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Modal Behavior Analysis of 220kV Transmission Line Tower using SAP 2000 in Wind Zones I and V

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Abstract*: *For every developing country, Electrical system plays a crucial role not only in developing the Nation's economy but also in survival of human beings. The present study deals with a typical 3 Dimensional 220 kV double circuit transmission-line tower is modelled using Sap 2000. The loading conditions considered are normal, earthwire broken and conductor broken conditions. The wind zones I and V are considered since wind zone I has the lowest wind speed 33m/s and for wind zone V having wind speed 50 m /s (Visakhapatnam). All the other parameters like steel sections, height of tower and base width of tower is kept constant for studying the results after the analysis is done. After analysis of tower corresponding wind zones, the results are compared for maximum axial positive and negative deflections, reactions at the supports, different mode shapes and time period, modal mass participation factors, modal participation factors for modal stiffness and frequencies, Eigen value.

***Index Terms*: *Modal stiffness, frequencies, modal participations factors, Eigen value and deflections*.**

I. INTRODUCTION

For the production of electricity, it requires a source of fossil fuels, water, wind and the temperature. With the above sources, power can be generated with use of turbines. After production, this power should be distributed for different places in the country. Since power capacity is high, transmission line tower is used for distribution. The distribute power can be utilized for different purposes depending on the usage.

1.1 Transmission line tower: Transmission tower lines are life-line structures. Electricity can be supplied to various regions of the nation by using Transmission line tower. Tall structures with relatively small cross section with a large ratio between height and maximum base width are known as towers. These are used when lines are to be supported at longer distances.

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1.2 SAP 2000: SAP stands for Structural Analysis Program. Static, dynamic and finite element analysis of structures can be done using software. It is a non linear computer program. In this software analysis, mode shapes, frequencies, Eigen values, modal mass participation factors, modal stiffness can be found out with respect to time period.

In addition to above parameters, nodal axial displacements, support reactions can be also carried out after the analysis.

II. TOWER MODELLING

For building the Tower, the steps to be followed are:

2.1: Tower Configuration: The type of Tower selected was Suspension and self-supporting tower. Four-legged tower with double circuited was used. The model of the tower bracings is Pratt bracing system. Since this is the most widely used. The height of tower is calculated as per CBIP Manual and base width is taken as 1/6th of height of tower. The sections used for the tower are all mild steel angles confirming to IS 2062.

2.2: Load calculation: Loads are calculated as per IS 802: 1995, IS 875: Part III, CBIP manual. Each load is applied at the nodes or joints only. Loading conditions are Wind load, Normal loading condition, Broken wire condition and broken conductor.

2.3: Modelling: Tower can be modelled using joint coordinates and joint to joint connections. Initially create the grids in 3 mutually perpendicular directions. Then join corresponding joint to joint connections in sequential order until you get the structure. Calculated loads can be applied at the corresponding joints.

2.4: Tower Details: Tower Height considered is 33.52 m, Base width of the Tower is 5.5966 m, Bottom Crossarm width is 10.31 m, Middle crossarm width is 9.26 m, Top Crossarm width is 8.86 m, ISA Angle sections are considered.

III. MODAL ANALYSIS

Modal analysis is performed in SAP 2000 a Non linear computer program. The wind force acting on the tower is considered as Equivalent static force applied at the joints. The tower elements are modeled using 3 – D frame elements. After running the analysis with loads and load combinations with respect to wind zones I & V, the parameters taken into consideration for comparison are Axial displacements, support reactions, modal mass participations factors for both axial displacements and rotational displacements, modal participation factors for modal stiffness, modal frequencies and time periods. Figure 1 represents 3 – D model tower with 5.5966 m Base width. Figure 2 – 6 represents Mode shapes of tower along with time periods in Zone I. Figure 7 – 10 represents Mode shapes of tower along with time periods in Zone V.

