Chapter 4

Layout of power line towers

A review of the main components of a conventional transmission tower (figure 4.1) is given below. The outline of the tubular test tower is given for comparison (figure 4.2). A power line tower has two major functions or requirements; firstly, the structure must resist the mechanical loads generated from wind loads on the structure and conductors and secondly, the structure must ensure minimum phase-to-phase and phase-to-ground clearances.

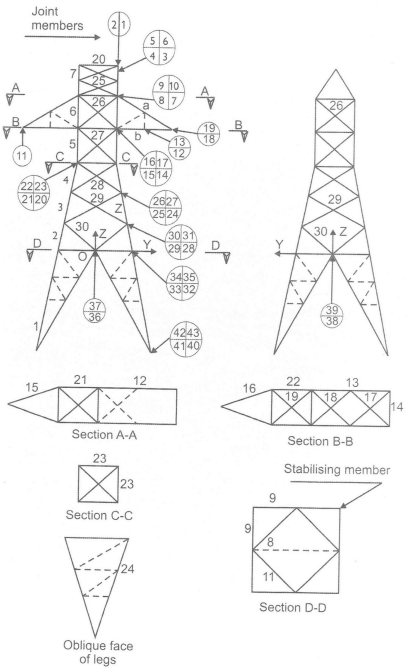


Figure 4.1: Typical tower geometry.

As stated earlier, a power line tower is part of a system comprising of conductors, insulators, foundations, hardware and the manufacturers of tower members. Each of these aspects should be considered when planning and designing structures in order to achieve near optimal structures.

Power line towers are designed as vertical cantilever beams. In low voltage (LV) power lines, it is typical to have the vertical cantilever beam as a monopole fabricated from either wood or steel, whereas in high voltage (HV) and extra high voltage lines (EHV) it is much more economical and practical to have a vertical cantilever fabricated as a lattice beam (see figure 4.3).

From the structural requirements we can derive that a tower has the following components of importance:

- tower bracing system
- tower body
- tower hamper
- tower cross arm

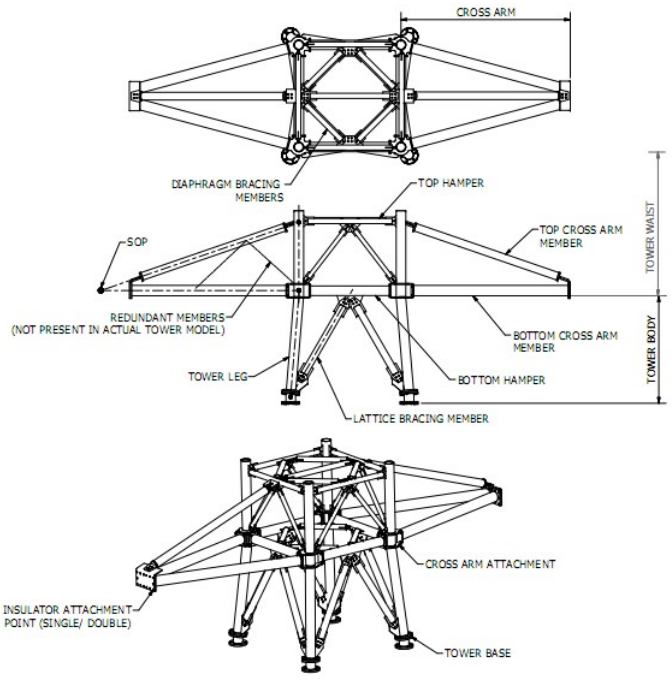


Figure 4.2: Layout of tubular test tower.

The components of a power line structure has been unchanged for several decades. Specific reference to a document first published by Ryle (1945) is made in order to prove this. Figure 4.4 shows a typical 220/330 kV tower used in single circuit (horizontal configuration) lines that is still implemented in current line designs today. Figure 4.5 shows another single circuit structure (delta configuration) and figure 4.6 shows a double circuit structure (vertical configuration).



Figure 4.3: Lattice type tower.

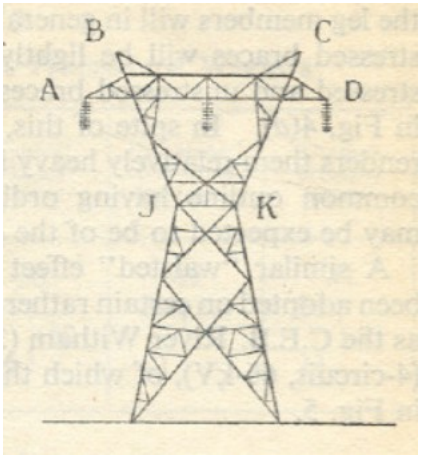


Figure 4.4: 220/330 kV power line structure.

