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Analysis of server rack under seismic vibration

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ABSTRACT

The major aspects that should be considered in the evaluation of seismic response of offshore structures through a study of a server rack substructure supporting a conventional steel Topside structure. It highlights the importance of selecting the most appropriate arrangement for the connection between the Topside and the Substructure and its effect on the seismic performance of the platform. The advantages of performing a detailed global 3-D non-linear analysis of the whole structure in order to predict its dynamic performance during a seismic event are discussed. The seismic analysis showed that the seismic performance of the platform is satisfactory, with plastic hinges developing in a small number of elements in the Topside.To ensure network integrity and equipment compatibility, the incumbents have established a set of guidelines that service providers and equipment suppliers must comply with before the equipment can be installed in their facilities. These criteria are called Network Equipment-Building System criteria or NEBS for short.

This kind of analysis used to predict the observed buckling modes of a server rack, during a strong earthquake. The calculations include modal, spectral and time-history analysis using two finite element models. The Server inside the rack was modeled using specific Ansys finite elements. Thus, the numerical models succeeded in capturing not only the server mass, but also its behavior. The calculated results show the predicted rack behavior is similar to the real one, and the structure interaction was accurately modeled.

***Keywords*— Seismic, Non-Structural Elements, discretization**

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I.INTRODUCTION

The seismic response analysis has been performed using linear response spectrum method. Feasible structural enhancements have been designed. In order to verify the designs a second seismic analysis has been accomplished using time history method. The structural responses to site-specific design accelerograms have been computed.

A fixed-base assumption is made in many codes of practice for seismic design. This assumption is reasonable if the structure seat on solid rockand the structural response can be evaluated by subjecting the foundation to the free-field ground motion that would occur in the absence of the structure. On a deformable soil, however, a feedback loop exists—the structure responds to the dynamics of the soil while, simultaneously, the soil responds to the dynamics of the structures.[2][3] Structural response is then governed by the interplay between the characteristics of the soil, the structure and the input motion. Therefore, soil-structure interaction problems require combined soil and structure models. While structure models are very well established in the literature, soil models involve complicated analysis due to their unbounded nature. The resulting bounded domain can be analyzed using the domain discretization techniques, such as finite element method and the finite difference method. The general framework of the soil-structure interaction analysis may be summarized as the domain discretization technique plus absorbing boundary condition.[3] Thus, we require that the dynamic interaction analysis be performed not only accurately but also efficiently. In dynamic soil-structure interaction analysis, it is effective to treat the soil and the structure by explicit and implicit algorithms respectively, which is due to the following two considerations: (1) Structure is relatively stiff, and therefore impose stringent time step restrictions if dealt with explicitly. So, it is sensible to analyze the structure by implicit procedures. (2) Degree-of -freedom of the soil is large in direct method for soil-structure interaction analysis, and the soil is always not very stiff, therefore it is efficient to analyze the soil using explicit algorithm. The displacements and stresses at any point in soil-foundation-structure system can be calculated simultaneously.

In this, it is necessary to take account of the nonlinearities induced in the soil of the free field by seismic waves and of the additional nonlinear effects created by the structural vibrations. Approximate theories have to be used because the rigorous approach to the nonlinearity of pile-soil structure system is difficult. Lumped-mass model proposed was a popular approximate method to solve the soil-structure interaction account for its convenient application to engineering practices. Many FEA software's with the development of the computer technologies have been developed to the high quality engineering tools, which can be used to design, and analysis. Such as ANSYS, that can provide a common platform for fast, efficient analysis in a lot of important areas. Thus, the soil and structure interaction should utilize this effective tool, too.[4]

1.1 Seismic performance

Seismic performance is the ability of a structure or a building to maintain its capability to perform the designed functions, including the incorporation of all the safety aspects, after an earthquake. A structure is generally recognized as safe if the lives and property in the building are not in danger. The technique of seismic analysis is a modern growth in the technology of earthquake engineering.

Seismic performance analysis is conducted normally by the earthquake response spectrum method, in which similar motion is forced into oscillators by vibration, as visualized during an earthquake, and the response of displacement, velocity, and acceleration are measured. The ultimate reaction of buildings or structures to earthquakes of varying frequencies can thus be evaluated, and these values form the basis of earthquake building codes for that region.