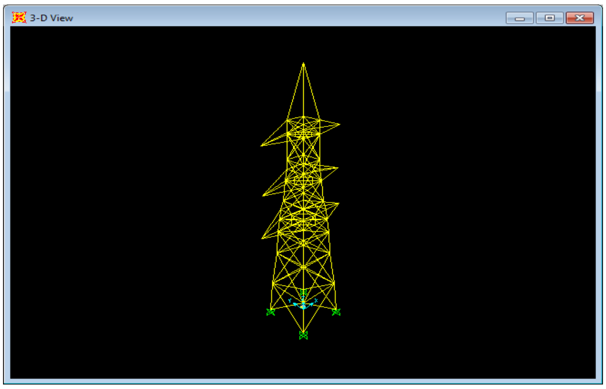

Figure 1 : 3- D model Tower with 5.59m Base Width

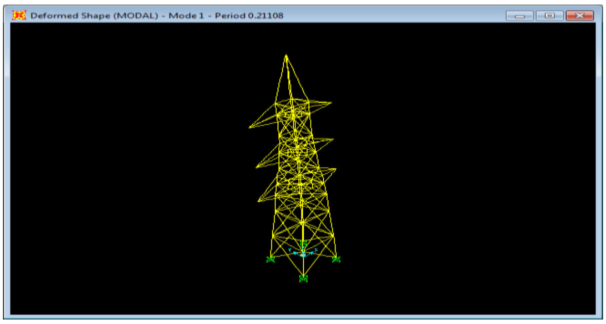

Figure 2 : Mode shape with Period 0.21108

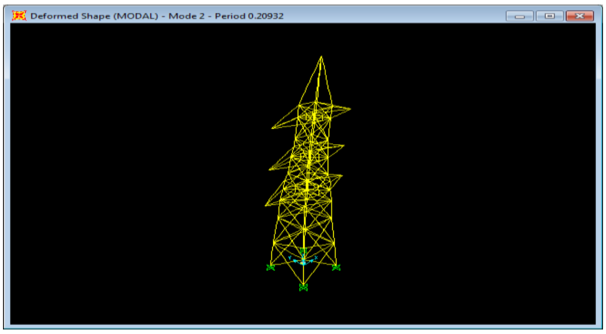

Figure 3 : Mode shape with Period 0.20932

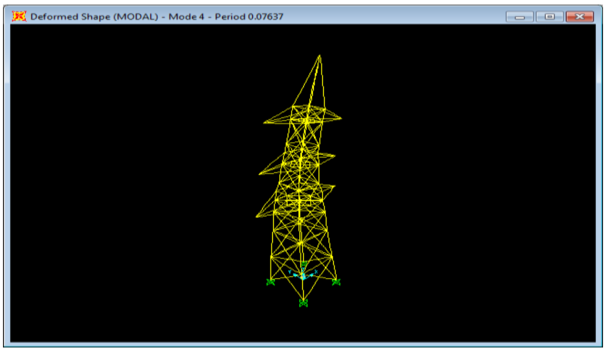

Figure 4 : Mode shape with Period 0.07637

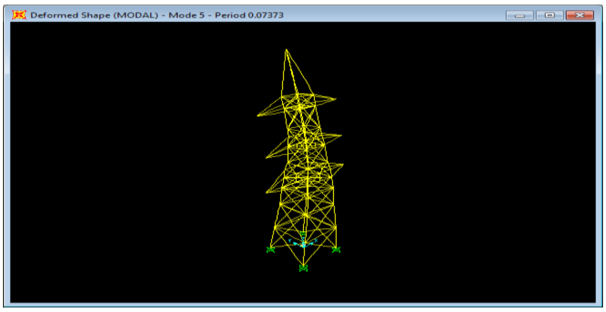

Figure 5 : Mode shape with Period 0.07373

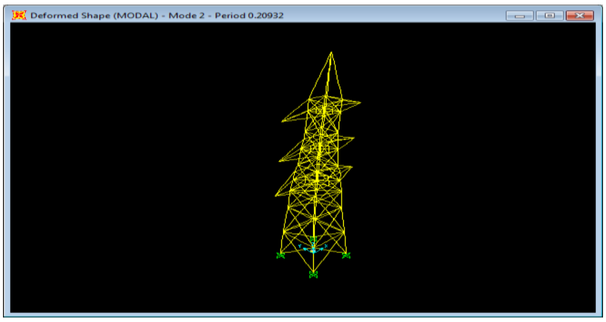

Figure 6 : Mode shape with Period 0.20932

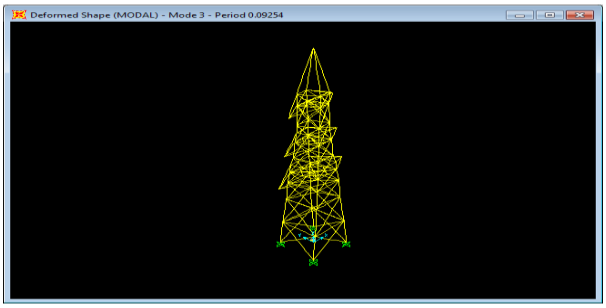

Figure 7 : Mode shape with Period 0.09254

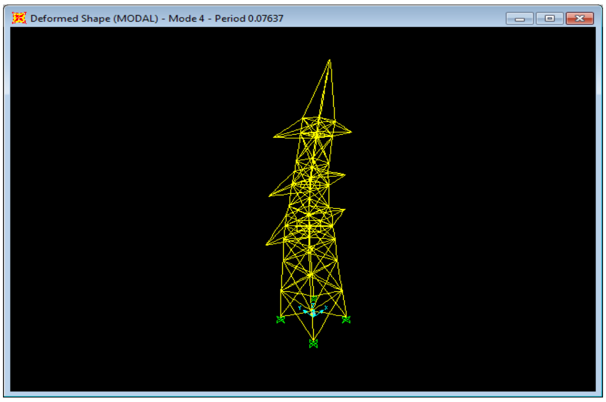

