CHAPTER 1
INTRODUCTION

1.1 GENERAL

A stage has been reached, wherein man's life is much dependant on electrical power. In the recent past, the world has spent a major part of its financial resources in setting up power plants, be it hydel, thermal or nuclear. Research on new sources of electrical power like Solar and Wind is also being carried out at a fast pace. Electrical energy is now so intricately linked with our living conditions as to make the per capita consumption of electricity, a realistic yardstick for measuring the progress and prosperity of a nation.

The author's own nation, India, has also been trying hard since Independence to meet the ever increasing demand for electrical power. From an installed capacity of 2,300MW in 1950, Power generation rose to 46,855 MW by the end of 1984-85 and is expected to go up to about 72,000MW by the end of 1989-90 - a thirty fold increase within the past four decades. In order to distribute this huge quantity of power to load centres, the existing transmission lines are to be strengthened and new lines have to be laid. With the national policy to locate super thermal stations at the pit-heads and to strengthen the inter state ties for effective functioning of the regional load despatch centres, the programme of providing adequate transmission capacity becomes very stupendous.

In a transmission and distribution network, the purpose of transmission line tower is to support conductors carrying electrical power and one or two ground wires at suitable distances above the ground level and from each other. The transmission line towers contribute about 35-45 percent to the total cost of the transmission line and development of an optimum design can, therefore, result in substantial economy. Great responsibility thus rests on the transmission line engineer who has to prepare not only economical but also dependable design.
A transmission line tower is a highly indeterminate space frame structure. Its cost is in proportion to its weight. The weight in turn is influenced by the designer's diligence and his efficient application of the governing specifications. Given the same codal provisions with respect to material, ruling dimensions, loads and allowable stresses etc., any two competent engineers should be able to produce designs resulting in structures which are strikingly similar in weight. This similarity is only possible if designers aim at selecting the most economical configuration for the tower and the choice of the various sections is done with a thought of conserving every kilogram of steel possible, within the limitations of the specifications consistent with reliability.

The selection of an optimum outline and bracing pattern contributes to a great extent in developing an economical design of a transmission line tower and thereby reducing the overall cost. The selection of an outline is quite flexible. For high voltage and extra-high voltage towers, many configurations have been tried and adopted from considerations of economy, efficient performance of line and to some extent aesthetic values. For a particular tower configuration selected, the outline decided shall satisfy both electrical and structural requirements consistent with economy.

Tower bases adopted are generally rectangular and square. The square type broad-based towers are the most commonly used. The number of circuits the tower is to carry, the number of earth wires, right of way etc., also affect its configuration. Depending upon the position of the tower along the transmission line, the tower can be classified into one of the three or four categories such as tangent, angle and dead-end types. Each type fulfils slightly altered functional requirements with some modifications in the profile suitable for the varying conditions.

Over the years no radical changes had taken place either in the configuration or in the methods of analysis and design of these towers. The towers are mainly subjected to dead loads, wind loads and line tensions. Earlier, these towers were being analysed by graphic static methods. With the advent of modern high speed digital computers and the Matrix and Finite Element Methods, it has become possible to consider most of
the complexities of the structure and provide a very rigorous and near accurate analysis of the tower for various load conditions. In conventional analysis of a tower, a three dimensional space truss is idealised as a set of statically determinate planar trusses and is designed on a conservative assumption that longitudinal forces acting on the tower are resisted by members in the longitudinal planes and the transverse forces by members in the transverse planes and torque due to unbalanced forces as shear forces in all the planes.

The design that follows the analysis arrives at the size of members which are structural rolled steel angle sections. These angle members are relatively easy to fabricate and erect and are extensively used as legs and bracings in a transmission line tower. These are selected from the commercially available sections and materials such that the stresses obtained from the analysis are not exceeded. Though the designer may try to arrive at the optimum sizes, he is constrained by the commercial availability of the sections and the codal provisions of that particular country. This generally leads even the best design, to be conservative. Under such circumstances, seeking a very rigorous analysis which may be costly in terms of computational effort may not be desirable. But if the analysis were to be simplified, one should have an estimate of the loss of accuracy arising out of the simplification made, so that unsafe design is avoided.

