

Design of Turbo-Generator Foundations

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ABSTRACT: Turbo-Generators are power generation machinery used in the Power Plants. A Turbo generator is a turbine directly connected to an electric generator for the generation of electric power. Turbo generators in power stations are often placed on foundation structures that are flexible over the running range of the machine and can therefore contribute to its dynamics. Established methods of obtaining structural models for these foundations, such as, finite element method have proved successful because of the realistic approach used in the analysis considering all the complexities of the parameters. Dynamic effects of the Turbo-generators also play a major role on sizing of the foundation wherein conditions like resonance is avoided by varying stiffness and mass of the structure which leads to modifications in foundation sizes. For carrying out these studies a detailed 3D Finite Element (FE) analysis approach is considered.

This paper describes integrated software customized for the Power Sector using which, the process of Data Specification, Analysis, Design, Report Generation and Production of Structural Drawings can be completed within a very short period of Time. Also, alternative designs can be performed and an optimal design can be selected.

1 Introduction

A typical Turbo Generator foundation comprises of Top-Deck, Supporting structure and a foundation system (Figure 1). Top deck supports all the equipments including turbine, generator and other rotary equipments. The top deck is again divided into two areas, Turbine area & Generator area. The supporting structure transfers the loads from top deck to the foundation. Foundation may consist of rafts or piles resting on soil. Based on the functionality and requirement, the top deck is monolithically built with the supporting structure or supported on vibration isolation system (VIS) which are mounted on the supporting structure. The Finite Element (FE) model comprises of all these components being modeled as an integrated one if there are no VIS and otherwise modeled separately as top deck and supporting frame to study the behavior of TG foundation.

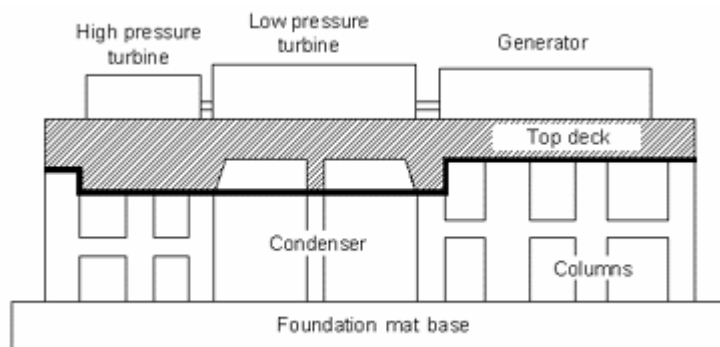


Figure 1. Layout of Turbo-generator foundation

NISA/McFdn, customized software from Cranes Software International Limited, offers CAD based solutions to different power house structures such as Turbo generator foundations with or without VIS and Block foundations. Backed by powerful NISA II Analysis and DISPLAY III/IV – the graphical Pre and Post processor of NISA suite of programs, NISA/McFdn provides seamless interface for modeling, Static, Eigen, Shock & Forced Vibration analysis and design of TG Foundation.

2 Proportioning Criterion:

Proportioning of the components of TG foundation is carried out based on the following criteria:

- Shape of top deck, number of level of beams & their sizing based on TG configuration and its auxiliary units
- To separate the frequency of machine with natural frequency of foundation,
- To limit maximum amplitude of structure as per codal provisions and functional specifications of equipments.
- To carry Dead loads, thermal loads, equipment loads, operating loads, erection loads, unbalanced loads, loss of blade, short circuit and seismic loads.

3 Types of TG foundations:

Different types of TG foundations are considered based on power generation capacity & supported with or without vibration isolators. Types of TG foundations are: 1) Top Deck with Vibration Isolation System with power generation capacity 210MW, 250MW, 500MW and support Frame. In this type top deck and supporting structure are modeled separately. The VIS is modeled using spring elements. 2) Top Deck without VIS with power generation capacity 210MW, 250MW, 500MW. In this an integrated model of Top deck, supporting structure and foundation is generated.

4 GUI Design:

NISA/McFdn as a tool gives an end to end solution with a user friendly Interface for input of Geometric, Loading and other important connection details such as Insert plates and Embedded Parts as per TG manufactures data without sacrificing the flexibility for possible variations in data. Friendly features such as import of data in the Excel format are also provided. Soil parameters as per site conditions are also considered for computation of spring stiffness. User interface also provides direct specification of input details like geometry and elevations. Figure 2 & Figure 3 shows a typical UI text input for McFdn.