Seismic designs have been developed by the use of modern technologies that can assist in the minimization of earthquake damages. Though the incorporation of seismic designs is expensive, unsuitable designs may cause extensive earthquake damage. However, seismic designs do not guarantee full protection against earthquakes, as these have been developed by a process of trial and error. In accordance with the Standard codes, structures should be designed to withstand the earthquakes of the largest possible severity, thereby minimizing the loss of life and property. Seismic design is achieved by evaluation of the likely failure modes of structures, and ensuring provision of suitable strength and shape to the structures. Seismic design will depend upon the type of structure, location of site, and requirement of ground stabilization beneath the structure.[4][5]

II.FEM ANALYSIS

2.1 Seismic Analysis Methods

The methods used for seismic analysis of subsystems include, modal response spectrum analysis,time-history analysis, and equivalent static analysis. Any physical system can vibrate. The frequencies at which vibration naturally occurs, and the modal shapes which the vibrating system assumes are properties of the system, and can be determined analytically using Modal Analysis.[6] Analysis of vibration modes is a critical component of a design, but is often overlooked. Structural elements such as complex steel floor systems can be particularly prone to perceptible vibration, irritating structure occupants or disturbing sensitive equipment. Inherent vibration modes in structural components or mechanical support systems can shorten equipment life, and cause premature or completely unanticipated failure, often resulting in hazardous situations. Detailed fatigue analysis is often required to assess the potential for failure or damage resulting from the rapid stress cycles of vibration. Detailed seismic qualification also requires an understanding of the natural vibration modes of a system, as the large amount of energy acting on a system during seismic activity varies with frequency. Detailed modal analysis determines the fundamental vibration mode shapes and corresponding frequencies. This can be relatively simple for basic components of a simple system, and extremely complicated when qualifying a complex mechanical device or a complicated structure exposed to periodic wind loading. These systems require accurate determination of natural frequencies and mode shapes using techniques such as Finite Element Analysis.[7]

2.2 FEA Procedure (Finite Element Analysis)

FEA tool is the mathematical idealization of real system. Is a computer based method that breaks geometry into element and link a series of equation to each, which are then solved simultaneously to evaluate the behavior of the entire system? It is useful for problem with complicated geometry, loading, and material properties where exact analytical solution are difficult to obtain. Most often used for structural, thermal, fluid analysis, but widely applicable for other type of analysis and simulation. Figure shows procedure of FEA[8][9]

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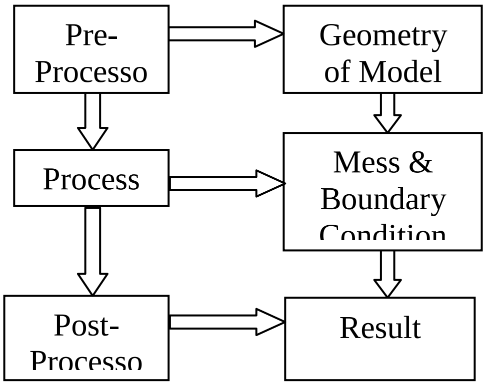


Figure:General Analysis Procedure using FEA Software

2.3 Objective of Analysis

a. Develop a mathematical model of the current rack & chassis system. In the current mathematical model the blades are modeled as concentrated mass.
b. Analyze the current model for earthquake dynamic loading i.e. GR-63 Zone 4.
c. Summarizing the Results & Findings

III.Methodology

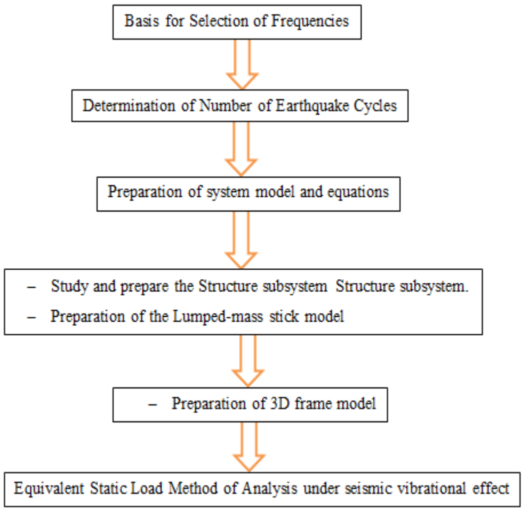


Figure: Stepwise Flowchart for completing analysis of server racks

1.2 Material Property

For Making of model of server rack analysis of rack following material is to be selected

