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Robustness Analysis of Transmission Line Tower

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A B S T R A C T

India has a sizable population spread out over the nation, which necessitates a sizable transmission and distribution system to meet the country's need for power. A transmission line is an integrated system made up of one subsystem for each type of support structure, a conductor subsystem, a ground wire subsystem, and a ground wire subsystem. Due to the enormous span, high height, and flexibility of the gearbox tower line system, many of the gearbox towers are damaged by significant wind loads.

EHV transmission lines are often supported by steel lattice towers. The design and analysis of a transmission line tower under the combined action of wind and seismic stresses are suggested in the current work. Finding the transmission line tower's collapse pattern under heavy loads and replacing the members that failed because of inadequate reinforcement with functionally graded materials (FGM).

Keywords: Transmission line tower, robustness analysis, seismic force, pushover analysis.

1. Main text

India has a large population residing all over the country and the electricity supply need of this population creates requirement of a large transmission and distribution system. Also, the disposition of the primary resources for electrical power generation viz., coal, hydro potential is quite uneven, thus again adding to the transmission requirements. Transmission line is an integrated system consisting of conductor subsystem, ground wire subsystem and one subsystem for each category of support structure. Mechanical supports of transmission line represent a significant portion of the cost of the line and they play an important role in the reliable power transmission. They are designed and constructed in wide variety of shapes, types, sizes, configurations and materials. The supporting structure types used in transmission lines generally fall into one of the three categories: lattice, pole and guyed.

The supports of EHV transmission lines are normally steel lattice towers. The cost of towers constitutes about quarter to half of the cost of transmission line and hence optimum tower design will bring in substantial savings. The selection of an optimum outline together with right type of bracing system contributes to a large extent in developing an economical design of transmission line tower. The height of tower is fixed by the user and the structural designer has the task of designing the general configuration and member and joint details. • The goal of every designer is to design the best (optimum) systems. But. because of the practical restrictions this has been achieved through intuition, experience and repeated trials, a process that has worked well.

Suspension towers: These towers are used to support the transmission lines from the top, and are suspended in the air. They are typically identified by their shape, such as "A-frame" or "V-frame" towers.

Tension towers: These towers are used to support the transmission lines from both ends, and are under tension. They are typically identified by the number of insulator strings they have, such as "double-circuit" or "quad-circuit" towers.

Dead-end towers: These towers are used to anchor the transmission lines at the end of a run, and are not under tension. They are typically identified by their shape, such as "delta" or "portal" towers.

Angle towers: These towers are used to change the direction of the transmission lines, and are identified by their angle, such as "45-degree" or "90-degree" towers.

Terminal towers: These towers are used to connect the transmission lines to a substation or other equipment, and are identified by their function, such as "busbar" or "disconnect" towers.

1.1 Structure

Tower legs: The tower legs are the main vertical components that provide support for the transmission line. The legs are usually made of steel, and their height can vary from a few meters to over 100 meters, depending on the voltage and length of the transmission line.

Crossarms: Crossarms are horizontal components that are attached to the tower legs and provide support for the transmission lines. They are usually made of steel, and their length can vary depending on the number of circuits and the spacing of the conductors.

Insulators: Insulators are used to isolate the transmission lines from the tower structure. They are usually made of porcelain or composite materials and are attached to the crossarms.

Bolts and nuts: Bolts and nuts are used to join the different components of the tower together. They are usually made of high-strength steel and are tightened to a specific torque to ensure that the tower is stable and can withstand wind and other environmental loads.

Foundation: The foundation is the part of the tower that is buried in the ground and provides support for the tower. The foundation can vary in size and depth depending on the soil conditions and the size of the tower.

1.2 Construction of references

Site preparation: Before the tower can be constructed, the site must be cleared and leveled. This involves removing any vegetation, rocks, or other obstacles that may interfere with the tower construction.

Tower component fabrication: The tower components, such as the tower legs, crossarms, and insulators, are fabricated in a manufacturing plant or factory. The components are usually made of steel or other high-strength materials, and they are designed to meet the specific requirements of the transmission line.

Foundation construction: The foundation is the part of the tower that is buried in the ground and provides support for the tower. The foundation is constructed by excavating a hole in the ground, pouring concrete into the hole, and installing the anchor bolts that will be used to attach the tower to the foundation.

Tower assembly: Once the foundation is in place, the tower components are assembled on site. This involves bolting the tower legs, crossarms, and other components together to form the tower structure. Cranes and other heavy equipment are used to lift and position the tower components.

Installation of transmission lines: Once the tower is erected, the transmission lines are installed. This involves stringing the conductors between the towers and attaching them to the insulators on the crossarms.

Testing and commissioning: After the tower and transmission lines are installed, they are tested and commissioned to ensure that they are operating safely and reliably. This involves conducting electrical tests, such as insulation resistance and high voltage tests, and checking the tower and transmission line alignment.

1.3 Section heading

General Information: This section includes the project title, date, and location, as well as the name and contact information of the designer and the client.

Design Criteria: This section describes the design requirements for the tower, including the voltage rating, line configuration, and environmental loads such as wind, ice, and earthquake. It also includes the relevant codes and standards that the design must comply with.

