A Comparative study on various types of transmission line towers foundation

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Abstract: Transmission line towers are tall structures used to transmit power either through AC or DC systems. They carry overhead high voltage power line ranges 66KV, 111KV/132KV, 230KV/220KV, 400KV, 745KV/AC. They are very important as they maintain proper space between inter-conductor spacing's within requisite limits under any conditions. As the transmission voltage levels increases the height as well as weight increases. As the height of the tower increases thereby resulting in higher loads which require bigger and heavier foundation. In many situations the cost of foundation increases because of designs and challenges like the remoteness, soil condition and improper marking of route. In such conditions proper determination of design parameters of soil and type of foundation chosen on it is very important. In this paper the comparison of transmission line tower foundations and types of tower foundations will be discussed.

***IndexTerms* – Tower, Stub, Foundation, Transmission lines.**

I.INTRODUCTION

A transmission line high power tower is a tall structure, usually a steel or tubular framed tower, generally supported over a ground. The power grid is connected through this loaded transmission power lines centers (cities) through a sub-transmission network of normally 33kV (or sometimes 66kV) lines. They are used in high voltage AC/DC systems, and it comes in a wide variety of shapes and sizes. Typical height varies from 15 to 55 m. Apart from steel; other materials like concrete and wood can be used. Anchoring of transmission tower legs consisting of angle (in the same slope as that of the tower leg) with bearing cleats at the bottom, all embedded in the concrete foundation, which is known as Stub.

II.TRANSMISSION LINE TOWER FOUNDATION

Foundation of any structure plays a crucial role in safety and satisfactory performance of the structure because it transmits its own weight from structure to earth. While not having a sound and safe foundation, structure cannot perform the functions that it's been designed for. Therefore, the planning for foundation should be given at high priority. Past records show that failures of tower foundations are mainly responsible for collapse of towers. These failures have typically been related to sure deficiencies either within the style or classification or construction of foundations. Foundation cast are over safe because of inappropriate classification, resulting in resource wastage. From design point of view, selection of most suitable type of tower foundation is challenging because of the various soil conditions at the site of construction of tower. The foundations in different types of soils have to be designed to suit the soil conditions of particular type. As the thought of safe value for properties of soil has been distributed with within the style of foundation, limit value of properties of soil ought to be obtained from soil investigation report.

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III.STEPS FOR CONSTRUCTION OF TRANSMISSION LINE TOWER FOUNDATIONS

(i) Excavation

(ii) Stub setting

(iii) Base levelling with sand filling

(iv) PCC

(v) Concreting

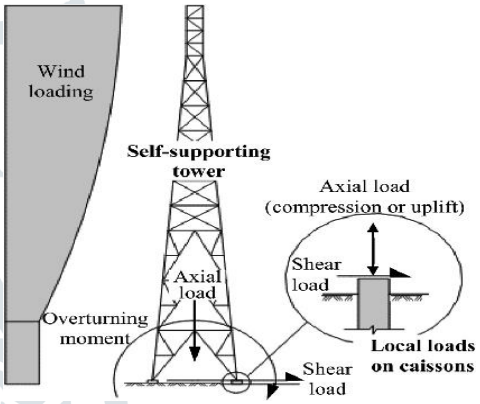
(vi) Stub Footing concrete

(vii) Stub Concrete

IV. TYPES OF LOAD ON TRANSMISSION LINE TOWER FOUNDATIONS

The foundations of transmission line towers measures only to a few forces -
a. The compression or downward thrust;
b. the strain or uplift forces
c. The lateral forces or aspect thrusts in each crosswise and longitudinal direction.

The magnitudes of above forces rely on the categories of tower. The magnitudes of limit loads for foundations must be taken 10% more than those for the corresponding towers.



V. TYPES OF TRANSMISSION LINE TOWER FOUNDATION

Tower foundations are designed for different forces such as uplift force, downward thrust, lateral force and over turning moments for different soil. Already stated on the basis of ground water table, types of soils and rock transmission line tower foundations can be classified as follows.

5.1 ON THE BASIS OF GROUND WATER TABLE

5.1.1 Normal dry soil foundations

When water table is below foundation bed and when soil is cohesive and homogeneous with full depth of 10-15 % clay content then foundation for tower is known as normal dry soil foundations.

5.1.2 Wet soil foundations

When water table is below foundation bed and is below 1.5 m ground surface. The foundation in the soils is having standing surface water for a long period for penetration not exceeding 1m below ground level is also termed as wet foundations.

5.1.3 Partially submerged foundations

When water table is at a depth between 0.75m to 1.5m below ground surface and when the soil is normal and cohesive then partially submerged foundation is provided.

5.1.4 Fully submerged foundations

When water table is within 0.75m below ground level and soil is normal and cohesive then the foundation is known as fully submerged foundations.

5.1.5 Black cotton soil foundations

When the soil is cohesive having inorganic clay content greater than 15% and having high shrinkage and swelling property then the foundation is known as black cotton soil foundations.

5.1.6 Partial black cotton foundations

When the top layer of soil upto 1.5m is black cotton and thereafter if it is normal and dry cohesive soil then it is known as partial black cotton foundation.

5.1.7 Soft rock/Fissured rock foundations
When discomposed or fissured rock, hard gravel or any other similar nature is met this can be executed without blasting. Under cut foundation is to be used at these locations.

