Effect of Seismic Parameters on Analysis of Turbo-Generator Foundation

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***Abstract*—The finite element modeling and dynamic analysis of massive and elevated foundation of steam turbine generator is considered in this paper. The damping ratio, seismic zones and support conditions are very important for analysis of massive machine foundation in general and the steam turbine generator foundation in particular. Inefficient modeling of the foundation may result in an unnecessary increase in the foundation size to limit the vibration amplitude within the machine manufacturer specified limits. The work in this paper investigates the effect change in Seismic Zones, and support condition for column at base on the response of foundation to dynamic machine load. Response spectrum analysis is done by using STAAD software to check effect seismic zone factors as per IS 1893-2002 (Part 1) on frequencies. Finally, the response of the machine foundation to seismic forces is evaluated. Seismic analysis is performed using two approaches: (1) by changing zone factors as per IS 1893-2002 part 1 (2) by changing support condition fixed and pinned.**

A detailed model of the steam turbine generation foundation is constructed using as per clause number 9.1.1 from IS 2974 part 3. This model is used to perform response spectrum analysis.

The influence of changes is those parameters on the foundation response is determined. The results are compared for with respect to frequency, amplitude and deflection.

Analysis showed that the change in the seismic zones has almost no effect on the natural frequencies whereas deflection increases 1.2 to 1.8 times and Response Spectrum analysis showed that the change in the Support condition from fixed to pin there is Minor change in vertical frequencies whereas horizontal frequencies decreases by 50%.

Keywords—Turbo-Generator Foundatio; Seismic Zones; Column Support Conditions

I. INTRODUCTION

Turbine generator machines form the heart of any power plant. Thus for any developed or developing nation, capacity of supplying unhindered energy not only ensures a steady industrial growth, but also goes into improve the quality of life in long way. The main source of this energy is obviously electricity and this is what the turbine generators machines generate. The turbine generator machine is one of the most important and complicated system in design, manufacturing and testing. The turbine generator machine has a huge weight usually ranging from 6000 kN to 17000 kN, which is imposed on a large massive concrete foundation pedestal. Thus if the foundation which supports these critical machines misbehave and the machine trips during operation, the consequences on the end user and the industry dependent on the power generated could suffer severe losses. If the shortage is severe in nature, this could even have a very adverse effect on the economic growth to a complete part of a country. Accordingly, we can say that for successful operation two aspects become critical for these machines : 1) The machine itself should run smoothly (round the clock) ; 2) The foundation supporting the equipment is capable of sustaining the various loads coming from the turbine under operation (dynamic loads) as well as those that could develop due to the vagaries in nature or otherwise like earthquake, thermal, electrical faults, short circuits etc.

The structural engineer plays an important role in the analysis and design of such foundations and structures subjected to dynamic loads especially for the turbine foundation. The analysis is considered a very complex problem because of the interaction of the structure, the subsurface soil, and the vibrating machine. The analysis and design of these foundations and structures became less complex after the introduction of the finite element method and design software's. The concern of this study is the analysis turbo-generator foundation to check the effect on analysis of turbo-generator foundation by changing seismic zones as per IS 1893:2002. Such foundation type is subjected to time and frequency varying loads due to the machine oscillations. Under such types of loading a response spectrum analysis is considered and compared the variation in frequency, amplitude and deflection. The effect of foundation on these vibrations during the machine operation is severe and the application of the dynamic principles in evaluating the response of the structure is very important.

Normally the dynamic analysis using any finite element method is carried out using a deterministic approach with constant material properties, damping ratios, seismic parameters. In this paper, the effect of those governing parameters that affect the global response of the foundation is studied. In addition, study the effect of the different type of column supporting condition on turbine generator foundation as per IS 2974 part 3 clause 9.1.1.