Tower Geometry: This section describes the geometry of the tower, including the tower height, width, and crossarm spacing. It also includes the dimensions and shapes of the tower components, such as the tower legs, crossarms, and insulators.

Materials and Fabrication: This section describes the materials and fabrication processes used for the tower components. It includes information on the types of steel, bolts, nuts, and other materials used, as well as the welding and fabrication methods.

Foundation Design: This section describes the foundation design, including the type of foundation, soil characteristics, and anchor bolt layout. It also includes the calculations and analysis used to determine the foundation size and depth.

Assembly and Erection: This section describes the assembly and erection process for the tower, including the sequence of tower component installation and the use of cranes and other equipment.

Testing and Commissioning: This section describes the testing and commissioning process for the tower and transmission line, including electrical tests, tower and line alignment checks, and other tests required to ensure that the tower and transmission line are safe and reliable.

1.4 Footnotes

Load and Design Assumptions: This footnote can provide additional details on the load and design assumptions used in the tower design. For example, it may include information on the wind speed, ice thickness, and earthquake magnitude used in the design calculations.

Materials Specifications: This footnote can provide more information on the types and specifications of the materials used in the tower fabrication. For example, it may include details on the steel grade, galvanization, and surface treatment used for the tower components.

Foundation Design: This footnote can provide additional details on the foundation design, including the soil properties and bearing capacity, as well as the anchor bolt specifications and layout.

Tower Assembly and Erection: This footnote can provide more information on the tower assembly and erection process, including the equipment and tools used, and the safety measures taken during the construction process.

Testing and Commissioning: This footnote can provide additional details on the testing and commissioning process, including the specific tests conducted and the acceptance criteria used to ensure the tower and transmission line are safe and reliable

2. Illustrations

Tower Elevation: This is a vertical view of the tower that shows the overall height and configuration of the tower, including the tower legs, crossarms, and insulators.

Tower Section: This is a cross-sectional view of the tower that shows the internal components, such as the tower legs, crossarms, and insulators, as well as the foundation and anchor bolts.

Foundation Detail: This is a detailed view of the foundation that shows the excavation, concrete pour, and anchor bolt placement.

Crossarm Detail: This is a detailed view of the crossarm that shows the insulators, hardware, and conductor attachment points.

Assembly Sequence: This is a step-by-step illustration of the tower assembly process, showing how the tower components are bolted together and erected on site.

Line Configuration: This is an illustration of the transmission line configuration, showing how the conductors are strung between the towers and the insulator stringing pattern

3. Equations

1. Wind Load Calculation: The wind load on a transmission line tower is calculated using the following equation:

$F = 0.5 \times \rho \times V^2 \times Cd \times A$

where:

F = Wind force on the tower (N)

ρ = Air density (kg/m^3)

V = Wind speed (m/s)

Cd = Drag coefficient

A = Projected area of the tower perpendicular to the wind direction (m^2)

2. Tension Calculation: The tension in the conductor is calculated using the following equation:

$T = W \times L$

where:

T = Tension in the conductor (N)

W = Weight of the conductor (N/m)

L = Span length between towers (m)

3. Sag Calculation: The sag in the conductor is calculated using the following equation:

$S = (L/2) \times [(T/W) + (W/2 \times H)]$

where:

S = Sag in the conductor (m)

L = Span length between towers (m)

T = Tension in the conductor (N)

W = Weight of the conductor (N/m)

H = Conductor height at midspan (m)

4. Tower Design Loads: The tower design loads are calculated using the following equation:

W = (Wc x Cc) + (Wg x Cg) + (Wi x Ci)

where:

W = Total design load on the tower (N)

Wc = Weight of the tower components (N)

Cc = Load factor for the tower components

Wg = Weight of the conductors and ground wire (N)

Cg = Load factor for the conductors and ground wire

Wi = Weight of the ice (N)

Ci = Load factor for the ice

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With Sincere Regards,

K. Sai Bhaskar Vasmi

Mani Kranthi

Yagna Prasad

5.Appendix

Tower Standards and Codes: This appendix can include a list of the applicable standards and codes that govern the design and construction of the transmission line tower. This can include local and national building codes, as well as industry-specific standards, such as those set by the American Society of Civil Engineers (ASCE).

Tower Component Specifications: This appendix can include detailed specifications for the tower components, including steel grades, dimensions, and tolerances. It may also include information on the coatings and finishes used for the tower components.

Foundation Design Calculations: This appendix can include detailed calculations and drawings for the tower foundation design, including soil borings, bearing capacity calculations, and anchor bolt layouts.

Wind and Ice Load Calculations: This appendix can include detailed calculations and charts for the wind and ice loads used in the tower design. This can include information on the wind speed and direction, ice thickness, and other relevant factors.

Tower Testing and Inspection Procedures: This appendix can include information on the testing and inspection procedures used during tower fabrication and construction. This can include information on destructive and non-destructive testing methods, as well as procedures for visual inspections and quality control.

Glossary of Terms: This appendix can include a glossary of technical terms used in the transmission line tower design document. This can be useful for stakeholders who may not be familiar with the terminology used in the document.

6. References

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