5.1.8 Hard rock foundations
Ground requires chiseling, drilling and blasting for constructing transmission line foundation then the foundation will be termed as hard rock foundation.

5.1.9 Sandy soil foundations
Soil with low clay content (0-10%). then the foundation will be termed as sandy soil foundation.

5.2 ON THE BASIS OF STRUCTURAL ARRANGEMENT OF FOUNDATIONS

5.2.1 P.C.C Type
It is having plain cement concrete in footing with reinforcement in stub portion only. The stub is connected to footing with the help of cleat angles or by keying rods. The footing may either be pyramidal or stepped.

5.2.2 R.C.C Type
In both footing and stub potions of R.C.C type foundation it will monolithically casted by reinforcement and concrete. In this many different types can be designed for tower foundation. Three most commonly used are R.C.C spread type foundation (chamfered type), RCC spread type foundation with working clearance and RCC spread type foundation without working clearance.

5.2.3 Block Type
In this type of foundation it is having block concrete and chimney. It is usually provided in both soft and hard soil. Generally footings are provided with minimum 1.5 m below the ground. The size of it is decided after checking various design consideration such as uplift capacity, bearing capacity etc.

5.2.4 Under-Cut Type
This type of foundation has an undercut at foundation level. This under-cut will help to increase uplift resistance as it behaves like a anchored key with footing and soil. This type of footing is usually provided in normal dry cohesive soil, hard murom, fissured/soft soil and in soil with clinkers.

5.2.5 Grouted Rock and Rock Anchor Type
This type of foundation is provided for very hard rock soil. In this foundation is divided in two part viz. block of small depth and bars which needs to be anchored in a grout. The anchoring bars should have minimum 12 mm diameter and the grouted hole should be of 20 mm more than the diameter of bars. For bond between reinforcement bar and grout/concrete the hole need to be roughened enough. Anchoring of soil and reinforcements can be done with the help of mechanical tools like eye-bolt, fox bolt or by using threaded bars or anchored bars.

5.2.6 Augur Type / Under Reamed Pile Type
Augur type foundation is similar to pile foundation in which the cement concrete with reinforcement is placed in a hole drilled by augur. Hole from augur can be done either manually or by mounted truck. After hole is done by augur the hole is stabilized by the bentonite slurry so as to stand firm.
In under-reamed pile the piles are having shaft of range 2.5 to 3 times of pile diameter. Shaft helps to prevent piles to resist from negative skin friction and from expansive/contraction reaction by black cotton soil. The safe bearing can be achieved if the height is kept nearly 3.5 m length.

5.2.7 Steel Grillage Type
In Steel Grillage type of foundation the footing pad is made of series of steel joists placed horizontally and the stub is placed directly over it. It is provided for smaller height towers. For heaver tower the lateral forces are taken care by additional bracing member which will carryover the additional shear directly to the grillage beams downward in pad. Since it is prepared from steel joist so it need to prevent it from corrosion, steel joist need to paint from bitumen coat. After the erection of stub and bottom potion of towers, the back fill of soil need to be done. The back fill should be properly compacted so that no pocket voids would present in it.

5.2.8 Steel Plated Type
In this type of foundation the base is same as steel grillage; it has a pressed steel plate instead of footing. It is provided in firm soil which can resist lateral force as well as uplift force. The base area of pressed steel is depending upon the head loading from transmission line tower. It needs very careful excavation at bottom.

5.2.9 Pile Type
This type of foundation is provided in place where the water bodies like sea bodies, river bed and its probability like scouring, flooding may arise. If the bearing capacity of soil is very low then also this type of foundation is needed over there. It is designed based on the soil exploration data like type of soil, maximum discharge of flood, scour depth etc. Uplift resistance is done by the pile cap and dead weight of the concrete.

5.2.10 Well Type

It is provided in major river bodies where flow discharge is huge and scouring/silting activity is also very much. In well foundation the curb need to sinked up to hard strata from where lateral movement could be resisted. The general parameters needed to design well foundation are soil parameters like angle of internal friction, cohesive properties at various levels, maximum scour depth and maximum velocity of water.

Design philosophy for transmission line tower foundation depends upon the type of soil. The foundation needs to be strong and stable to carry loads such as wind load, live load and seismic load. For perfectly designed these forces should transmit to soil and should not exceed soil bearing capacity. Therefore for different types of soil different suitable foundation needs to be provided as summarized below –

Srno	Types of soil and rock	types of foundation to be provided
A	**Soils**	
1)	Non cohesive soils	
i)	Sandy soils	RCC spread type, pile foundation
ii)	Soft and hard murrum	RCC spread type, underreamed pile foundation, grillage foundation
2)	Cohesive soils	
i)	Normal soils having mixture of silt and clay (Clay not exceeding 15 %)	RCC spread type, Block type
ii)	Normal soils having mixture of silt and clay (Clay exceeding 15 %)	Augur type / under reamed type foundation steel plated type, pile foundation
iii)	Marshy soil	well foundation
B	**Rocks**	
i)	Soft rock / fissured rock	Block type, undercut type, pyramid chimney type
ii)	Hard rock	Grouted Rock and rock anchored type, steel plated type, Block type

CONCLUSION

There many types of foundations that can be provided for towers. Even though more than one type can be used for particular case, the optimization remains a challenge for designer. Thus a comprehensive understanding of the nature of forces acting on foundation, vis-à-vis their interaction with soil through the foundation need to be developed to achieve economy along with safety

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