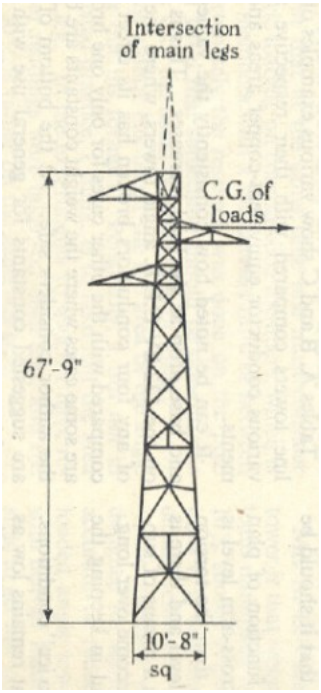


Figure 4.5: Single circuit tower - delta configuration.

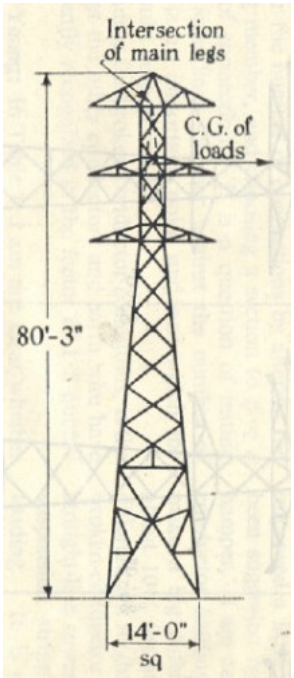


Figure 4.6: Double circuit tower - vertical configuration.

When designing bracing members, it should be kept in mind that there are two types of bracing members typically found in lattice type structures. The first brace type is the main braces in the tower that is used to take up the horizontal loads in the structure. These are usually highly stressed members. The second type of bracing is the redundant members (the term redundant is typical in the transmission industry) or secondary bracing members that are used to reduce the unsupported length of the main leg and bracing members to increase buckling stability. These braces also increase the stiffness of the structure. The design load of the redundant bracing members range from 1.5% to 2.5% of the maximum load of the main member it supports. Figure 4.7 highlights the two different bracing systems. The lines in bold are the main bracing members and the dashed lines the support or redundant members. Ryle suggested that the weight of a bracing member in compression is $Pl + cl^2$ and that of an unstressed or redundant member is proportional to l^2, where P is the load in the member, c is a constant an l is the unsupported length.

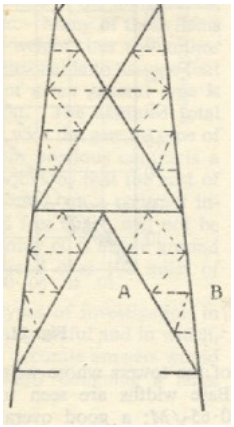


Figure 4.7: Various transmission tower bracing types. The solid lines represent main braces, while the dashed lines represent redundant members.

It can thus be seen that it is advantageous to reduce the loads in the bracing system in order to reduce bracing member weights. Ryle reported that the weight contribution from braces on the total weight of a power line structure varies between 43% and 53%. Various bracing systems (figure 4.8) should be considered when planning the structure, additionally, one should consider variations of where the intersection of the leg members and the total force resultant coincide (figure 4.9). Depending on the type of tower that is being designed, it is preferred that most of the load is transferred through

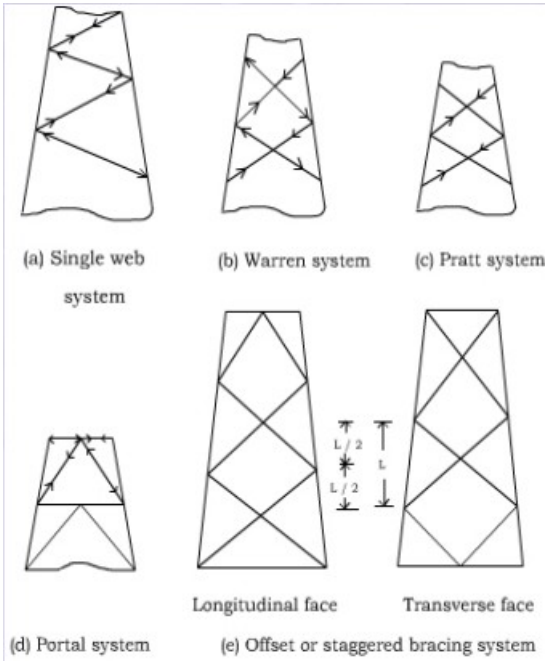


Figure 4.8: Various bracing systems typically used in power line towers.

the main leg members and very little through the braces. It is considered economical to have the resultant of the forces below the intersection of the main leg members in order to reduce the bracing loads and in return have smaller members and less weight.

The increase in bracing dead loads (self weight) also affects the forces in the lower leg members. Ryle (1945) indicated that the load in the bottom leg member as a percentage of tower weight may be as much as 40% in large river crossing structures. This is a significant number and it can be seen that by implementing tubular members, the total tower weight will be reduced and the size of the main members will also reduce. This in return also reduces the overall projected area of the structure which then reduces the overturning moment and the loads on the foundations. It can be seen that it is worthwhile to carefully consider the layout and design of the main leg members and the bracing system.