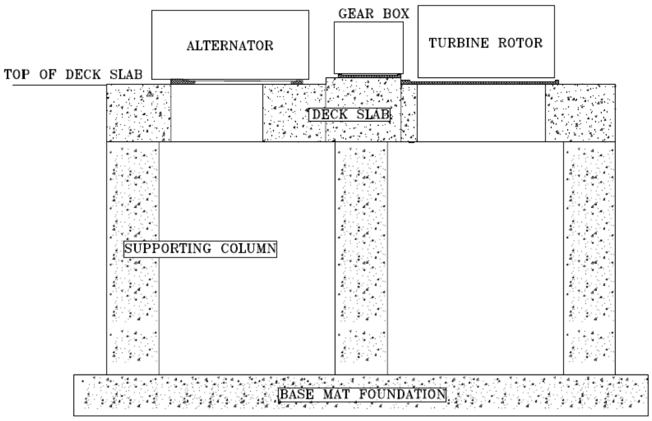

Fig. 1. Layout of Turbo-generator foundation

II. OBJECTIVE AND SCOPE OF WORK

The objective of this study is to determine the dynamic response of the turbine foundation where the effect of different parameters on the calculated response is evaluated. This includes:

a) Seismic Zone Factors as per IS 1893 part 1 Zone II, III, IV & V

b) Study the effect of Column support condition at fixed as per IS 2974 part 3 and Considering Pinned support.

The effect of these parameters change on the foundation natural frequency is calculated and the dynamic response is calculated. Moreover, Effect of seismic zone factor on frequencies is calculated. In addition, evaluation of foundation response at two different support conditions checked.

III. METHODOLOGY

1. Collect all site data

2. Prepare TG models in staad software as per IS 2974 part 3 clause 9.1.1

3. Apply loads and load calculation

4. Compared the results for different design parameters as damping ratio, seismic zone and support condition.

IV. LOADS AND LOAD COMBINATIONS

Primary loads.
1) Dead load (DL)
2) Operation load (OL)
3) Normal machine unbalance force (NUL)
4) Temperature loads in foundation (TLF)
a) Uniform temperature
b) Temperature gradient across members.
5) Short circuit forces (SCF).
6) Loss of blade unbalance (LBL)/Bearing failure load (BFL)
7) Seismic loads (SL)
8) Wind Load (WL)

Load combination.
IS 2974 gives the following load combination to be considered for design
a) DL+OL+NUL+TLF
b) DL+OL+NUL+TLF+SCF
c) DL+OL+TLF+LBL/BFL
d)DL+OL+NUL+TLF+SL

Apply the loads and seismic parameters.
Use response spectrum analysis.
Check the difference in frequencies for different cases as specified below
Inputs for the design are used from the 45MW power plant project. Analysis & Design is carried out as per Indian Standards as per IS 2974.

V. CASE STUDY

Response Spectrum analysis is done for different parameters as Seismic Zone and different support conditions.

INTRODUCTION

To study the effect on analysis of turbo-generator foundation considered 45 MW power plant project. A turbo-generator consists of a turbine generator and other auxiliaries like condenser, pipelines carrying superheated steam etc. Turbo-generator falls under high speed rotary type machines and its capacity varies from 2 MW to 45MW. The turbo-generator foundation consists of turbo-generator and its auxiliaries mounted on a table top foundation. The foundation can be either made of steel or RCC. The top deck, column and bottom raft together constitute the turbo-generator foundation facilities the supporting of Turbine, Gear Box & Alternator. The general arrangement is as per shown in figure 1. The structure proposed is of RCC frame structure. All structural members are modeled and analyzed in STAAD software. Analysis & Design is carried out as per Indian Standards as per IS 2974. The foundation is modeled as a three-dimensional space frame in which the columns & beams are idealized as 3-D beam elements with six degrees of freedom at each node. Slabs are modeled using plate element. Also, nodes are specified to all bearing points, beam - column junctions and mid-points. Equipment loads as mentioned in vendor drawing is applied. Structure is analyzed & designed for various loads & combinations of loads as stated in further sections

Structural description

This steam turbine generator (STG) concrete pedestal is classified as a frame foundation type The configuration of the machine itself imposes the type of the structure carrying it. In the study there are a turbo-generator consists of a turbine generator and other auxiliaries like condenser, pipelines carrying superheated steam etc, so the choice of the frame system as a structural system is to satisfy the machine configuration in order to perform its function which is generating electric power in an efficient way. In some few cases, the manufacturer designs the condenser to be placed beside the machine (turbines & generator), so in this case the structural engineer can use block type foundation rather than frame type foundation.

