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Analysis of Structural Behaviour of Transmission Towers

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ABSTRACT Now days, electricity is having more demand in all countries. Many lives are depending on this electricity. From a source point to a substation, to pass and electricity; conductors (wire) are required. But to hang the high voltage cables, the need for transmission tower is unavoidable. The transmission tower should have good strength under cable hanging load, wind load etc. So, designing of transmission tower is a very challenging task for a design engineer. In this work, 36m of tall transmission tower is selected and it was analyzed using simulation software ANSYS. The deformation, stress, axial force and bending moment are analyzed in transmission tower by varying the cross-section thickness and cable load. As well, the analysis is further extending to develop the surrogate model using FEA results. The 3D line body tower is modeled in Solid Works and structural analysis performed in ANSYS. Kedro software is used to develop the surrogate model. Once the surrogate model is prepared, ANSYS results are compared with this and both has good agreement between them. This model is useful to analyze the structural behavior by changing the thickness and load.

KEYWORDS: Electricity, Deformation, Axial Moment, Bending moment, Kedro software.

I. INTRODUCTION

Now days, electricity plays a key role in almost every industry in the world. In order to send the electricity from one source to the other, components such as conductors and wires are required. To carry the loads of the wire, a tall transmission tower is very important . So, the structure of the transmission tower must be stable, should have good strength, should be durable and should bare the load . For that analysis of transmission tower is an interesting research and many researchers have worked on it. Finite element methods are in huge demand in all industries. The finite element method is used to identify the truss structural behavior and can analyze the strength of tower. Now days, government and private sectors are constructing transmission towers to reach all remote areas. To analyze the strength of the transmission line, this type of work will be very useful. Before constructing the structure, how FEA analysis is useful will be seen in this work. Approximate values are also analyzed in this work. The creation of geometry is complex, so it is convenient to use the model instead of studying the effects of some parameter changes and surrogate models are designed and all the possible analysis are made before the construction of the transmissiontower.

1.1 Aim of Project

The aim of the work is to develop a surrogate model to analyse the load, thickness, stress, bending moment, axial force and deflection. In the transmission tower it is difficult to create a digital model of towers to study various parameters, so it would be useful to obtain an approximation model**.**

1.2Description of transmissiontower

The need for electricity is very much needed for every country in the world and also the requirement for the electricity is more in developing countries. One of the main structures for the transmission of electricity is transmission tower line . The main purpose for transmission towers is to supply the electricity to various parts of the world. Due to this, the necessity of building the power station is increased and when the power stations are more, more will be the transmission tower lines from the power stations where the electricity is needed. To improve the reliability the connection between the transmission lines is also increasing. The construction of transmission line is very much important because it should be built in a way to

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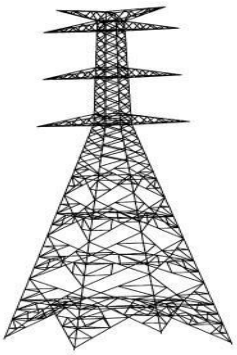
withstand any natural calamities . The construction of transmission line should follow certain standards. To arrange and design a transmission tower, certain procedure must be followed considering on electricity and construction view point. Based on electricity view point, the main specification the material insulation and also authorization for the material that conducts electricity is very much required. For the structural view point, cross section of the materials that carries electricity, position of each and every conductor's present, placement of both the ground wires with reference to conductor. And these are the things that will determine the starting point and design of the transmissiontower.



1.3Parts of TransmissionTower

Choosing the right tower is based on land from which the line lies. The union of the below shown tower are very much suited to most of the transmission line. Based on the angle of deviation, the transmission towers are classified into six types seen in the belowfigure.

