Optimization of Structural Design for Sustainable Construction of Transmission Tower Based on Topographical Algorithm

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Abstract. Optimization of transmission tower structures is traditionally based on either optimization of members sizes with fixed topographical shape or based on structural analysis modelling strategies without taking cognizance of fabrication and constructability issue facing the contractors. This paper look into an integrated optimum design approach strategies whereby size, shape and topology are combined together with the fabrication issues in the construction of the transmission tower. The topographical algorithm is based on changing the inclination degree of the legs of the tower at first with optimum individual members sizing and later rationalized member sizes are performed through member groupings for the ease fabrication and construction of the transmission tower. The optimum weight using topographical algorithm obtained for the transmission tower is 10,924 kg for singular members and 18,430 kg for element grouping at 10° inclination angle.

1. Introduction
Optimization, sustainable design and construction of the transmission tower has become the main concern due to the escalating cost of steel. Designer of transmission tower are having a common aim to develop an efficient way to design a cost effective and optimized transmission tower. It is almost an impossible task to optimize the structures by trial and error method, even by an experience designer, where convergence can be achieve in compliance with the optimum member sizes (size is a variable factor), topographical factor (structural shape is a variable) in conjunction with fabrication sizes and cost (member grouping is a variable).

Several studies on the structural assessment module of current steel design models for transmission and telecommunication towers have been carried out [1] and [2]. Optimum design module has been studied [3], [4] and [5]. Simultaneous optimization for both sizing and topographical algorithm of the Transmission Tower has been studied by Neves and Fonseca [6]. Shape optimization of trusses has been carried out by Saka [7]. A review paper on numerical methods for shape optimization has been given by Vanderplaats [8]. Rajan developed a genetic algorithm that optimizes sizing, shape and topology variables in a truss using a genetic algorithm [9].

The main objective of this paper is to optimize the transmission tower design based on integrated approach combining simultaneously the size factor (member sizes is the variable) and shape factor (tower shape is the variable) in conjunction with member groupings for fabrication cost and ease of

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construction. It is envisaged in future that the design process will be based on an integrated optimum
design approach that can both integrate size and topographical algorithm to achieve least fabrication
cost in the construction of the transmission tower.

2. Methodology
The selection and development of a topographical algorithm to alter the leg coordinates of the tower is
based on the legs inclination angle of the tower. The Visual Basic is used to develop as a pre-processor
interface topographical algorithm program. Structural modelling analysis strategy for the Transmission
Tower are based mixed truss-beam analysis. This mixed modelling strategy can produce more
realistic structural behaviour. In the mixed beam-truss analysis, all the vertical member of the tower
are modelled as beam elements whilst all the other the horizontal and incline members inclusive of the
cross arms act as a space truss members.

The space algorithm program will extract the .std input file from the STAAD Pro and alter the co-
ordinate automatically in accordance with the user define inclination angle of the leg as shown in
Figure 1. A series of inclination angle then can be set to obtain the most optimum weight based on the
inclination angle and above method of structural analysis.

3. Discussion
Figure 2 shows the process of analysis and optimization of transmission tower in STAAD Pro where
the analysis started by setting the new inclination angle of the leg of a transmission tower.

3.1. Loading Trees
A combination of several load which consists wind load, self weight and the load from each condition
of the loading trees are considered. There are four combinations of load shown in Figure 3. Firstly, the
combination 1 is wind load, self weight and normal condition. Second, the combination 2 is wind load,
self weight and ground wire broken. As for the third combination is wind load, self weight, top
conductor and middle conductor broken and lastly, it is the combination 4 of wind load, self weight,
middle conductor and bottom conductor broken or top conductor and bottom conductor broken. The
factor of safety will be included for each load which is 1.0 for self weight, 1.25 for wind load, 2.5 for
normal condition and 1.25 for broken condition.

In this case, the application of shape factor in this project is to alter the angle of the leg of the
Transmission Tower as shown in Figure 4. Optimization process that arbitrary change the nodal
coordinates above the tower legs are likely to lead to violation of electrical clearance requirements [3].
3.2. Topographical Algorithm in the Structural Analysis.

Mixed beam-truss analysis is a modelling strategy combining beam and truss elements. The main structure will use spatial beam elements. This mixed modelling strategy can produce more realistic structural behaviour with respect to making it as close as possible to the actual built-up structure.

In this paper, the software is tested for 5 different inclination angle of the leg of transmission tower. The inclination angles are 5°, 10°, 15°, 20° and 30°. The weight of the tower at the start of the optimization process mentioned as initial weight is 22,000 kg to 65,000 kg depending on the inclination angle with the optimum weight obtained 10,871 kg to 25,044 kg for singular members and 18.366 kg to 52.425 kg for grouping members. It undergo the optimization design using the topographical algorithm for each singular member weight and later into grouping to come with the rationalize the fabrication cost and ease of construction for the transmission tower.

Generally, optimization based on individual member generates the least weight however practical consideration for fabrication cost and ease of construction requires grouping of members. The selection criteria of member groupings are based on height strata of the members in the tower and its functions as vertical, horizontal or incline members. Thus, the fabrication grouping weight lies in between the initial and the optimize singular members. It under the optimization design using the topographical algorithm for each singular member weight and later into grouping to come with the rationalize the fabrication cost and ease of construction for the transmission tower.

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4. Conclusions

The optimum weight using topographical algorithm obtained for this tower is 10,924 kg for singular members and 18,430 kg for element grouping at 10° degree inclination angle after taking due cognizance of foundation loading and deflection. Beyond the 15 degree leg angle, the total weight increases exponentially which is too expensive for the cost of the tower. The topographical algorithm is based on changing the inclination degree of the legs of the tower to obtain the optimum weight in the design and fabrication is viable to be used in the design. The topographical algorithm simultaneously optimized size, shape, and topology variables in the tower and was proven to be successfully integrated in the actual design of the tower. The element groupings can be manipulated within the set criteria to achieve the minimum fabrication cost and ease of construction for the tower.

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