www.ijiarec.com

ISSN:2348-2079

Volume-5 Issue-1

International Journal of Intellectual Advancements and Research in Engineering Computations

Failure analysis of transmission line towers

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Abstract - **Transmission line towers forms an integral part in the transmission of electric power. Even though the transmission line towers are designed properly as per various codalprovision specified by various countries, they may collapse during even on moderate circumstances if they are poorly designed. Studies were made on various types of Failure cases, that were observed on the full-scale prototype testing of a transmission tower at Tower Testing and Research Station, Structural Engineering Research Centre (CSIR – SERC), Chennai, Tamilnadu, India. This paper summarizes the Full scale testing of a 400 kV DC Transmission line tower, which was abruptly failed under safer load itself. The sudden failure of the Leg member in the +0M body extension on the compression region causes sudden failure of the tested tower.**

Index terms: **Transmission line towers, Tower testing, Structural Failures**

I. INTRODUCTION

Electric power transmission line towers forms essential structure in the overhead electric power transmission system. These towers have to perform well even in natural calamities like flood, cyclones etc., in addition to heavy power transmission along with conductors and various other essential components of the power transmission system. Hence a tower has to be designed so that it should be able to withstand even in complex situations including their actual behavior.

Generally the transmission line towers are classified in to two major types viz Tangent and Suspension type towers. It is also classified according to the number of circuits carried by them viz Single, Double and Multiple Circuit towers. There were various types and classification according to their function, location etc.,

A transmission line tower comprises of legs, primary bracings, secondary bracings, cross arm members, conductors etc., Self-weight and Wind loads are the major criteria under which the tower was essentially designed. Situations such as Broken wire conditions, angle of deviation, icing loads, erection loads etc., are also taken into consideration. The members and connections are detailed by specified codal provisions.

Failure analysis of transmission line towers are the most important aspect in the design of the transmission line towers. Even though they are designed perfectly according various codal provisions, the tower may fail in some certain cases. Hence a designed transmission tower must be tested either experimentally or analytically before implementing the actual design in the field. These test results shows the failure mode of the towers and these failures can be eradicated by implementing various strengthening techniques.

The full scale prototype testing of the tower was carried out to find out the failure mode of the tower. Though the Full scale testing was too expensive, exact failure of the tower can be defined. The same tower had been modeled in Finite element software with all the necessary requirements and it is analyzed for the given loading conditions. The analytical results are compared with the Experimental values.

II. STUDIES ON FAILURE OF TOWER

In reviewing the literatures of failure analysis of transmission line towers, Various Finite element software's were employed by the researchers for determining the analytical behavior of the towers. These results were made into comparison with the values obtained during the full scale testing of the towers.

F.Albermani, S.Kitipornchai, R.W.K.Chan (2008) revealed that the structural failure analysis was predicted by a non-linear analysis methodology of a 275kV DC transmission tower. The tower was modeled as an assemblage of beam-column and truss elements. Initially self-weight was applied first followed by the incremental application of specified load till the ultimate capacity of the tower. The load-displacement curve obtained represents the predicted tower response. These results were compared with prototype test. They concluded that A non-linear analysis technique for a transmission line tower structure can be used effectively to predict the structural failure response.

F. Albermani , S. Kitipornchai& R.W.K. Chan (2009), used nonlinear methodology for structural failure analysis. Analytical method may be used for the analysis instead of expensive full scale testing. So that the structure can be modified and be easily upgraded shows economical. They concluded that for design upgrades and modifications nonlinear methodology may be effective than full scale testing.

JU Yan-zhong (2009), described a research on ultimate load and failure mechanism of a tower. He modeled the tower as beam elements and apply loads in lateral, longitudinal as well as vertical directions with an effect of ice coating. Finite element analysis shows that this results represents the mechanical behavior of the steel member is similar to that of steel member.

N. Prasad Rao, G.M. Samuel Knight , S.J. Mohan , N. Lakshmanan (2012),observed different types of premature failures during full scale testing of transmission line towers at Tower Testing and Research Station, Structural Engineering Research Centre, Chennai. The model was created in a finite element software NE-NASTRAN and was analysed. This study shows that a nonlinear static analysis is essential for understanding thebehaviour, probable load carrying capacity, design deficiencies and instability in the structure.