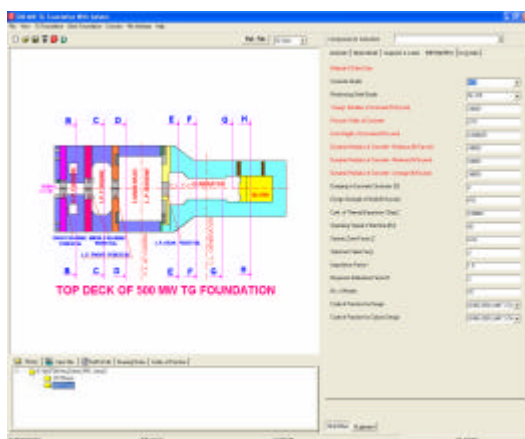


Figure 2. Typical Users' Interface for top deck

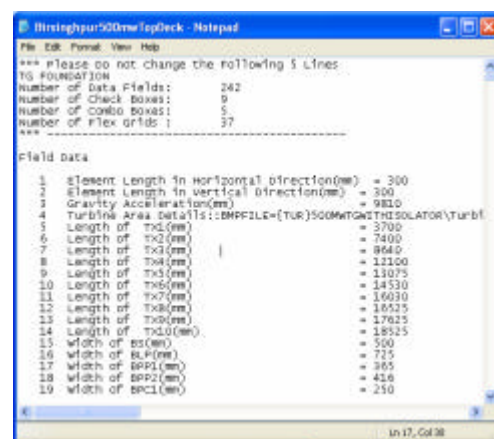


Figure 3. Typical Text input file for top deck

5 FE Modelling:

Based on the geometry and loadings input, FE models are generated automatically. Two types of FE models are generated i.e. Beam/shell model and a detailed 3D solid model. Beam/Shell integrated model is generated for the design of RC structural components conforming to Indian standards. This model is also

used for arriving at the required foundation size. Beam elements are modeled with a two noded NKTP 12, 3D beam element having six degrees of freedom with 3 translations and 3 rotations at each node. Shell elements are modeled with a four noded NKTP 20, 3D General Shell element having six degrees of freedom with 3 translations and 3 rotations at each node. All these elements belong to NISA element Library. A detailed 3D solid model is used to evaluate the dynamic behavior of the structure. Solid model uses an eight node NKTP 4, 3D Solid element having three degrees of freedom with 3 translations at each node. This model is used to evaluate the natural frequency of the structure and perform the frequency response analysis due to harmonic loads on the structure. Vibration isolators (VIS) used to isolate top deck with rest of the supporting structure which eliminates dependency on approximate soil properties, to avoid disturbance on to the surrounding structure. In this case of Top deck supported on VIS, the vibration isolators are modeled using spring elements using a two node NKTP-38, 3-D general spring element with six independent spring rates and six degrees of freedom (UX, UY, UZ, ROTX, ROTY, ROTZ) per node. The spring constants are computed based on Standard specifications. McFdn has an extensive database of the Isolators from which relevant spring data are extracted and applied on the F.E.Model for analysis. A facility of automatic selection of Isolation springs is also available. The soil base below foundation is also modeled using the spring elements and corresponding constants are modeled using the soil data. Loads and boundary conditions are applied on the FE models and a typical FE model auto generated by McFdn are given in Figure-4 through Figure 9. Equipment loads are modelled using 3D mass elements @ the c.g locations and connected to the anchoring points in the FE model by rigid links. Application of the loadings are based on user specified input data and provisions of IS 2974 – Parts III are also considered.