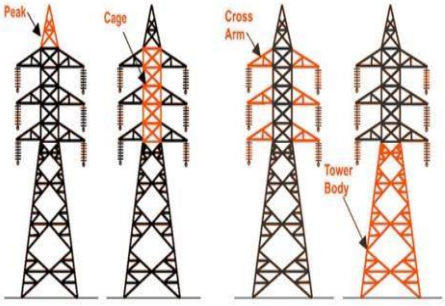


Figure: Parts of transmission tower

1 Upper body of the tower(peak)
2 Caged container where the cross arm isplaced
3 Cross arm for carrying conductors.
4 Bracing with body of the tower
5 Towerlegs

1.4Design of transmissiontower

The design of transmission tower is classified in to two types. They are lattice and tubular steel type.Lattice steel type structure has multi components of steel members are assembled with the help of welding and bolding together.Tubular steel pole is a hollow steel pole and made of single member. Various parts are combined to form a single member.

1.5Types of TransmissionTower

Now days, transmission towers are used to support high voltage conductor power line. These can be classified depending on geometry, load carrying, height and mechanical strength [10]. The few types of transmission towers are double circuit tower, waist type tower, tubular steel pole, crossing pole, guyed cross rope suspension tower and guyed Vtower.

1.5Waist typetower

It is a most common type of electricity transmission tower which is used for 110 to 735 kV transmission line networks. It is simple geometric shape structure which can be easily assembled and also dissembled easily, see Figure 2.3. These types are most suitable for cross vary uneven terrain. Total truss is constructed with the help of x type bracings. The transmission tower consists of two sections which is tower top and tower body. The parts present in the tower top are beam, cross arm, fork, insulator ring and conductor bundle. The tower body contains waist, horizontal member and main leg.

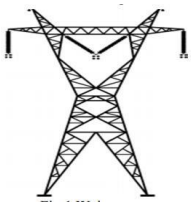


Figure Waist type tower

1.5 Double circuittower

It is a small foot print tower, which is used generally for 110 to 315kV transmission network. The height is around 25m to 60m, see Figure 2.4. In this work we consider this type of transmission tower . The double circuit transmission tower has four cross arms, bracings, leg extension, cage and stub. In the double circuit transmission tower, the base of the tower is wide and the top part appears to be narrow. Inside the tower body, the bracing is crossed and appears to becaged.

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1.6 Guyed-Vtower

These types of towers seen in Figure 2.5 are generally constructed to transmit high voltage network such as 230 to 735kV. The guyed V- tower parts are bottom mast, guy wire, extension wire and cross arm. This type of transmission type is most economical compared to the above two transmission towers. The structure wire is in V shape with cross arm and the guy wire is connected from ground to cross arm.

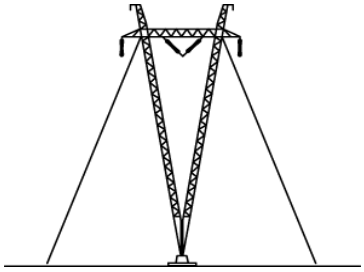

Figure Guyed –v tower

1.7Tubular steelpole

This type of pole sees in Figure 2.6, used in area where there is less space because this tower is small and light weighted compared to others. Because of this advantage this tower is used in cities which are highly populated.

Figure Tubular steel pole

II. LITERATURE REVIEW

N. Prasadetal , he analyzed on steel tower, which is one of the main components in transmission line. In order to maintain reliability, prediction of failure is very much important. Once a steel structure is failed, the loss will unexpected and huge. Due to this, power supply from one end to other will be ceased. In his research, he analyzed different types of towers and he observed various early failures in those towers. The observed failures and the reason of failure are reported in detail. In his work he mainly concentrated on k-type and x-type braced panels. The truss members are modeled as beam element. He also used finite element analysis to analyze tower using NASTRON software. He considered elasto-plastic behavior of steel. Due to this maximum load to withstand deformations and stresses are found numerically. Performance of steel tower wasdiscussed.

Y.M. Ghugal et al , a transmission tower with four legged are commonly used on transmission network. A three-legged tower is normally used for telecommunication, radio and microwaves, but not in electricity transmission towers. In his work, he concentrated on 400kV transmission line network tower. Three legged and four legged with constant height, constant loading, bracings and angle sections are considered in his study. Slenderness effect, deformation and section forces are taken are output for the transmission towers. Different loadings are considered and found that 21% of steel weight is reduced for three-legged tower when compared to four-legged tower.