N. Prasad Rao, G. M. Samuel Knight, S. Seetharaman, N. Lakshmanan&Nagesh R. Iyer (2011),says that nonlinear finite element software was used to model the elasto-plastic behavior of the tower. Their results revealed that bracing members with slenderness ratios above 170 become ineffective, even though they have to carry insignificant forces and nonlinear finite-element analysis is useful in understanding the system behavior and for prediction of the failure pattern and ultimate load.

III. OBJECTIVES

- The main objective of this paper is to predict the failure of the transmission tower by analyzing using finite element software.
- To predict the failure cause and mode of the tower failure analytically and experimentally.
- To finalize a solution to overcome the observed failure of the tested transmission line tower.

IV. FULL SCALE PROTOTYPE TESTING

A 400kV DC (15˚ - 30˚) type transmission tower is tested for the given loads. This is a square tower of base width 23.7 m and 56.25 m in height. Pointed cross arms of different length are used on both the sides of the tower. The tower was tested with 9m body extension. Steel of grades HT 350MPa and MS 250MPa were used for the structural members. The tower configuration is shown below

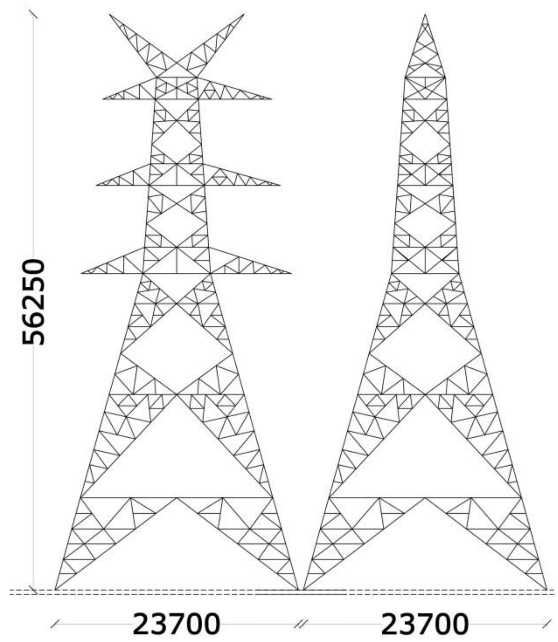


Fig 3 Transverse and Longitudinal face of the tower

Arrangement of Test appurtenances

Initially the Stub was placed in correct position even with a precision of 1mm using Total station. All the structural members were erected using Crane and are connected using bolts.

Fig 3.1.1 Transverse and Longitudinal face of the tower

Systematic arrangement using steel wires are provided for the application of the loads called Rigging. Two types of sensors namely Load and Angle sensors are commonly used. First one is provided at tips of the cross arm, which are used for measuring loads. Later is provided to measure and control the direction of application of the loads.

Loads are applied on 3 mutually perpendicular directions along Longitudinal, Transverse and Vertical directions by means of Servo controlled Hydraulic actuators. All the load cells are calibrated using proving ring before initializing the test. Graduated scale is fitted at top of the tower on both transverse and longitudinal faces of the tower. The rigging arrangements for the application of the loads are shown.

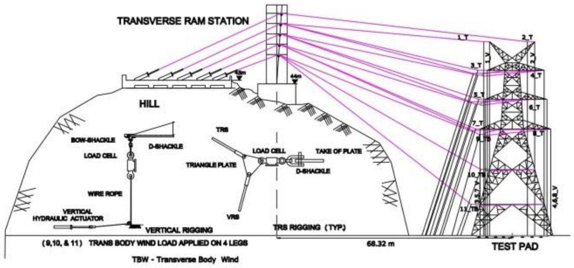


Fig 3.1.2 Transverse Rigging arrangement

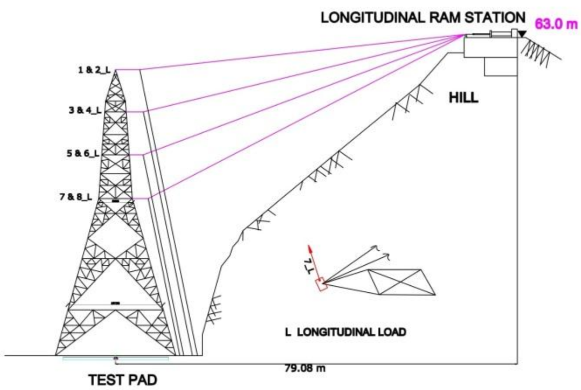


Fig 3.1.2 Longitudinal Rigging arrangement

Testing Procedure

The tower testing was made as per the specifications prescribed in IS:802 Part III. After the completion of the rigging of tower, a trial test is conducted with about 10% of the loading in all the load points. During this trial test, rigging arrangement, hydraulic actuators, functioning of the control system are checked effectively.