Figure 8 : Mode shape with Period 0.07637

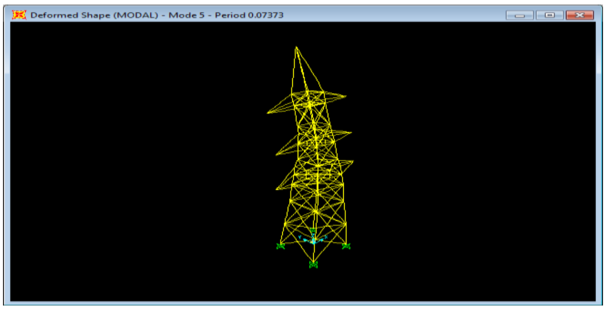

Figure 9 : Mode shape with Period 0.07373

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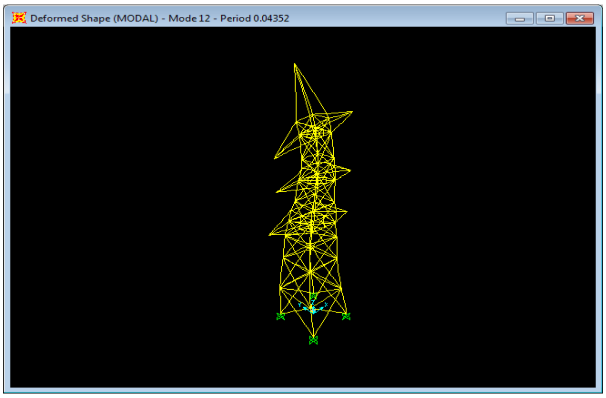

Figure 10 : Mode shape with Period 0.04352

IV. ANALYSIS OF RESULTS

With the help of Sap 2000, analysis was done using Run analysis Command. The following parameters are considered.

Comparison of Axial displacements: Maximum positive and negative axial displacements along the three mutually perpendicular directions in wind zones I & V are presented in Table 2 & 3 and represented in Figures 11 to 14.