1. Material of Server Rack :Steel
2. Elastic Modulus - 200 x 10^3MPa
3. Poisson's Ratio - 0.30
4. Density - 7850 Kg/m^3

3.2 Geometry

The below image shows the geometry of server rack imported into the simulation software for Analysis. Before importing a model into analysis which can be prepared by modeling software like Solid work 15.Figure show the rack created by CAD software for further analysis.These models after importing cananalyses by using Workbench Ansys 15.0

Properties of model:

1. Mass of model: 1291.5 kg
2. Volume: 0.10559 m³
3. Bounding Box:
   a. Length of X: 0.9144 m
   b. Length of Y: 2.1337 m
   c. Length of Z: 1.0668 m
4. Nodes: 36858
5. Element: 36699

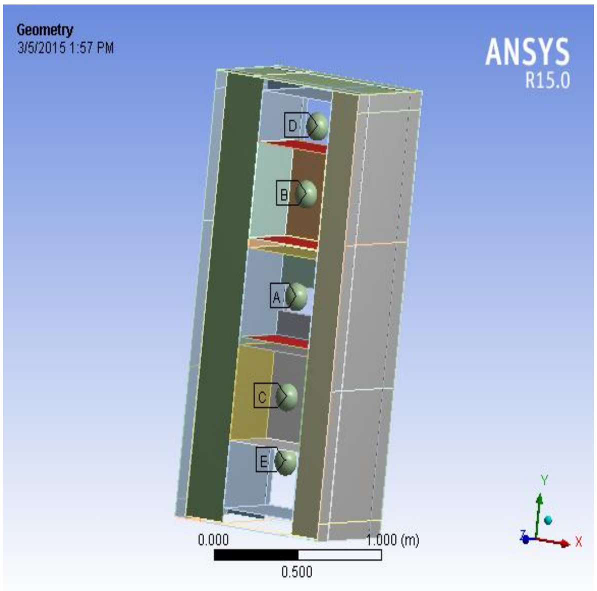


Figure:Model of Server Rack (According to NEBS Standards)

3.3 Finite Element Model:

The element selected for meshing the server rack model is shell 181 & Beam 188 type of element. The mesh count for the model contains 36858 numbers of nodes and 36699 numbers of elements. Figure 4 shows the meshed model of server rack.

