response spectrum method.
3. Analysis of diagrid bracing, diamond bracing and knee bracing tower with IS1893-2016 analysis of steel structure using SAP2000 software.
4. To analyze the transmission line tower system when subjected to different load conditions by using SAP2000 software.
5. To determine the base shear force, time period, modal mass participations, self-weight of transmission line tower.

Table No 1: Detail Features of Tower Structure

Sr. No	Parameters	Values
1	Material Used	Steel Grade Fe-250
2	Plan Dimension	
3	Total height of tower	40m
5	Unit weight of steel	78.50 KN/m3
6	Poisson Ratio	0.2-Concrete And 0.15-Steel
9	Code Of Practice Adopted	IS800:2007, IS1893:2016 IS875-part -III
10	Seismic Zone for IS1893:2016	IV
12	Importance Factor	1
13	Response Reduction Factor	5
14	Foundation Soil	Medium
18	Live Load	$7KN/M^2$
19	Earthquake Load	As Per IS 1893-2016
20	Size Of section	90x90x10, 65x65x8,55x55x8
24	Ductility Class	IS1893:2016 SMRF

Different bracing pattern

A. Double Bracing Tower Structure

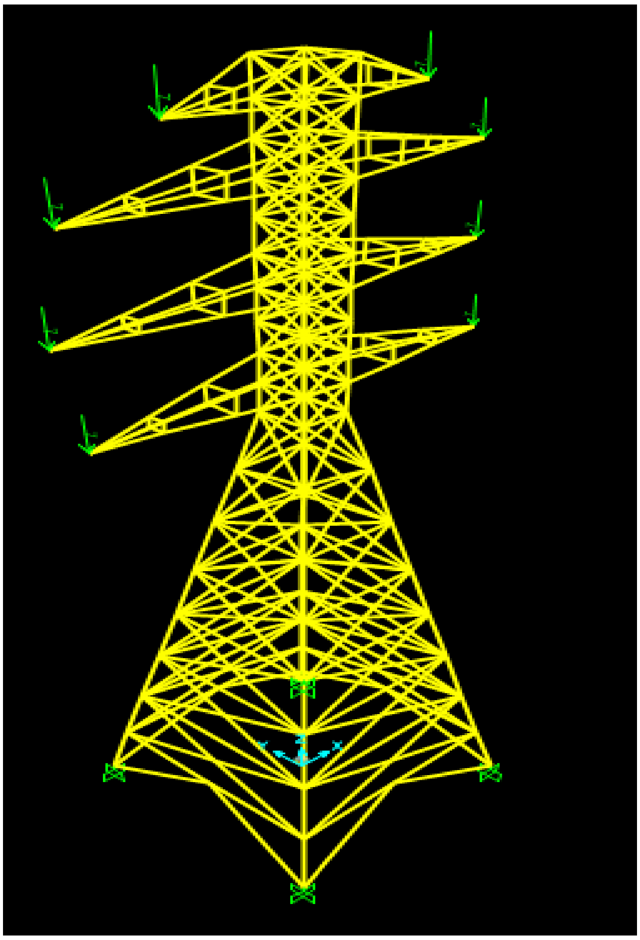


Fig. 1.2 Transmissions Line Tower X-Bracing Modes

Types of Loads

Unless otherwise specified, all loads listed, shall be considered in design for the Indian Code following load combinations shall be considered.

Load case

1) DL: Dead load
2) LL: Live load
3) EQ: Earthquake load
4) W: Wind Load

Load combination

1. 1.5DL+1.5LL
2. 1.2DL+1.2LL + 1.2EX
3. 1.2DL+1.2LL- 1.2EX
4. 1.2DL+1.2LL+ 1.2EY
5. 1.2DL+1.2LL - 1.2EY
6. 1.2DL+1.2LL+1.2WLX
7. 1.2DL+1.2LL-1.2WLX
8. 1.2DL+1.2LL+1.2WLY
9. 1.2DL+1.2LL-1.2WLY
10. (0.9DL±1.5EQ)

V. RESULTS

Base Shear Results

Table 1.2 Base Shear Transmission Line Tower Diamond Bracing Response Spectrum Method

TABLE: Auto Seismic - IS 1893:2016							
Load Pat	**Z Code**	**Soil Type**	**R**	**T Used**	**Coeff Used**	**Weight Used**	**Base Shear**
Text	Text	Text	Unitless	Sec	Unitless	KN	KN
EQ+X	0.24	II	5	0.0624	0.06	1649.213	98.953
EQ-X	0.24	II	5	0.0624	0.06	1649.213	98.953
EQ+Z	0.24	II	5	0.0629	0.06	1649.213	98.953
EQ-Z	0.24	II	5	0.0629	0.06	1649.213	98.953