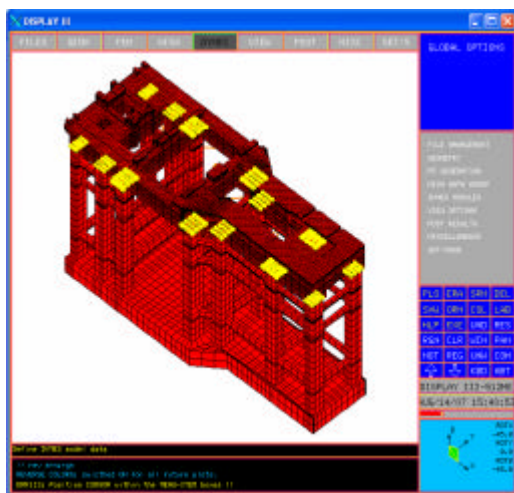


Figure 4. FE Model Auto-Generated using 3D Solid Model for Integrated Top deck and Supporting Structure model

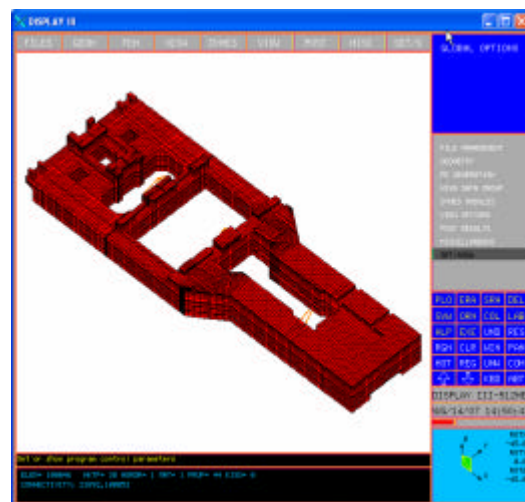


Figure 5. FE Model Auto-Generated using 3D Solid Model for Top deck Supported on VIS

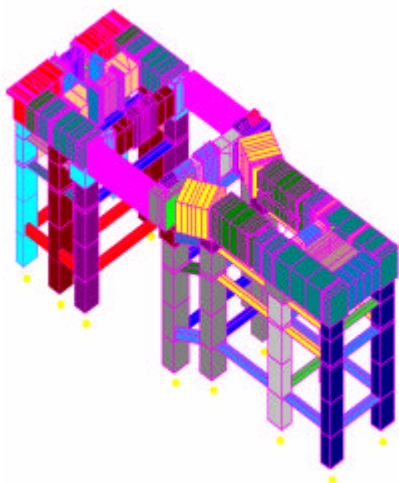


Figure 6. FE Model Auto-Generated using 3D Beam Model for Top deck Supported on VIS.

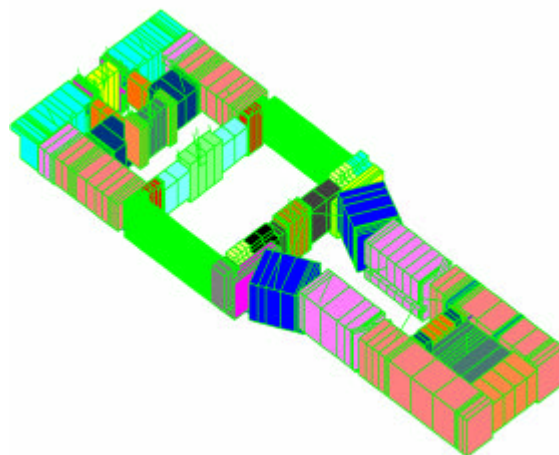


Figure 7. FE Model Auto-Generated using 3D Beam Model for Top deck Supported on VIS.

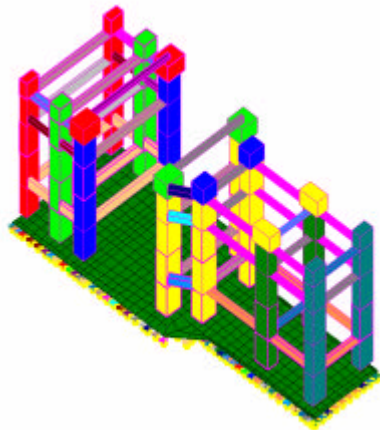


Figure 8. FE Model Auto-Generated using 3D Beam Model for Supporting Structure with raft