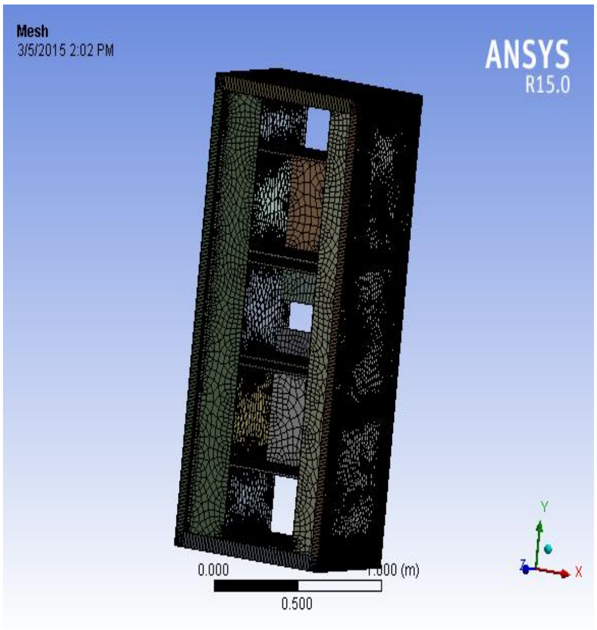


Figure:Mesh Model of Server Rack

Properties of Meshing:
Inflation: Transition ratio: 0.272

3.4 Loading &Boundary Condition:

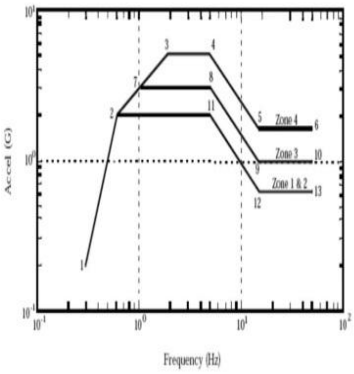
Mode superposition transient finite element analysis using response spectrum is carried out to study the response of the system for dynamic loading i.e. GR-63 Zone 4.
FEA analysis is divided into two sub analyses

1. Modal Analysis
2. Transient Mode Superposition using Response Spectrum Analysis

For all the analysis following parameters are used -

1. Number of modes - 100
2. Damping Ratio - 1.0%

The server rack is considered for seismic vibration according to Dynamic acceleration loading - Zone 4 GR-63. Following graph and table shows the higher seismic zone 4.



Coordinate Point	Frequency (Hz)	Values for Upper Floor Acceleration (g)	Coordinate Point	Frequency (Hz)	Values for Upper Floor Acceleration (g)
Zones 1 and 2			Zone 4		
1	0.3	0.2	1	0.3	0.2
2	0.6	2.0	2	0.6	2.0
11	5.0	2.0	3	2.0	5.0
12	15.0	0.6	4	5.0	5.0
13	50.0	0.6	5	15.0	1.6
Zone 3			6	50.0	1.6
1	0.3	0.2			
2	0.6	2.0			
7	1.0	3.0			
8	5.0	3.0			
9	15.0	1.0			
10	50.0	1.0			

Figure: Loading Condition - Frequency vs. Acceleration Graph

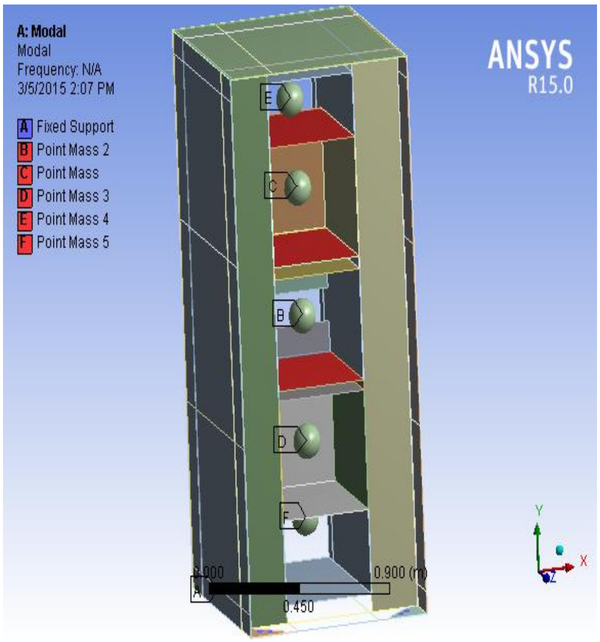


Figure: Loading &Boundary condition

IV.RESULT AND DISCUSSION

After giving all loading and effect following are the results were obtained on workbench Ansys 15.0

4.1 Total Deformation

Figure shows the maximum deformation of server rack due to application of external frequency in the form of seismic load for first frequency is 22.697 Hz.

Total Deformation: Maximum: 1.6927e-003 m
Minimum: 0. M
(Frequency: 22.697 Hz)