GopiSudam et al , he analyzed transmission tower in a narrow-based transmission line network. Light weight material fortransmission tower is very important to increase the demand for electricity, because low weight structure are less cost compared to conventional tower and due to this many towers can be constructed. In his work he mainly concentrated on cost effectiveness to provide ideal power supply for the required area. He selected 110kV and 220kV multi-voltage narrow transmission lines and steel tower. The STAAD PRO software is used to analyze the transmission tower and he carried his work on 3Dview.

Mustafa Mahamid et al , transmission tower is made of steel lattice structure. Steel angular is used to connect each other with the help gusset plates. To analyze the real time true behavior, a full-scale transmission tower is considered in the analysis. Finite element software ABAQUS is used to analyze the structure. Using these main investigations was done to find local bucking behavior of the truss. In this all the member are taken as a beam element and angular sections are used. The joint behavior is represented using the pinned section. Deformation and bending stress are considered as output parameters for transmission tower and they are compared to find out the optimum transmission model.

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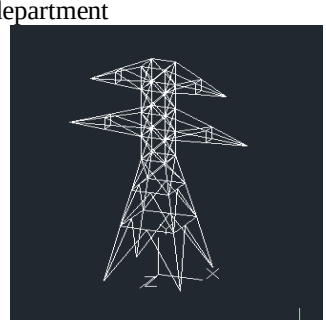
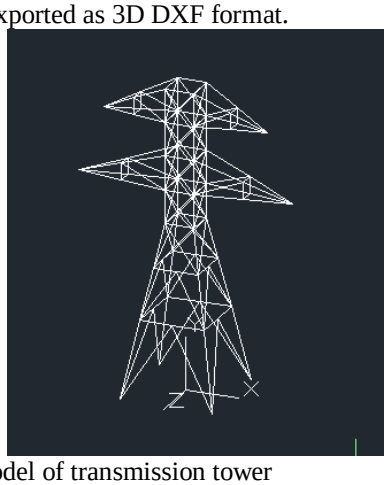
III. METHODOLOGY

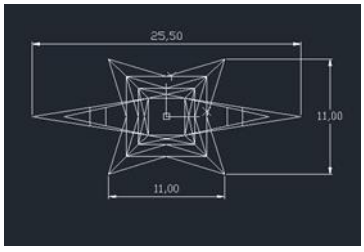
In this work, a static structural analysis on transmission tower is done. The geometrical parameters such as shape of tower, type of cross section, length, width and height are taken from the electrical department



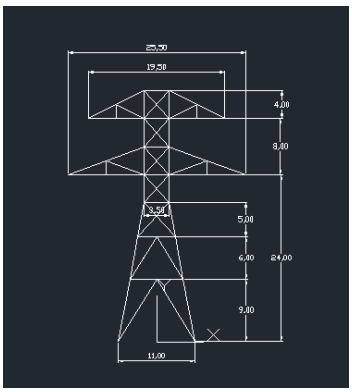
Initially, once the data is taken from the electricity department. The model is created in AutoCAD software. AutoCAD is user friendly software where the 2D drawing can be easily implemented. In this work, transmission tower is a quadrangular shape that consists of different element with different length. Even it is a complicated structure; line body model is created within short time. The model has 11m width and length at the bottom. The total height of the tower is 36m. It is created with line and end point snap command in AutoCAD. Once the model is prepared, it was exported as 3D DXF format.