Table 1: Maximum Positive Axial Deflections

Zone	Maximum Axial Deflections (mm)		
Direction	X	Y	Z
I	2.915	13.343	306.348
V	5.691	20.91	474.639

Table 2: Maximum Negative Axial Deflections

Zone	Maximum Axial Deflections (mm)		
Direction	X	Y	Z
I	-39.04	-14.72	-0.13
V	-39.04	-22.27	-0.13

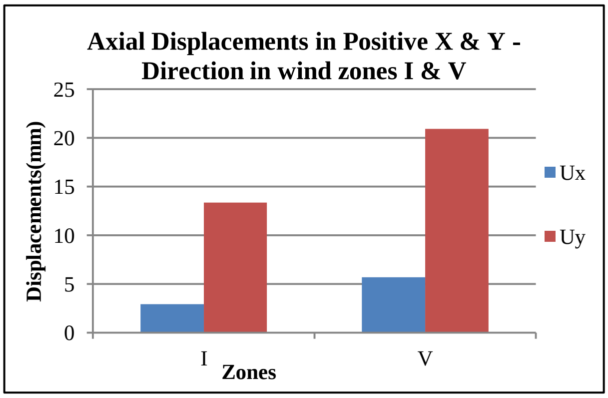

Figure 11: Axial Displacements in Positive X & Y Direction in Wind Zones I & V

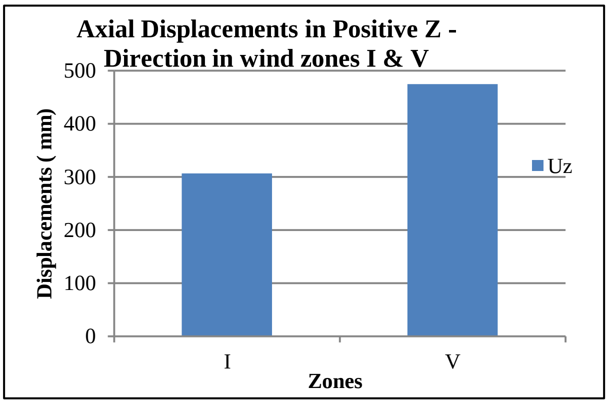

Figure 12 Axial Displacements in Positive Z - Direction in Wind Zones I & V

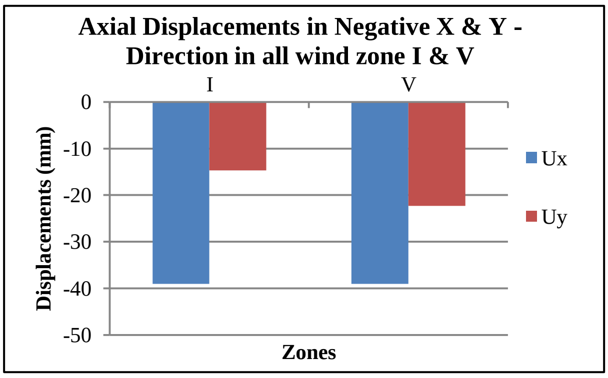

Figure 13 Axial Displacements in Negative X & Y - Direction in all wind zone I & V

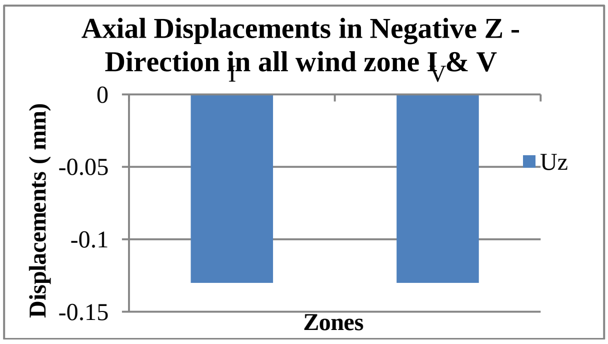

Figure 14 Axial Displacements in Negative Z - Direction in all wind zones I & V

Comparision of Support Reactions: Maximum support reactions Fx, Fy, Fz, Mx, My, Mz are compared in two wind zones are shown in Figures 15,16,17 and tabulated in Table 3.