The layout of the operating deck and base mat is shown in Figure 2 and Figure 3

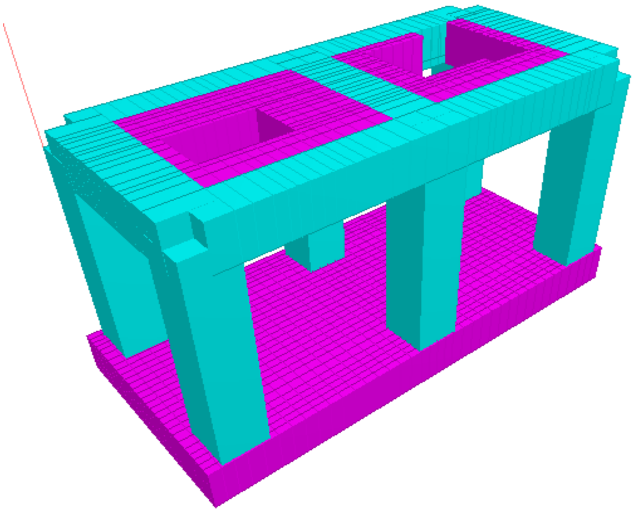

Fig. 2. Isometric View of TG foundation system

Design Data :-

1) Finished ground level (FGL) = EL(-0.3) m
2) Foundation Level = EL(-2.5) m
3) Top level of TG slab = EL + 10 m

4) Maximum permissible Amplitude of Vibration on top of Deck = 30 Microns
5) Rated Speed = 1500 RPM

6) Grade of Concrete
For TG deck Slab = M35

For TG slab supporting Beams= M35
For Columns = M35

For Base Raft / Mat = M25

7)Dynamic Properties of Concrete (As per IS 2974 Part - 3 cl. 9.1 e&f)

For M35 Elasticity E = 3.80E+07 kN/m2
For M25 Elasticity E = 3.13E+07 kN/m2
Damping = 2%

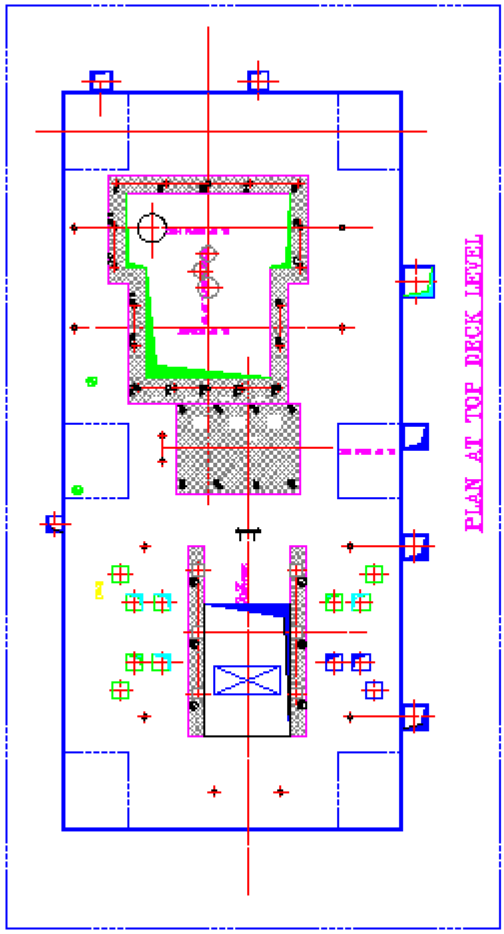

Fig. 3. Plan View of TG foundation at Tabletop Level

8) Clear cover to reinforcement ….(As per IS 2974 Part - 3 cl. 12.6)

For Top Deck = 50 mm

For Beams & Columns = 50 mm

For Base Mat / Raft = 100 mm.