The tower body is located just above the leg members and below the tower cross arms. The body of the tower is the section that provides the required phase-to-earth clearance and transmits the vertical and horizontal loads from the conductors. There is also a large amount of bracing mem-

bers located in the tower body. The main structural members (leg and main bracing members) usually follow a linear path through the tower body. The body of a tower is usually square and tapers down towards the top of the tower.

Considering that the body of a tower covers a large portion of the structure which is exposed to wind loading, the advantages of using tubular members throughout the body are:

1. reduced number of redundant (secondary) bracing members (Nielsen & Stottrup-Andersen (2006)).
2. reduced tower member wind resistance (Nielsen & Stottrup-Andersen (2006)).
3. reduced visual impact on the surroundings due to less tower members (Nielsen & Stottrup-Andersen (2006)).

The selection of the tower base width takes proper planning and consideration of the leg intersection point with the resulting wind loads. Also, the cost of foundations must be considered when selecting the tower base width.

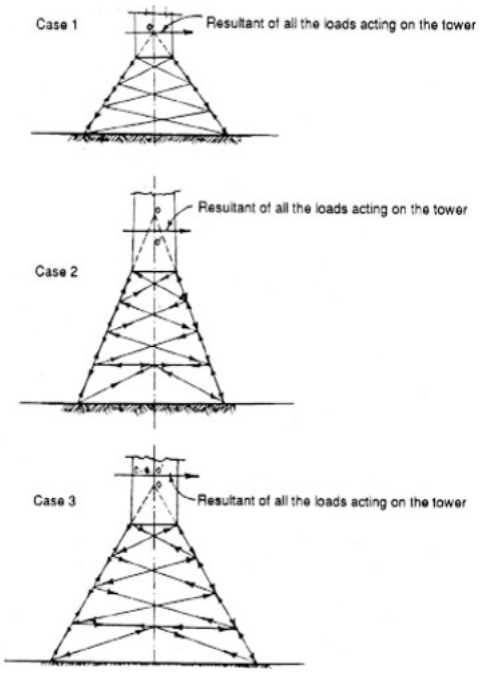


Figure 4.9: Variation in intersection of leg members with resultant load.

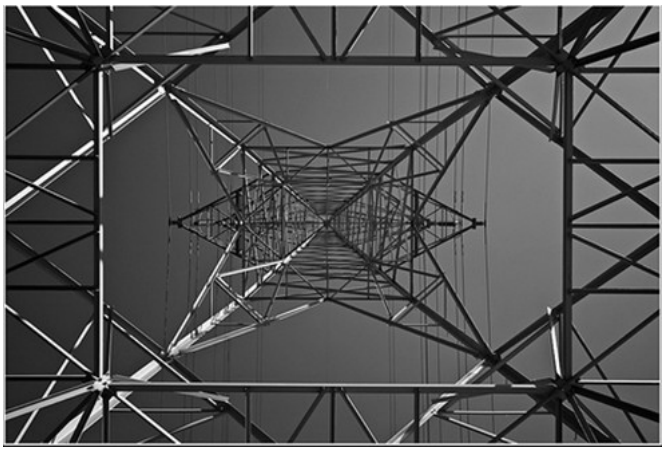


Figure 4.10: Diaphragm bracing in the tower body that are used to take up torsional loads.

Ryle (1945) suggested that the base width ($feet$) lie between $0.35\sqrt{M}$ and $0.65\sqrt{M}$. Where M is the moment at the base of the tower. This should prove to be a practical starting point for the base width.

It is also common to find horizontal braces (diaphragm braces) in the body section (figure 4.10). The horizontal braces absorb the torsional loads generated by an imbalance in the structure. They are usually found between the tower legs and body section and where there is a change in tower geometry.

The tower hamper is the section above the tower body where all the cross arms are attached. The purpose of the hamper is to ensure that the required phase-to-phase clearances are maintained and that the mechanical loads from the conductors are effectively transferred to the tower body. Ryle (1945) indicated that the weight of the hamper and cross arms contributes between 18% and 30% of the total tower weight. The advantages of using tubular members in the tower hamper are the same as for the tower body.

4.1 Conclusion

Considering the layout of a typical transmission tower, it can be seen that towers designs have been unchanged for the last couple of decades. From the layout of a typical transmission tower it may be shown that there are four

main structural elements that need proper planning before the design may begin. These major components are; the tower bracing system, tower body, tower hamper and the cross arms.

The work done by Ryle (1945) indicates that the weight from the bracing members can be as high as 53% of the tower weight. Ryle (1945) also mentions that the weight contribution from the tower hamper and cross arms can be as much as 30%.

Importantly, a study on the advantage of using tubular profiles for telecommunication structures has shown that by using circular hollow section, angular section towers have more redundant bracing members, higher wind resistance and has a higher visual impact on the surroundings compared with circular hollow section towers.

Thus, to conclude, the overall weight and visual impact may be reduced by; firstly, proper planning be designing the structure and secondly by using circular hollow sections throughout the power line structure.