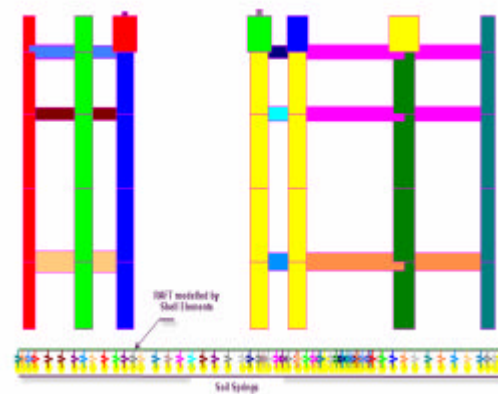


Figure 9. Modeling of Soil springs below the raft foundation

6 Analysis:

Exclusive feature of NISA/McFdn is to analyze and design the entire TG foundation either part by part i.e. Top-Deck, Supporting Frame and Raft foundation or as a whole using both Solid and beam & shell models. A detailed process of FE analysis and design carried out by NISA/McFdn is given in Figure-10.

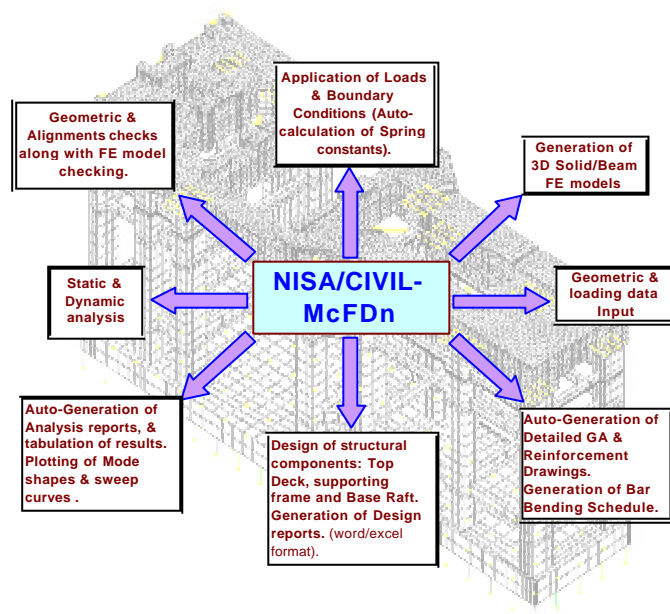


Figure 10. Block diagram of NISA/CIVIL McFdn Capabilities

The criteria for design of Turbo-generator foundations require that the natural frequency of the foundations should not coincide with the operational frequency of the machines and the vibration amplitude should not exceed a code limiting value.

Following types of analysis are carried out for TG foundations.

- Static analysis:* Performed by considering the gravity and lateral loadings for designing the members as per relevant codes of practices.
- Eigen analysis:* Performed to compute the natural frequency of the structure.
- Frequency analysis:* Performed to generate amplitude sweep curves, maximum amplitude, dynamic forces and also to check the shaft misalignment.

Automatic generation of corresponding Beam models with appropriate load combinations from Static & Dynamic loads for structural design can also be done. From the analysis results auto-generation of Amplitude-Sweep Graphs (Figure 11) using SRSS and other standard combination rules can be carried out

at all the rotor points in the Turbo-generator model to study the frequency response behavior of the rotor installations on the Top-Deck (Also it is possible to provide a facility to generate Amplitude sweep graphs at user defined locations). Specified checks for alignment of rotors as per various rules for both displacement and stresses can be made easily. Reports, including Graphical illustrations (Figure 12 & Figure 13) are generated easily.