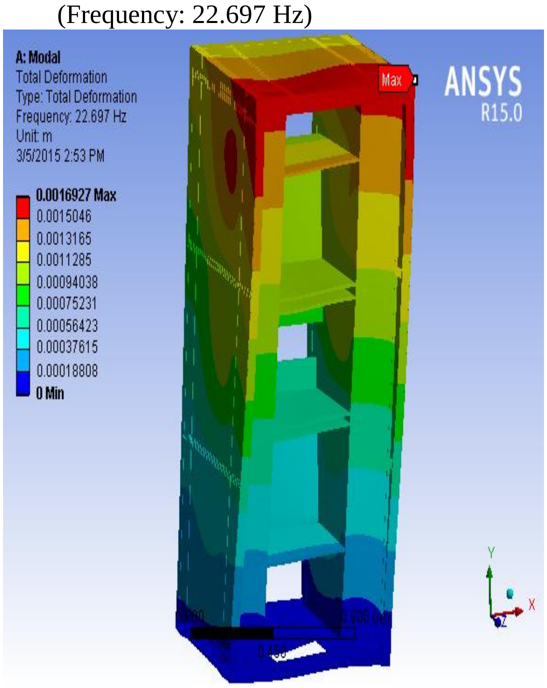


Figure: Total Deformation of rack under loading condition

Following are the output frequency for input no. of modes

Mode	Frequency	Mode	Frequency
1	22.697	51	142.18
2	31.148	52	146.36
3	54.114	53	147.51
4	54.258	54	148.08
5	54.445	55	148.39
6	56.141	56	152.01
7	59.593	57	153.83
8	59.709	58	154.78
9	59.826	59	157.17
10	60.214	60	157.86
11	65.969	61	158.33
12	66.073	62	161.48
13	76.612	63	162.64
14	81.142	64	169.79
15	81.284	65	170.14
16	81.844	66	170.22
17	82.69	67	170.78
18	85.701	68	173.07
19	86.103	69	175.14
20	86.49	70	175.97
21	86.671	71	176.75
22	87.376	72	177.09
23	91.624	73	177.38
24	94.194	74	177.48
25	95.372	75	178.08
26	102.77	76	178.86
27	102.96	77	183.25
28	105.36	78	183.84
29	105.42	79	184.56
30	107.17	80	188.64
31	108	81	189.15
32	112.25	82	190.17
33	115.64	83	191.05
34	115.68	84	192.3
35	116.63	85	192.98
36	117.96	86	193.57
37	119.5	87	196.21
38	120.05	88	196.38
39	120.11	89	200.25
40	120.73	90	202.6
41	120.78	91	203.88
42	121.15	92	204.34
43	121.27	93	205.36
44	121.77	94	209.32
45	124.76	95	209.77
46	125.04	96	210.93
47	126.95	97	211.46
48	130.7	98	211.5
49	133.34	99	211.66
50	141.77	100	212.02

4.2 Directional deformation

Following are the directional deformation of server rack in x direction for same input load. It show maximum direction deformation (X Direction) is 1.2944e-003 m

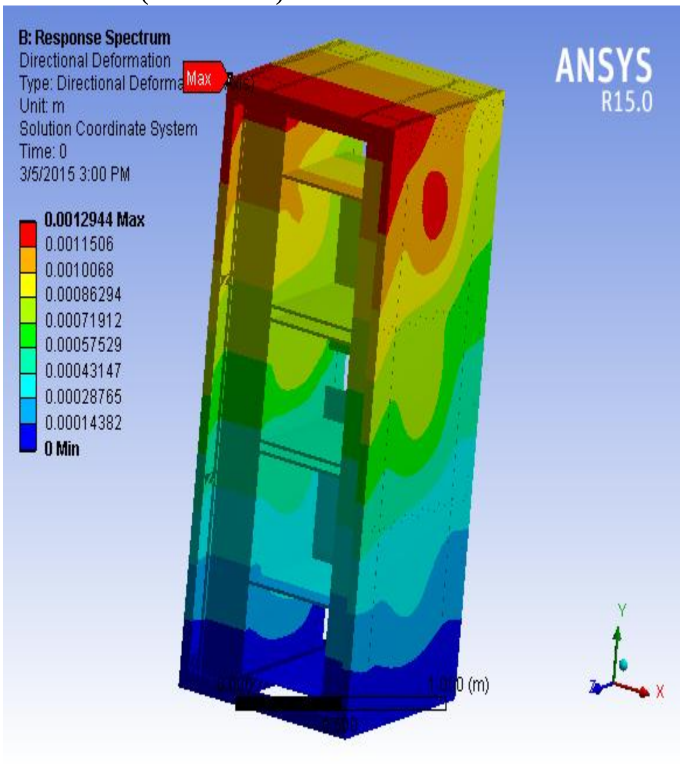


Figure: Directional Deformation (X- Direction)