Line model of transmission tower

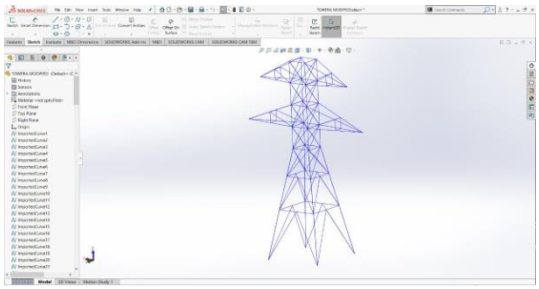


Top view of transmission tower



Front elevation of Transmission tower

Created geometry cannot import in to ANSYS software because it is not compact format in ANSYS. So, line body 3D DXF file formats have to convert as IGES file or para-solid file, so that a Solid Works software is used asconvertor to file format. A Solid Works is software that is released by Dassault systems. It is a good to create the complex geometry model in short time. It is user friendly software to create the solid and surfacing the modeling. But this work, the taken model is totally a line type geometry model. So, basically it is a difficult to create in Solid works so that the model is created in AutoCAD and it was transferred to ANSYS with Parasolid format through Solid Works



IV. RESULTS

Design of Experiments

Design of experimentation is a crucial part for accurate plan pie. Design of experiments acts as a prime part in the design of reliability which is also called as DFR and this help to analyze the result of different factors all at the same time and thus enables to provide optimum design. The design of experiments supports to pin down the connection between the effect and the source. DOE helps to understand the interconnection between the factors that are caused. It also helps to control the level of factor such as dimensions, design and material and thus providing with optimum reliability. Experimental errors such as noise can be minimized using DOE. It also helps to enhance the strength of

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the design and alternative procedure.

PhysicalExperiments

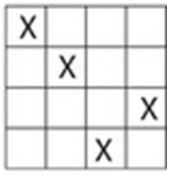
Physical experiment and computer simulation experiments are useful to identify the impact on input variables using outputs of engineering, scientific and technological importance. From last 15 to 20 yrs., these types of strategies are increasing with computer codes

Computer SimulationExperiments

In computer experiments, total work is performed on the computer. Now days, FEM has more demand in structural, thermal and CFD related problems [29]. Using the different input variables, we can identify the required output with low cost and without any experimental step up and instruments. This method is useful for students and also in industries. They can perform any analysis with low cost. Once the simulation is done and output is taken, using different parameters and set of sampling data are selected using Latin, orthogonal and random sampling methods

Latin Hyper cube sampling

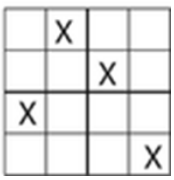
It is a sampling method to select evenly rough samples taken from sampling space dimension. For an example, if we take 2-dimensional space using Latin hyper cube, it does select all high and all low option at all



Latin Hyper cube sampling

Orthogonal sampling method

It is an extension method to Latin hyper cube sampling. In the orthogonal sampling approach, it is very small correlation between factor A and B. Each of the four subspaces is evenly selected



Orthogonal Sampling Method

Design of Experiments for Transmissiontower

For this study Latin hyper cube sampling method is selected. Now, we consider the maximum and minimum values for the input parameters such as cross-section thickness and load (force). These are entered in the Kedro software and from that we get different iterations to be performed for the further analysis. Here we consider the maximum and minimum values of cross- section thickness and load (force) as 15,7 and 15000,5000 respectively. After entering the values, the load design form is selected and, in this thesis work we consider 12 Latin hypercube sampling design form that is 12*2MSDLH file is selected

SurrogateModels

The main task for updating of finite element method is to reduce the systemic error in finite element model. So many engineers are using this finite element method approach to improve the efficiency in their model. But many researchers are considering the FEA report as insufficient. Because, the real time result doesn't match with the FEA results, which means it is a symmetrical error in structural component which is discretization error . But to reduce the error, high friendly finite element modeling software has more demand in many industries. To find out the results in a structure, iteration must be done repeatedly. To overcome these, surrogate model is new methodologies that attract many engineers. Now it becomes an alternative to FEA analysis. Surrogate modeling is a technique to reproduce the finite element model data using statistical and mathematical approach. It works and depends on input and output boundary condition of finite element model. The main concept of surrogate model is to apply to the reliability analysis. Recently, a surrogate model which is used to update the finite element model.