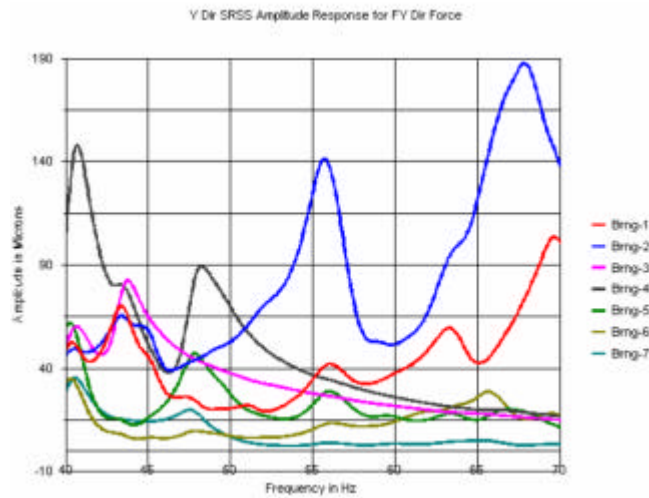


Figure 11. Amplitude sweep graphs

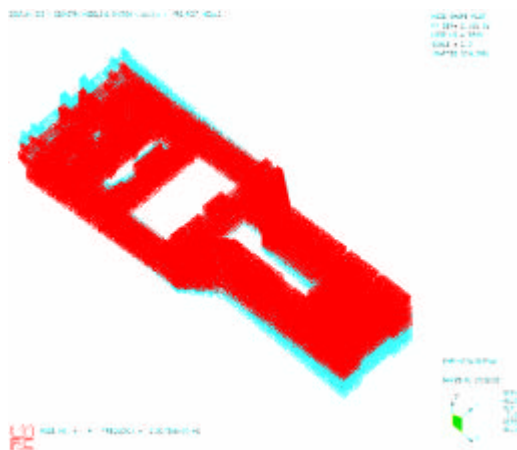


Figure 12. Mode Shape of Top Deck

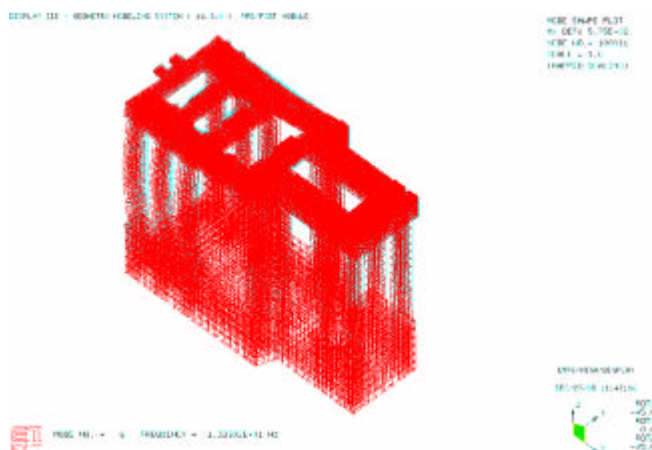


Figure 13. Mode Shape of integrated model of TG foundation

7 Design Criteria:

The design of a TG foundation should lead to a safe and economical foundation block satisfying the operational requirements of machinery and installations along with structural and psychological criteria. Vibrations of machine foundations induce elastic waves in soil (as it generates low strains) which may detrimentally effect surrounding buildings and their effects range from serious disturbances of working conditions for sensitive devices and people to visible structural damage. Therefore, in the design of foundations for such machines, it is important to have a reliable method to predict vibrations of the surrounding soil, structures and equipment. The nature of dynamic loads and the non-homogeneity of soil make the problem of analysis and design of a foundation more complex. Even though the magnitude of dynamic load is relatively small for machines, it needs special attention while designing.

Generated Beam models with appropriate load combinations are used to carry out Static & Dynamic analyses and structural design. Raft design is performed based on rigid beam theory and alternatively using shells supported on soil springs. Detailed design output for all the components are generated (Figure 14 through Figure 16). Design of structural steel members, RC beams, RC columns & RC Raft are carried out as per Standard codes of practice IS 800-1984 and IS456-2000 for Structural steel and Reinforced concrete respectively.