4.3 Equivalent Stress

The equivalent deformation produce in rack in modal analysis shows following figure

Transient Mode Superposition using Response Spectrum Analysis Result .Following figure shows Equivalent Von-Mises Stress Analysis

Following are the stress produce in the rack

1. Maximum: 2.6211e+008 Pa
2. Minimum: 51791 Pa

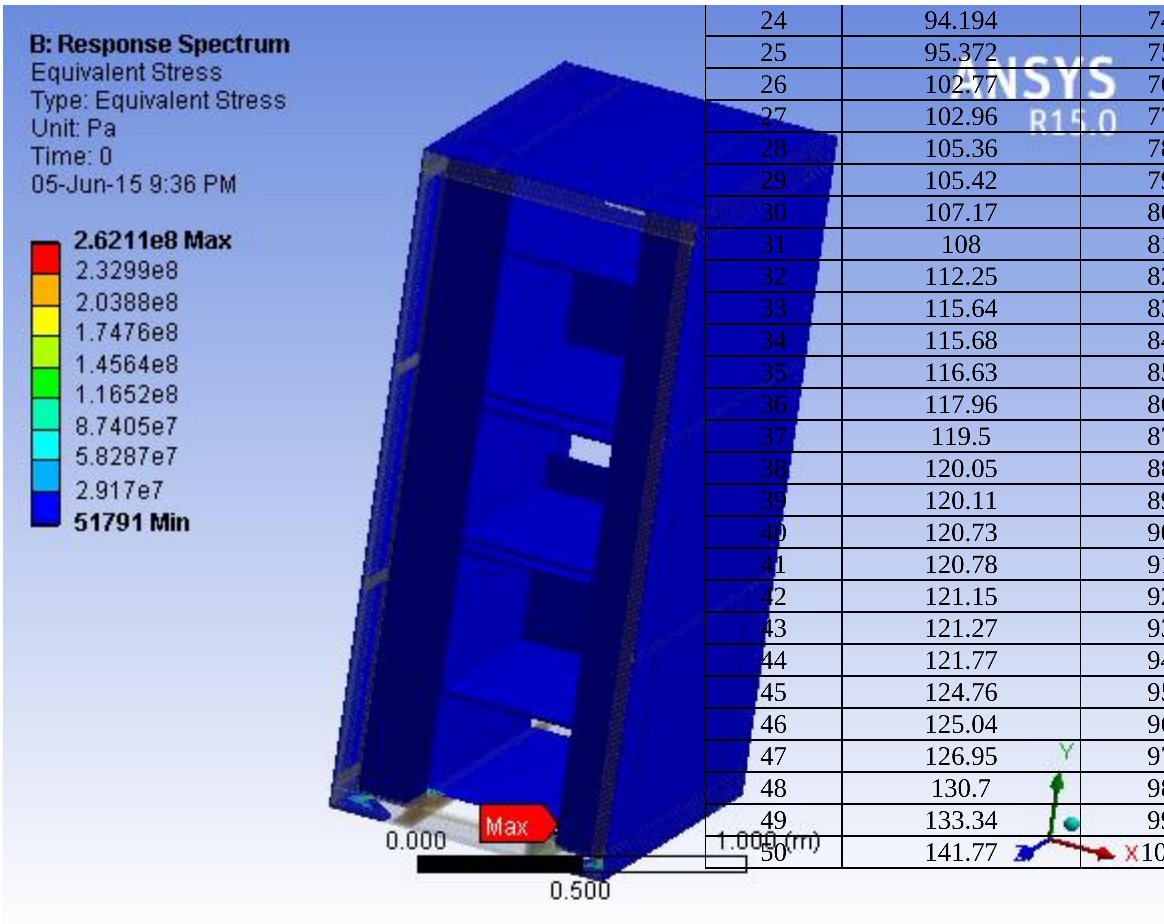


Figure: Equivalent Von-Mises Stress Analysis

4.4 Modal Analysis

Following table shows the First Natural Frequency (f) with first 100 modes of superposition.