9) SBC For Soil = 400 kN/m2

10) Modulus of Subgrade Reaction .(As per Foundation Analysis & Design by Joseph E. Bowles)

Ks = 120 x SBC
= 48000 kN/m2/m

Problem Description:

Response spectrum analysis is done by using STAAD software to check Damping effect. This is followed by changing seismic zone factors as per IS 1893-2002 (Part 1) to check the effect on frequencies. Finally, the response of the machine foundation to seismic forces is evaluated. Seismic analysis is performed using two approaches: (1) by changing zone factors as per IS 1893-2002 part 1 (2) by changing support condition fixed and pinned.

Following are the cases studied by changing seismic parameters, Support conditions.

Case I: Compare the effects on analysis of TG foundation for different seismic zones as per IS 1893 Part 1

Case II: Compare the effect on analysis of TG foundation if column support condition changed from Fixed to Pinned

Types of mode shapes

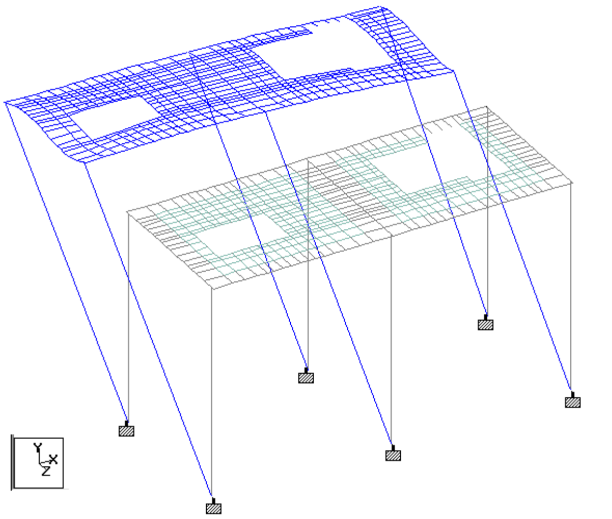

Fig. 4. Response Spectra-Mode Shape 1-Translational Vibration Along Z-Direction

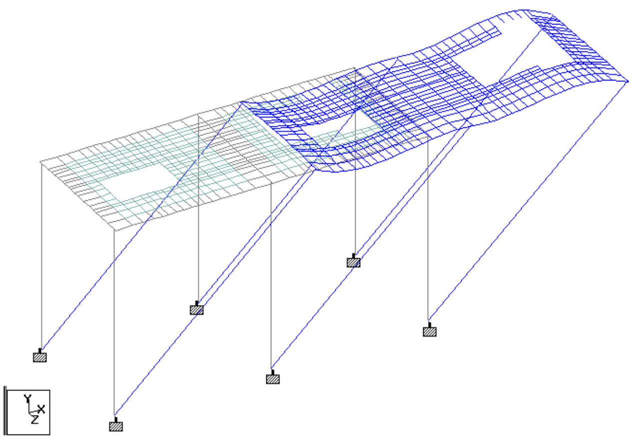

Fig. 5. Response Sectra-Mode Shape 2-Translation Vibration Along X-Direction

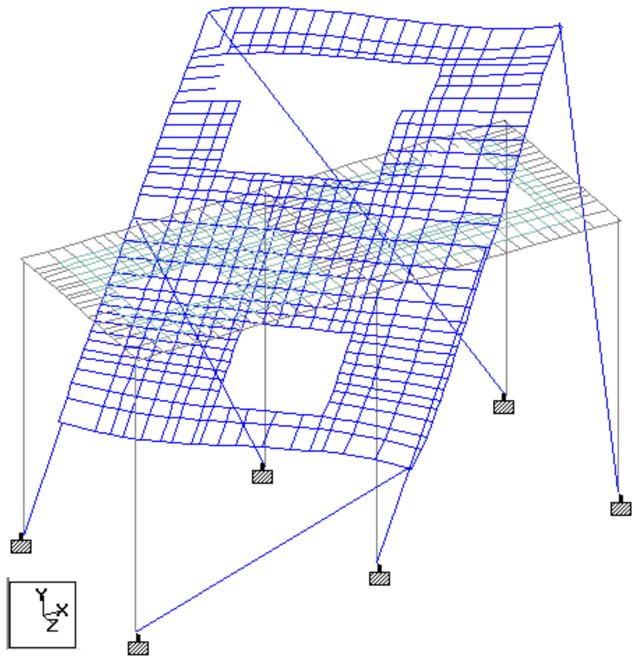

Fig 6 Response Spectra-Mode Shape 3-Torsional Vibration Around Y-Direction

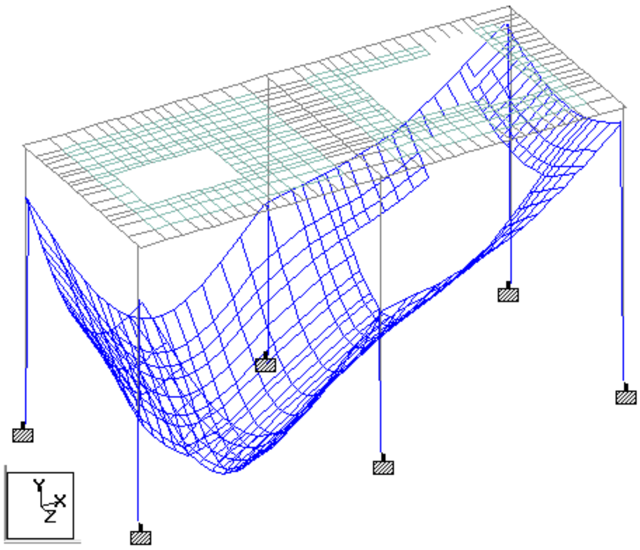

Fig 7 Forth Mode Shape for Seismic Zone II, Fixed Column Support

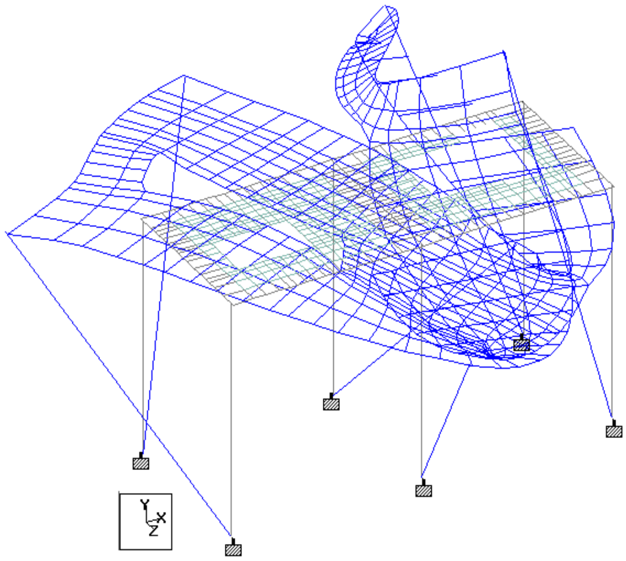

Fig. 6. Response Spectra-Mode Shape 5-Torsional Vibration Around X, Y & Z-Direction