Table 3: Maximum Support reactions

Direction	Maximum support reactions	
Zone	I	V
Fx (N)	140810.3	210936
Fy (N)	1065166	1626790
Fz (N)	-136991	-212382
Mx (N-m)	2002.61	2658.7
My (N-m)	156.74	245.98
Mz (N-m)	736.93	1122.85

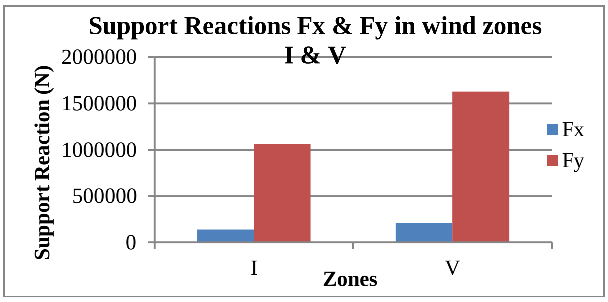

Figure 15 Support Reactions Fx & Fy in wind Zones I & V

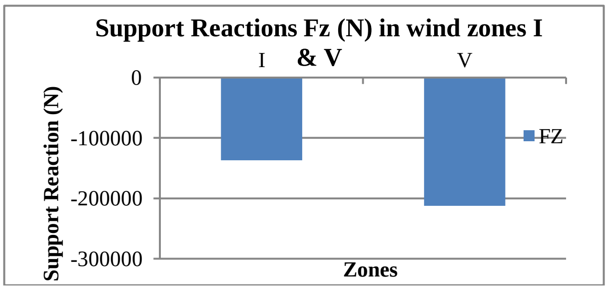

Figure 16 Support Reactions Fz in wind Zones I & V

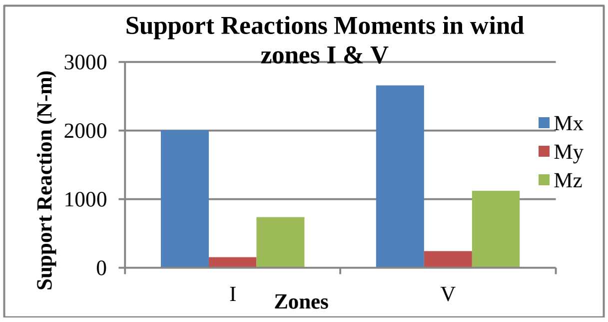

Figure 17 Support Reactions Moments Fz in wind Zones I & V

Modal mass participation factors: Depending on the mode shape and time period, modal mass participation factors for displacement can be found out and is presented in Figures 18 to 20 and is represented in Table 4.

Table 4: Modal Mass Participation factors for Displacement

Mode No	Period	Ux	Uy	Uz
1	0.211	0.59	4.56E-17	0.000271
2	0.2093	0.000273	1.11E-17	0.6
3	0.093	1.50E-18	4.08E-08	2.38E-15
4	0.076	0.27	8.23E-16	1.37E-07
5	0.074	2.04E-07	1.61E-17	0.27
6	0.0544	3.58E-14	0.02899	9.23E-14
7	0.0541	2.34E-14	0.000115	2.89E-14
8	0.0523	0.000165	4.06E-15	8.71E-09
9	0.052	2.20E-09	6.83E-18	6.74E-05
10	0.051	1.52E-14	2.13E-05	4.47E-15
11	0.0502	7.40E-16	1.08E-07	4.76E-15
12	0.044	0.079	1.245E-13	0.000013