Mode	Frequency	Mode	Frequency
1	22.697	51	142.18
2	31.148	52	146.36
3	54.114	53	147.51
4	54.258	54	148.08
5	54.445	55	148.39
6	56.141	56	152.01
7	59.593	57	153.83
8	59.709	58	154.78
9	59.826	59	157.17
10	60.214	60	157.86
11	65.969	61	158.33
12	66.073	62	161.48
13	76.612	63	162.64
14	81.142	64	169.79
15	81.284	65	170.14
16	81.844	66	170.22
17	82.69	67	170.78
18	85.701	68	173.07
19	86.103	69	175.14
20	86.49	70	175.97
21	86.671	71	176.75
22	87.376	72	177.09
23	91.624	73	177.38
24	94.194	74	177.48
25	95.372	75	178.08
26	102.77	76	178.86
27	102.96	77	183.25
28	105.36	78	183.84
29	105.42	79	184.56
30	107.17	80	188.64
31	108	81	189.15
32	112.25	82	190.17
33	115.64	83	191.05
34	115.68	84	192.3
35	116.63	85	192.98
36	117.96	86	193.57
37	119.5	87	196.21
38	120.05	88	196.38
39	120.11	89	200.25
40	120.73	90	202.6
41	120.78	91	203.88
42	121.15	92	204.34
43	121.27	93	205.36
44	121.77	94	209.32
45	124.76	95	209.77
46	125.04	96	210.93
47	126.95	97	211.46
48	130.7	98	211.5
49	133.34	99	211.66
50	141.77	100	212.02