The three types of popular surrogate models are as follows

Once the transmission tower analysis is solved in ANSYS, the results from ANSYS such as stress, bending moment, axial force are deflection for all the 12 iterations are noted and tabulated for the further analysis seen in Figure 4.10, 4.11 and among them few are shown in the below and the surrogate model is developed accordingly

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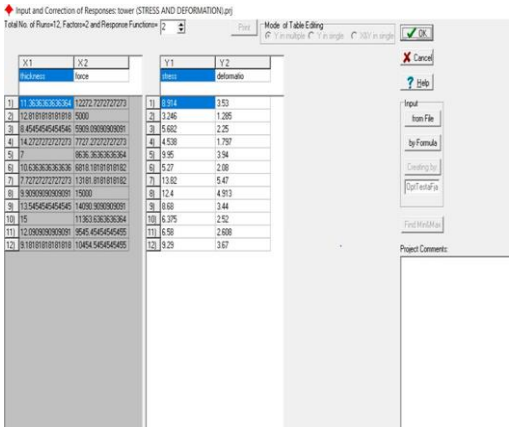
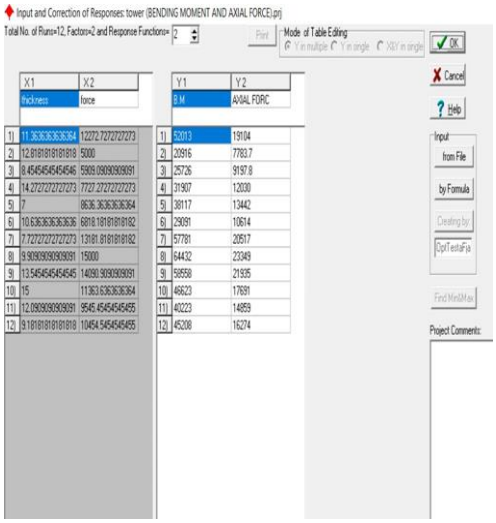


Stress and Deformation data in Kedro software



Bending Moment and Axial Force data in Kedro software

Developed surrogatemodels

First, we have to choose first linear approximation order and click on approximate. And when approximate option is clicked, we have to cross check the data. First thing to cross check is cross validate errors sigma percent and it should be below 20%. The adjustment coefficient of determining is another thing to be cross checked and have to keep at a value close to 1, Pearson's chi-squared test should be fulfilled till 90%. If it is not fulfilled at 90%, we have try for second order. Once it is fulfilled, the approximate order is selected. The same procedure is followed for other parameters like stress, bending moment, axial force, and deformation.

Table Error cross checking for stress and deformation. Linearapproximation

First linear approximation order		
	Stress	Deformation
Sigma cross %	24.891	24.839
R2 adjusted	0.958	0.958
F-Crit 99%	127.809>2.022	128.180>8.022

Table Second order approximation for stress anddeformation

Second approximation order		
	Stress	Deformation
Sigma cross %	7.199	7.218
R2 adjusted	0.998	0.997
F-Crit 99%	1099.909>8.746	1078.058>8.746

Table Third order approximation for stress and deformation

Third approximation order		
	Stress	Deformation
Sigma cross %	0.168	0.161
R2 adjusted	0.999	1
F-Crit 99%	1835218>99.38	2468859>99.38

We find the errors in stress and deformation. For first linear order when first approximate order is selected and step by step cross validation error is observed. When first linearapproximationmodels for deformation the cross-validation error is 24.839%. For second order Table 4.2the error is up to 7.1% for stress and 7.2% for deformation. In third order Table 1.4, the error is 0.16% for stress and 0.161% for deformation. When compared to all models what we have done above, this particular model has accurate results can be gained for the third order approximation and the R2 adjusted should be near to 1 and it is also satisfied and the F-Crit 99% is 99%. Hence satisfying all the three conditions in third order

Linear approximation for Bending moment and Axialforce

First linear approximation order		
	Bending moment	Axial force
Sigma cross	2.719	0.011

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%		
R2 adjusted	0.999	1
F-Crit 99%	11688.030>8.022	5.631e008>8.022

Second order approximation for Bending moment and Axialforce

Second approximation order		
	Bending moment	Axial force
Sigma cross %	0.1079	0.0148
R2 adjusted	0.999	1
F-Crit 99%	2666.0>8.746	2.0131e008>8.746