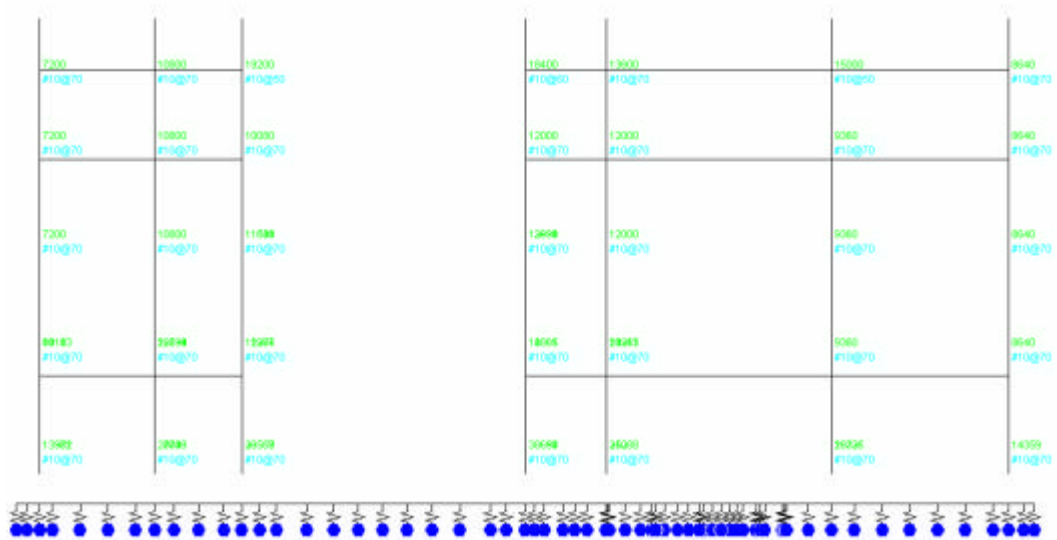


Figure 14. Graphical representation of Reinforcement requirement in columns

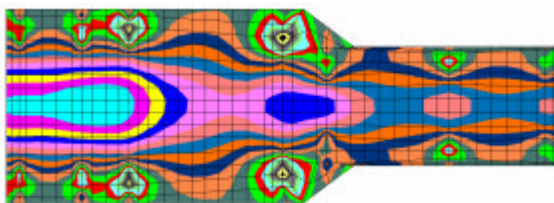


Figure 15. Graphical representation of Reinforcement requirement in raft



Figure 16. Graphical representation of Reinforcement requirement in beams

8 Auto-Generation of Detailed Drawings:

Based on the design results, Auto-Generation of General Arrangement Civil Drawings, General Arrangement Reinforcement Drawings – Top deck (Figure 17 & Figure 18), Beams, Columns, Condenser Pedestals, Raft Slab can be carried out. Along with this, bar bending Schedule as per Indian Standards can be prepared.

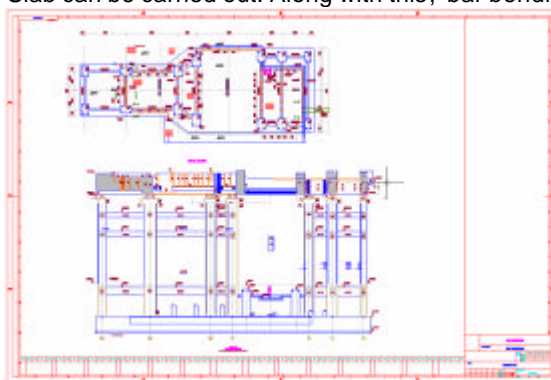


Figure 17. Automatically generated General Arrangement drawing of TG foundation

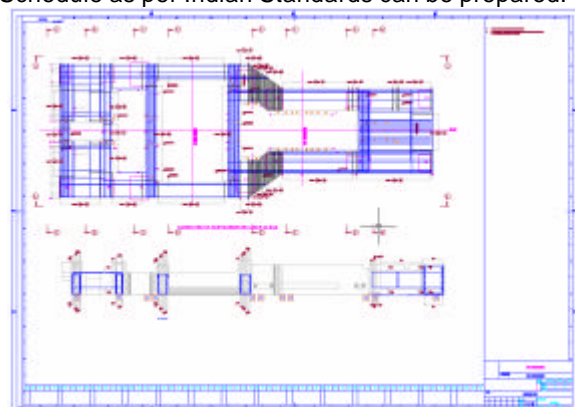


Figure 18. Automatically generated Reinforcement drawing of TG Top deck

9 Report Generation:

User friendly auto-generation of analysis and design reports is a unique feature of NISA/McFdn. A user-

friendly Interface is provided for selection of parameters from generation of the reports (Figure 19 through Figure 22). A typical design output is given in the Figure 11. Generation of reports in MS Word/Excel formats are also available. Report generation consists details of FE Model, Beam Results, Dynamic Analysis results, Amplitude Sweep curves, Maximum amplitudes, Design of RCC Sections.