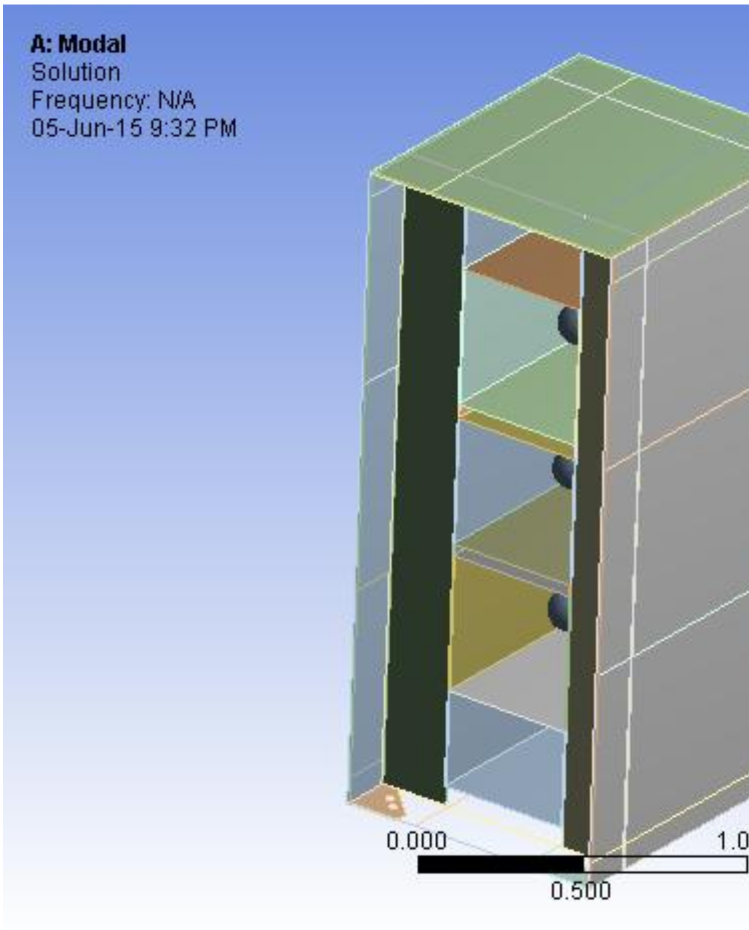


Figure: Modal Analysis of Server Rack

4.5 Total Deformation

Following figure shows the maximum deformation of rack in modal analysis

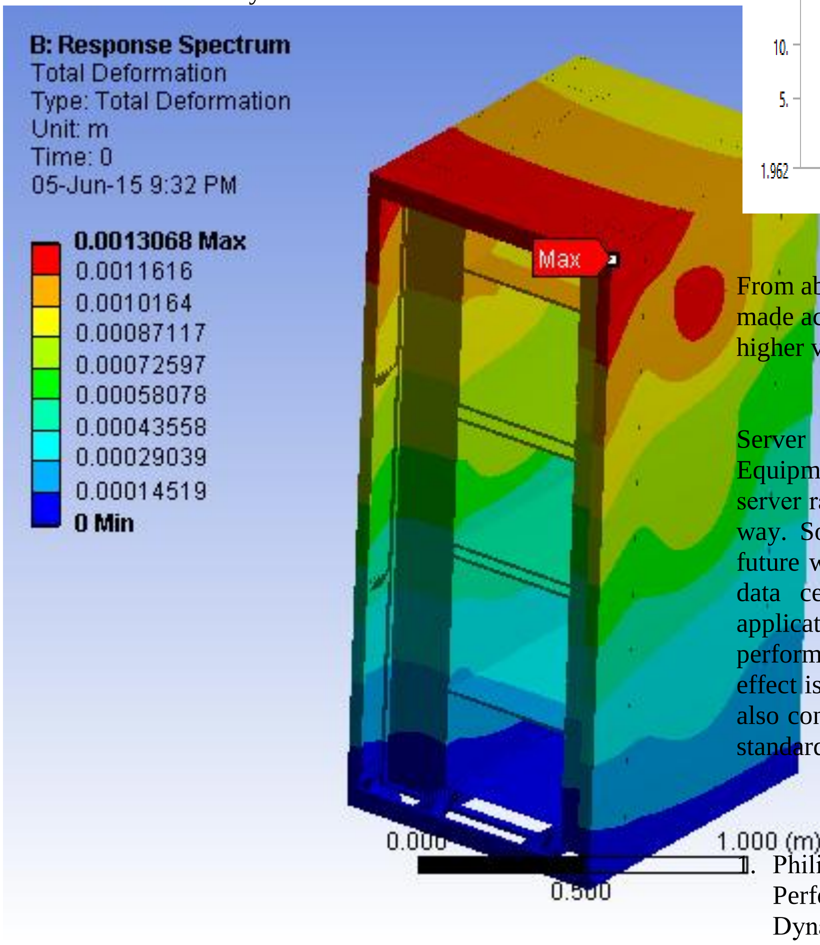


Figure: Directional- Modal Analysis

Total Deformation: Maximum: 1.3068e-003 m
Minimum: 0. M

4.6 Result

It is observed that, in higher seismic area final frequency for zone 4 which is shown in following table

Frequency (Hz)	Acceleration [(m/s2)]
0.3	1.962
0.6	19.62
2	49.05
5	49.05
15	15.696
50	15.696

Table: Final Frequency of Sever Rack with Output Acceleration

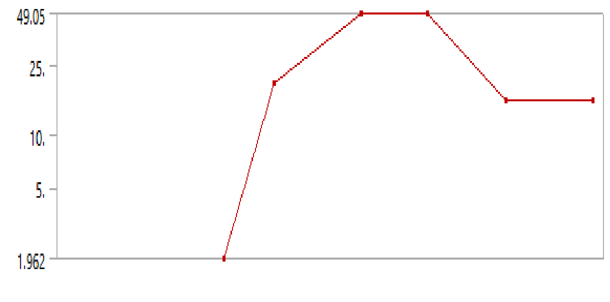


Figure: Graph of Frequency vs. Acceleration

From above frequency comparison it found that the model made according to NEBS standard that are sustained the higher vibration affect which helpful to server system.

V. CONCLUSIONS

Server rack manufacturing is depending on National Equipment Building System standard. But in practice server rack is can't give its proper performance in practical way. So, Experimental investigating of rack is work for future work. Sever rack performance is very important for data center due to its application. Due to important application of rack, their structural feasibility and performance under different loading condition like seismic effect is also important. The analytical and FEA analysis is also consider for server rack for future according to NEBS standard

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