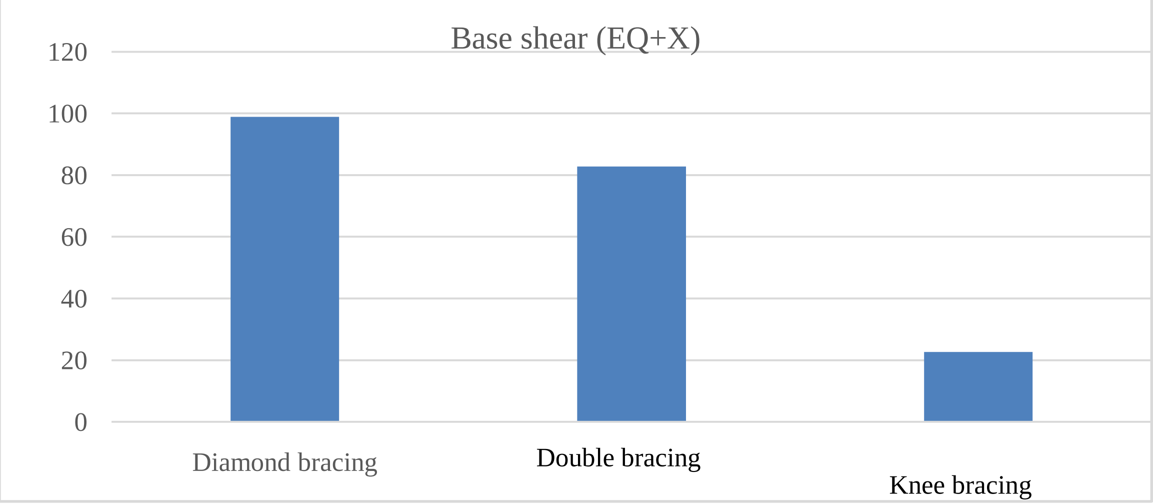
Table 1.3 Base Shear Transmission Line Tower double Bracing Response Spectrum Method

TABLE: Auto Seismic - IS 1893:2016						
Load Pat	**Z Code**	**Soil Type**	**R**	**Coeff Used**	**Weight Used**	**Base Shear**
Text	Text	Text	Unit less	Unit less	KN	KN
EQ+X	0.24	II	5	0.06	1379.958	82.797
EQ-X	0.24	II	5	0.06	1379.958	82.797
EQ+Z	0.24	II	5	0.06	1379.958	82.797
EQ-Z	0.24	II	5	0.06	1379.958	82.797

Table 1.4 Base Shear Transmission Line Tower knee Bracing Response Spectrum Method

TABLE: Auto Seismic - IS 1893:2016						
Load Pat	**Z Code**	**Soil Type**	**R**	**Co effs Used**	**Weight Used**	**Base Shear**
Text	Text	Text	Unit less	Unit less	KN	KN
EQ+X	0.24	II	5	0.026364	858.801	22.641
EQ-X	0.24	II	5	0.026364	858.801	22.641
EQ+Z	0.24	II	5	0.026868	858.801	23.074
EQ-Z	0.24	II	5	0.026868	858.801	23.074

Graph 1.1 Base Shear Vs. Bracing (Single, Double and Knee)



5.2 Modal Time Period

Table 1.5 Modal Time Period Transmission Line Tower Diamond Bracing Response Spectrum Method.

TABLE: Modal Periods and Frequencies			
Output Case	**Step Num**	**Period**	**Frequency**
Text	Unitless	Sec	Cyc/sec
Modal	1	0.229399	4.359207925
Modal	2	0.11903	8.401217041
Modal	3	0.094852	10.54269265
Modal	4	0.088371	11.31598338
Modal	5	0.085938	11.63627409
Modal	6	0.077385	12.92242908
Modal	7	0.062932	15.89020198
Modal	8	0.062436	16.01635614
Modal	9	0.058098	17.2121966
Modal	10	0.051453	19.43526427
Modal	11	0.051115	19.56387861
Modal	12	0.048398	20.66220921

Table 1.6 Modal Time Period Transmission Line Tower double Bracing Response Spectrum Method