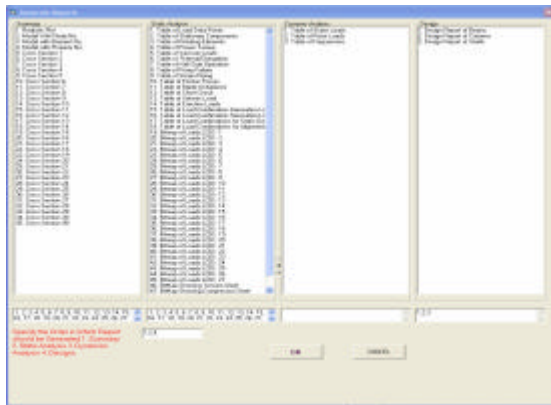


Figure 19. Customised Selection of output for report generation

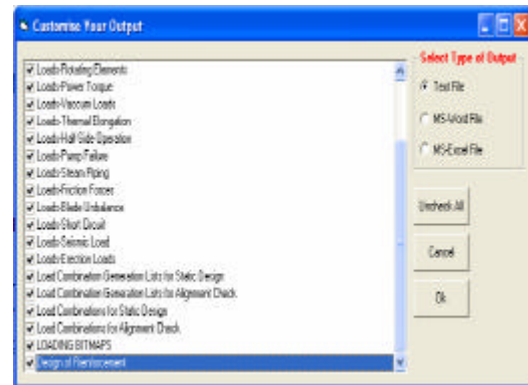


Figure 20. Customised Selection of output for report generation

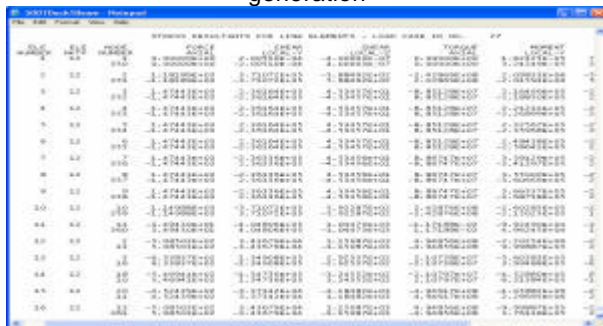


Figure 21. Stress resultant output in ASCII format

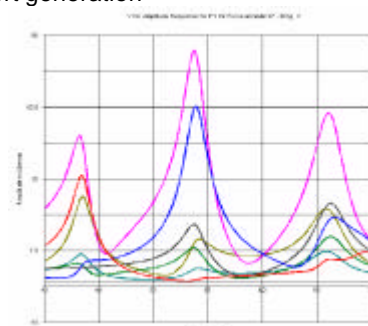


Figure 22. Maximum Amplitude curves

10 Interface to Other Software:

Translator facility for exporting the NISA files to ANSYS, STAAD and other environments are also available for the comparison and verification of results. Further a facility is available to export geometry into PDMS software (Figure 23). This helps in identifying potential interferences with respect to project components such as piping.

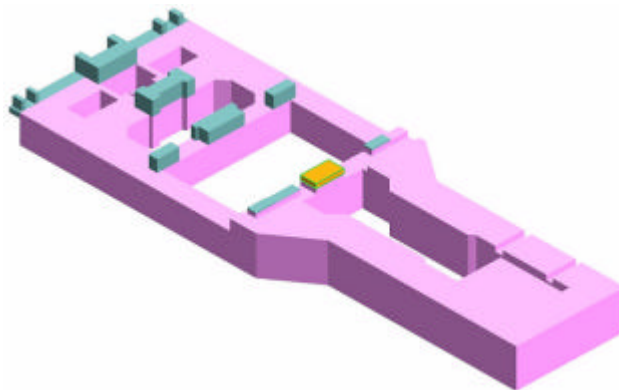


Figure 23. View of Top Deck in PDMS Software

11 Conclusions:

Current trends need special purpose software for Analysis, Design, and Drawing of Power Engineering Structures. NISA/CIVIL & NISA/MCFDN provide the necessary software for a quick, reliable, easy-to-use and

Engineer-friendly tool encompassing all the needs of the Civil Structures in Power Engineering.

12 Acknowledgements

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13 References

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