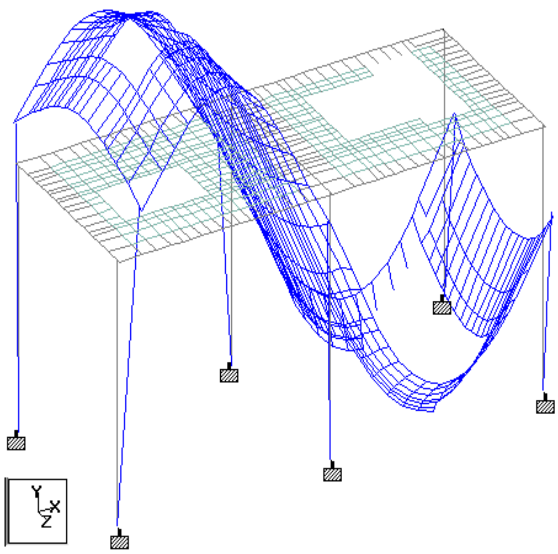

Fig. 7. Response Spectra-Mode Shape 6-Torsional Vibration Around X & Y-Direction

VI. RESULTS

Results for case I for different seismic zone II, III, IV, V for IS 1893 2002 as shown in Table I

TABLE I. : RESULTS FOR DIFFERENT SEISMIC ZONES

Case I				
Parameters for Check	Seismic Zone II	Seismic Zone III	Seismic Zone IV	Seismic Zone V
Max Vertical Frequency Hz	30.875	30.875	30.875	30.875
Max Horizontal Frequency Hz	6.972	6.972	6.972	6.972
Vertical Amplitude of vibration in deck mm	0.0084	0.0084	0.0084	0.0084
Horizontal Amplitude of vibration in deck, mm	0.024	0.024	0.024	0.024
Overall Horizontal Deflection mm	0.562	0.770	1.061	1.512
Overall Vertical Deflection mm	2.907	2.907	2.907	2.907

As observed from response spectrum analysis showed that the change in seismic zone form Zone II to Zone V has almost no effect on the natural frequencies, amplitudes but overall horizontal deflection increases.

Result for case II for different support condition as fixed and pinned as shown in Table II

TABLE II. : RESULTS FOR DIFFERENT SUPPORT CONDITIONS

Case II		
Parameters for Check	Support Fixed	Support Pinned
Max Vertical Frequency Hz	30.875	30.664
Max Horizontal Frequency Hz	6.972	3.616
Vertical Amplitude of vibration in deck mm	0.0084	0.0085
Horizontal Amplitude of vibration in deck, mm	0.024	0.055
Overall Horizontal Deflection mm	0.562	0.463
Overall Vertical Deflection mm	2.907	2.907

As observed from response spectrum analysis showed that the change in the column support conditions from fixed to pinned has almost minor effect on vertical frequency where as horizontal frequency decreased by almost 50% and horizontal amplitude increases approx 2 times than fixed support amplitude also for overall horizontal deflection decreases.

VII. SUMMARY AND CONCLUSION

Summary

The purpose of this paper is to highlight on the machine foundations types, applied loads and behavior under dynamic loading in general and to study the response of large framed foundation in particular. The famous example of the large framed machine foundation is the steam turbine generator foundation. The case study introduced in this paper is a 45 MW generator Captive Power Plant. The main analyses performed are Response Spectrum Analysis.

The analysis is performed to determine the natural frequency of the foundation and the percentage of masses captured by the modes of vibration and the frequencies corresponding to the effect of seismic zone factors and column supporting conditions.

Response spectrum analysis is performed to determine the response of the foundation to the dynamic unbalanced loads that applied from the machine to the foundation during the machine operation. The main aim of this paper is to study the effect of changing different seismic zone parameters as per IS 1893 part 1, and Column Supporting condition Fixed and Pinned on the response of foundation after performing the frequency and harmonic analysis

CONCLUSION

Analysis showed that the change in the Seismic Zone no significant change in natural frequencies whereas horizontal deflection increases 1.2 to 1.8 times and Response Spectrum analysis showed that the change in the Support condition from fixed to pin there is Minor change in vertical frequencies whereas horizontal frequencies decreases by 50%.

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