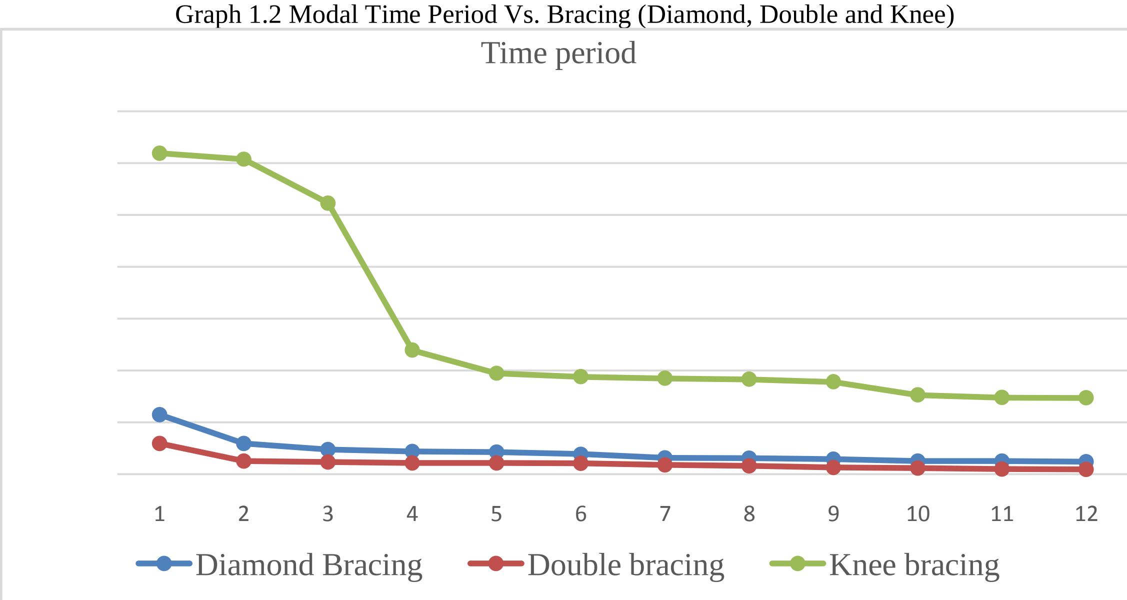
TABLE: Modal Periods and Frequencies			
Output Case	**Step Num**	**Period**	**Frequency**
Text	Unit less	Sec	Cyc/sec
Modal	1	0.11863	8.4294904
Modal	2	0.05127	19.503427
Modal	3	0.04721	21.184336
Modal	4	0.04396	22.749956
Modal	5	0.04337	23.056732
Modal	6	0.04241	23.577455
Modal	7	0.03643	27.447071

Modal	8	0.03284	30.453006
Modal	9	0.02663	37.558506
Modal	10	0.02384	41.943183
Modal	11	0.02029	49.275664
Modal	12	0.01888	52.970287

Table 1.7 Modal Time Period Transmission Line Tower knee Bracing Response Spectrum Method

TABLE: Modal Periods and Frequencies			
Output Case	**Step Num**	**Period**	**Frequency**
Text	Unit less	Sec	Cyc/sec
Modal	1	1.23807	0.8077089
Modal	2	1.21483	0.8231604
Modal	3	1.0452	0.9567562
Modal	4	0.47831	2.0906912
Modal	5	0.38874	2.5723967
Modal	6	0.37566	2.6620019
Modal	7	0.36943	2.706888
Modal	8	0.36603	2.7320112
Modal	9	0.35622	2.8072197
Modal	10	0.30567	3.2715092
Modal	11	0.2956	3.3829857
Modal	12	0.29421	3.3989396

Graph 1.2 Modal Time Period Vs. Bracing (Diamond, Double and Knee)



VI. CONCLUSION

In the present study, Relative Analysis of transmissions line tower using different bracing pattern in structure with different seismic zone I. e zone III & Zone IV

The structures are analyses for earthquake zone III & Zone IV with medium soiland Results Compare. It has been made on different structural parametersviz. base shear, Earthquake displacement, time period and modal mass participationsetc. Grounded on the analysis results following conclusions are drawn.

1. Analysis of transmission line tower with various bracing in zone IV. The base shear in x- direction, single and double bracing base shear is closely spaced, while double bracing base shear increased 1.27 times as compare to knee bracing system.
2. Transmission line tower with various bracing. The natural time period of double bracing and knee bracing are closely spaced, while single bracing time period increased 1.29 times as compare to double bracing and knee bracing.
3. Comparing double bracing with knee bracing, the knee bracing time period increase 1.06 times as compare double bracing shows quite good performance in natural time periods.

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Code Used

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