For the stress it is

$\square(t, F) = -0.00731\ t^3 + 6.4e\text{-}14\ F^3 + 6.92e\text{-}6\ t^2\ F - 8.82e\text{-}10\ t\ F^2 + 0.2371\ t^2 + 6.391e\text{-}9\ F^2 - 0.0002\ t\ F - 2.58313\ t + 0.002191\ F + 9.30266$

For the deformation it is

$Y(t, F) = -0.00319\ t^3 + 4.9e\text{-}14\ F^3 + 2.634e\text{-}6\ t^2\ F - 4.92e\text{-}10\ t\ F^2 + 0.1049\ t^2 + 4.909e\text{-}9\ F^2 - 7.523e\text{-}5\ t\ F - 1.167\ t + 0.000813\ F + 4.35767$

For the bending moment it is

$M(t, F) = -0.5421\ t^3 + 6.67e\text{-}11\ F^3 + 0.00053\ t^2\ F - 3.24e\text{-}7\ t\ F^2 + 15.441\ t^2 + 1.182e\text{-}6\ F^2 - 0.044\ t\ F - 165.821\ t + 4.699\ F + 604.448$

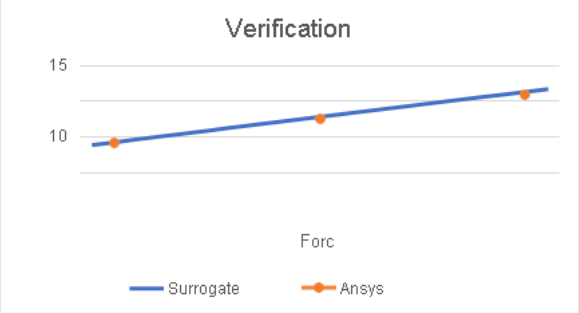
For the Axial Force it is

$\text{Axial Force}(t, F) = 0.0416\ t^3 + 7.55e\text{-}12\ F^3 - 3.929e\text{-}6\ t^2\ F + 1.575e\text{-}8\ t\ F^2 - 1.352\ t^2 - 4.137e\text{-}7\ F^2 - 0.00021\ t\ F + 15.8522\ t + 1.562\ F - 72.9151$

These data are gathering from the design of experiments from ANSYS and the particular data is imported to Kedro software and the related levels and factors are decided for combination of thickness and load and finally we have developed an equation. If we substitute the thickness and load in that equation, we will gain output from the surrogate model. It is one of the best sources for transmission tower complete analysis

Verification

The surrogate model and ANSYS results are compared to do verification of obtained approximation models. The following responses are analyzed for stress, axial force, bending moment anddeformation



Ansys and surrogate model results comparison for stress Vs force

V. FUTURE SCOPE

In this work, analysis is performed based on load and cross section thickness. And also, then type of cross section is change, height of tower and changing the material, further analysis can be performed. Increasing the number of factors and number of levels, surrogate model is developed and due to this the model related total structural character can be analyzed. The entire model is dedicated for the transmission tower in this work. But it can be implemented in many mechanical components for fastener joint. The DOA data is taken from FEA results in this work. But experiment data results can be taken to run thesoftware

VI. CONCLUSION

Now days, tall pylon is needed in electrical transmission network system that should be in material allowable limit once we applied the load. Transmission tower has a complex geometrical shape and has multiple number of members. All elements are joined together with the help of bolt, nuts or revit and acts as a single element. Once the load is applied on the structure, every element gains some stresses and deformation. To calculate the structural behavior by analytically is a complicated task to the engineers. This can be overcome by CAD software. ANSYS software is used for analyzing the structural behavior and cross section thickness limit is assumed as 5mm to 15mm and the load due to single cable it is considered from 5K N to 15KN. Design of experimental (DOE) analysis is a useful technique now days. Using this data, a new surrogate model is prepared which is useful alternative for the ANSYS software. But it is prepared from ANSYSsoftware.

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