Fig3.2.1 Tower to be tested

The test loads are applied at all load points in the stages of 25%, 50%, 75%, 90%, 95% and 100% of the ultimate test load. All the loads are maintained at a period of 2 minutes for each load increments for every stage and 5 minutes waiting period is provided after the application of 100% load. The movement of the deflection is measured as a value of deflection using theodolites on both the face of the tower.

The tower was proposed to design for 7 load cases. The test was initiated with a load case 1 of reliability condition. The corresponding deflection of the tower for each load increment is noted down. The test was preceded with load case 2. On a sudden the tower failed during the waiting period after the application of the 100% load. The failure was initiated at the leg member of size ISA 200x200x16 on the compression side of the tower between 0M extension and basic level of the tower.

Fig 3.2.2Failed Tower

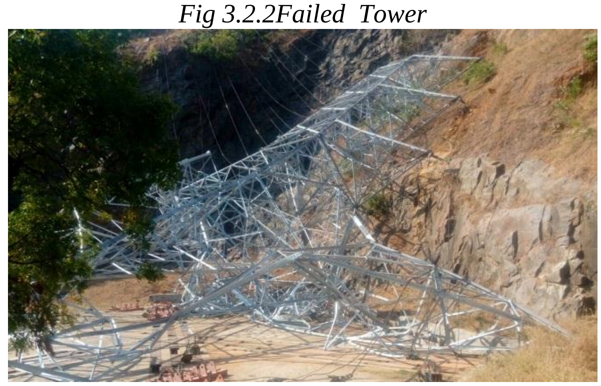


Fig 3.2.3Failed Tower

V. ANALYTICAL METHOD

In order to examine the failure pattern, the tested tower was modeled using beam element in a finite element software ANSYS. All the structural elements were incorporated as finite element.

Modeling

A finite element software ANSYS is used for modeling the tower. The version of APDL was used for modeling the tower with all the necessary component of structural members. The joints are provided as pinned connections.

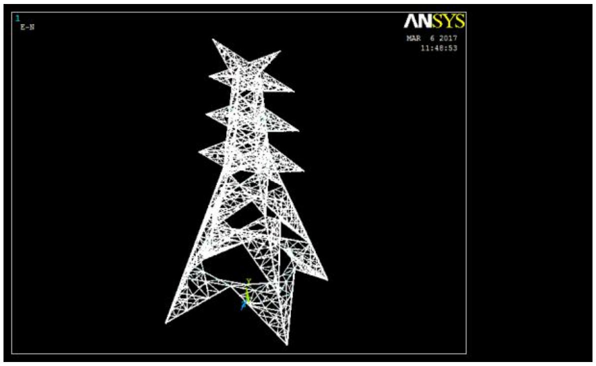
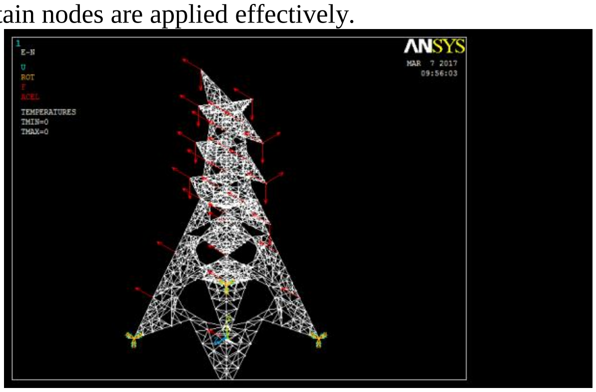


Fig 4.1.1 Tower Modeled in ANSYS

All the structural members of the tower are provided as beam elements. All the nodal joints are provided constraints of resisting moments as the beam elements experience rotation at the joints. All the members are modeled as same material prescribed in the Structural drawing.

Applying Constraints and loads.

The modeled tower was given constraints at all the nodal points. Constraint of All degrees of freedom are applied at the bottom most node on all the legs to provide as a fixed support. The loads which are predetermined by various aspects are for different load cases are tabulated. These loads are applied at certain nodes are applied effectively.



VI. CONCLUSION

In the future work, the proposed model will be then subjected to loads. The response of the tower to the applied loads will be taken for failure analysis. The exact cause of the failure, how the tower will fail will be able to get from the analytical method. Later both the results from the experimental and analytical works will be compared to finalize the cause of the failure of the tower.

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