One assumption usually made in the analysis is that the tower is a pin-jointed structure, i.e., members meeting at a joint meet at a single point. However due to practical difficulties, it is very rare that the tower is fabricated so. When the joint is not a pin-joint, there may arise secondary stresses in the members which are not included in the analysis. The aspect whether these secondary stresses could become important from the design point of view for the whole tower, especially in the leg members which carry the maximum load is not seriously investigated into, in the past. There have been some studies on the importance of these stresses in the cross arms. Roy et.al. [1] have concluded that secondary bending stresses have very little influence on the design of the tower, when arm proportions are adequate.
The secondary bracings used to reduce the slenderness ratio of the main members, specially the leg members, provide an opportunity to choose smaller sectional sizes \([2]\). This in effect is expected to reduce the total weight of the structure. In practice, it is found that the secondary bracings themselves constitute 15% to 20% of the total weight of the structure. Thus, one is left to ponder whether the decrease in weight of the main members due to the use of secondary bracings can offset the self weight of the bracings so that overall reduction in weight is achieved.

Having designed the tower, the validity and safety of the design is checked by a full scale prototype test in tower testing stations. This involves testing of a full scale tower to destruction using heavy and expensive equipment. The test is not only expensive but time consuming, though it would yield a real picture of the behaviour of the tower under different loading conditions. It may be worthwhile to reflect whether a small scale model test, involving lighter equipment and easier test procedures can be performed to check the adequacy of the design. The model test may be less costly than the prototype test. However, one should ensure that the scaled down model and the test procedures adopted as per the laws of similitude are such that the results of the model can be interpreted vis-a-vis the behaviour of the full scale tower. If the model test can be shown to yield reasonable results, probably it is worth going in for model testing rather than for a prototype test atleast for a preliminary check on the design.

This research project has been planned with the above aspects in mind.

### 1.2 SCOPE AND METHODOLOGY OF THE INVESTIGATION

This investigation tries to provide answers to the following questions.

1. Is it really necessary to do a costly rigorous three-dimensional analysis of the tower and what is the extent of inaccuracy brought in by the different simplifications made in the analysis procedure?

   To answer this question, an existing tower is analysed using Structural Analysis Program, SAP IV as
(a) Plane truss
(b) Space truss
(c) Plane frame and
(d) Space frame

The author himself has developed a space truss package and the tower is analysed using this program also.

The results of the different analyses are compared with the results of a full scale test done on a real tower at the Tower Testing Station of C.P.R.I., Bangalore, India. These test results are taken as basis for defining the inaccuracy brought in by the simplifications made in the analysis.

2. Do the secondary bracings reduce main member forces to that extent to cause an effective reduction in the weight of the structure? Or, can one do away with the secondary bracings?

To answer this question, the same tower considered above is analysed with and without secondary bracings and the results are compared to get an idea of the member forces.

3. Does the fabrication of the tower, done in such a manner that the members do not meet at a point at joints, give rise, under loads, to secondary stresses that may be important from the design point of view?

For the purpose of investigating this, a full scale test on the bottom segment of a tower with non-point joints is conducted and the stresses obtained at various locations are compared with the analytical results obtained by considering the segment

(i) as pin-jointed and
(ii) as fabricated.

4. Does a small scale model test, which is less expensive, reflect truly the behaviour of a prototype without any scaling effects and can the results of the model test be used in assessing the adequacy of the design?

For the purpose of studying this, two one-tenth scale models
of the prototype, one in aluminium with equal flange sections and another in steel with unequal flange sections have been tested in the laboratory and the results are compared with the prototype tower test results, as well as analytical results of the model and prototype.