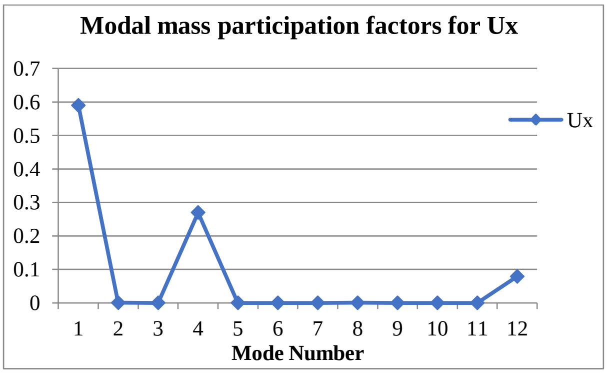

Figure 18 Modal Mass Participation factors for Ux

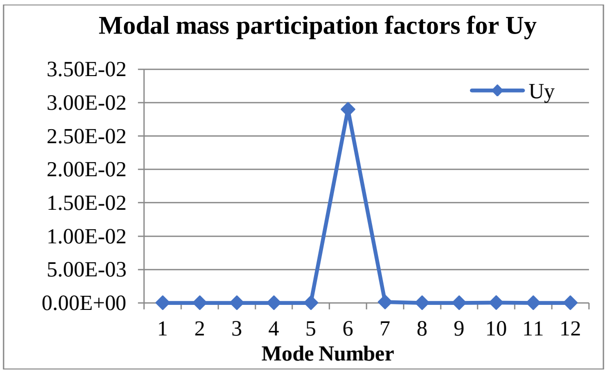

Figure 19 Madal Mass Participation factors for Uy

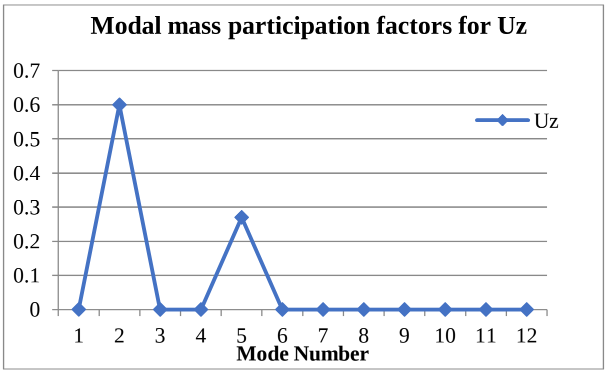

Figure 20 Modal Mass participation factor for Uz

Modal Stiffness: Modal Stiffness also depends time period. As the time period is decreasing the value of modal participation factors for modal stiffness increases as shown in Figure 21 and are tabulated in Table 5.

Table 5: Modal Participation factors for Modal Stiffness

Mode No	Period	Modal Stiffness
1	0.211077	886.09
2	0.209322	901.01
3	0.092535	4610.45
4	0.07637	6768.8
5	0.073731	7262.1
6	0.054364	13357.9
7	0.054052	13512.39
8	0.052263	14453.53
9	0.052222	14476.05
10	0.050693	15362.41
11	0.050231	15646.39
12	0.043515	20848.79

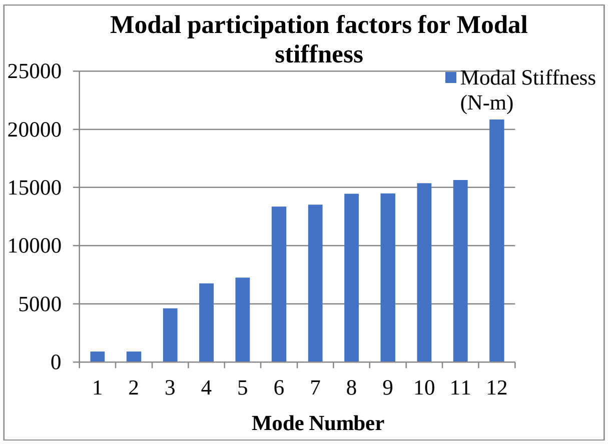

Figure 21 Modal Participation factors for Modal Stiffness

Comparision of Frequency, circular frequency and Eigen value: Based on the mode number and time period, the frequency, circular frequency and Eigen values varies as shown in Figures 22,23,24 and the values are in Table 6.

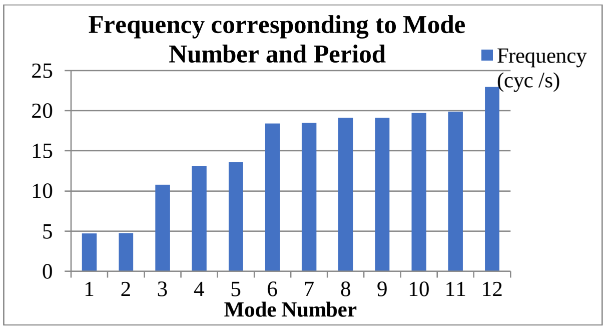

Figure 22 Frequency Corresponding to Mode number and Period

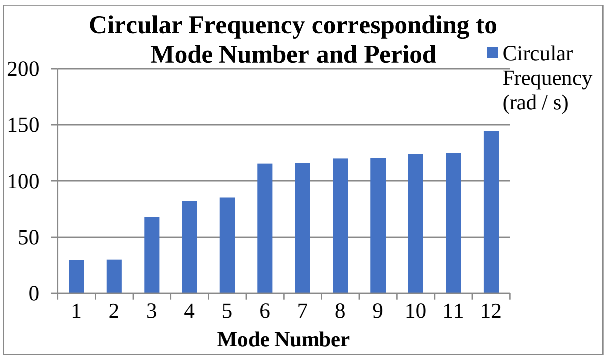

Figure 23 Circular frequency Corresponding to Mode number and Period

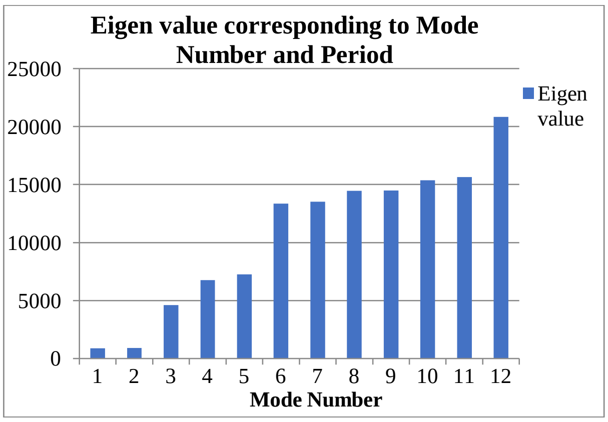

Figure 24 Eigen value corresponding to Mode Number and Period

Table 8: Modal Periods and frequencies

Mode No	Period	Frequency (cyc/s)	Circular Frequency (rad/s)	Eigen Value (rad^2/ s^2)
1	0.211077	4.7376	29.767	886.09
2	0.209322	4.7773	30.017	901.01
3	0.092535	10.807	67.9	4610.4
4	0.07637	13.094	82.273	6768.8
5	0.073731	13.563	85.218	7262.1
6	0.054364	18.395	115.58	13358
7	0.054052	18.501	116.24	13512
8	0.052263	19.134	120.22	14454
9	0.052222	19.149	120.32	14476
10	0.050693	19.726	123.95	15362
11	0.050231	19.908	125.09	15646
12	0.043515	22.981	144.39	20849

V. CONCLUSION

- ✓ The maximum positive deflection along Z - direction in zone I is observed to be increased by 54.93% in Zone V. where as in X direction it was 95.23% and along y direction it was 56.71%.
- ✓ The maximum Negative deflection along Y - direction in zone I is observed to be negatively increased by 51.29% in Zone V. where as in X and Z direction it remains same.
- ✓ The support reactions Fx in zone I is observed to be increased by 49.80% in zone V. where as in Fy by 52.72%, Fz by 55.03%, Mx by 32.76%, My by 56.93% and Mz by 52.36%.
- ✓ Frequency, circular frequency, eigen value and modal participation factor for modal stiffness increases with the decreases in time period.
- ✓ The modal mass participation factor for displacements are zero for some of mode numbers due to fact that the specific mode shape will exhibit torsion effect.

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