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Optimization of Transmission Line Tower

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ABSTRACT: Transmission line towers are the large structures used for supporting the extra high voltage transmission lines. It constitutes about 40% of the total cost of the transmission line and the investment in transmission facilities for extra high voltage networks has increased considerably. Thus minimizing the cost of transmission line structures is an obvious need. The design of transmission line structure is characterized by the special requirements to be met from both electrical and structural points of view. Thus the manoeuvrability in arriving at the optimum tower design is reduced by the electrical considerations. However there is a scope for the weight minimization and optimum geometry shaping of a transmission line tower. In this project, Particle Swarm Optimization (PSO) algorithm is chosen for optimizing the transmission line tower. Transmission tower optimization problems with respect to weight are analyzed and optimized using STAAD pro and the results are compared with meta-heuristic algorithm to show the efficiency and robustness of the algorithm. The PSO algorithm gives a best solution which was better than the previously reported best optimum solution by STAAD pro.

KEYWORDS: Optimization, Transmission line towers, PSO Algorithm.

I. INTRODUCTION

Optimization techniques play an important role as a useful decision making tool in the design of structures. By deriving the maximum benefits from the available resources, it enables the construction of lighter, more efficient structures while maintaining adequate levels of safety and reliability. A large number of optimization techniques have been suggested over the past decades to solve the inherently complex problem posed in structural design. Their scope varies widely depending on the type of structural problem to be tackled. The very purpose of optimization is to find the best solutions from which a designer or a decision maker can derive a maximum benefit from the available resources. The shortcomings of the indirect design can be overcome by adopting a direct or optimal design procedure. The feature of the optimal design is that it consists of only logical decisions. In making a logical decision, one sets out the constraints and then minimizes or maximizes the objective function (which could be either cost or weight function).

Traditionally, various mathematical methods such as linear, nonlinear, and dynamic programming have been developed to solve engineering optimization problems. However, these methods represent a limited approach, and no single method is completely efficient and robust for all types of optimization problems. The computational drawbacks of mathematical methods have forced the researchers to rely on meta-heuristic algorithms based on simulations to solve optimization problems. In last few decades, many new meta-heuristic algorithms have been developed and used in engineering optimization.

II. SCOPE AND OBJECTIVE

The objective of the study is to design and analyse the transmission line tower with particular loading conditions and to optimize. A high voltage transmission line structure is a complex structure in that its design is characterized by the special requirements to be met from both electrical and structural points of view. The electrical considerations decide the shape of the tower with respect to its height and the length of the cross arms that carry the electrical conductors.

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Thus optimizing the tower design is no doubt reduced by these electrical considerations. Still there is a scope for the weight minimization and optimum geometry shaping of a transmission line tower.

III. RELATED WORKS

Transmission line tower constitute about 40% of the total cost of the transmission line. Thus the increasing demand for electrical energy can be met more economically by developing different light weight configurations of transmission line towers. In the present study, transmission line tower design is done as per IS: 802 (1995) and the tower is analyzed using STAAD pro. The MATLAB software is widely used in many of science and engineering fields. It is an interactive program for numerical computation and data visualization. Known for its highly optimized matrix and vector calculations, MATLAB offers an intuitive language for expressing problems and their solutions both mathematically and visually. Thus the optimization of the tower is performed using MATLAB. The weight optimization of the transmission line tower under particular loading conditions is explained in this manual. The minimization of weight will obviously reduce the total cost of the structure.



IV. PARTICLE SWARM ALGORITHM

The PSO algorithm was first proposed in 1995 by Kennedy and Eberhart. It is based on the premise that social sharing of information among members of a species offers an evolutionary advantage. Recently, the PSO has been proven useful on diverse engineering design applications such as logic circuit design, control design and power systems design among others. The various advantages of PSO with respect to other global algorithms are:

1. The algorithm is robust and well suited to handle non-linear, non-convex design spaces with discontinuities.
2. It is more efficient, requiring a smaller number of function evaluations, while leading to better or the same quality of results.
3. It does not require specific domain knowledge information, internal transformation of variables or other manipulations to handle constraints.

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V. EXPERIMENTAL RESULT

VI. 2587 BAR TRANSMISSION LINE TOWER

A 400 kV double circuit steel transmission line with a suspension towers (20angle deviation) is considered as a case study. The model of tower is square base, self-supporting type with angle sections. The tower is analyzed using STAAD pro and the optimization is done for weight minimization. The isometric view of tower model in STAAD Pro software is given in figure 1.

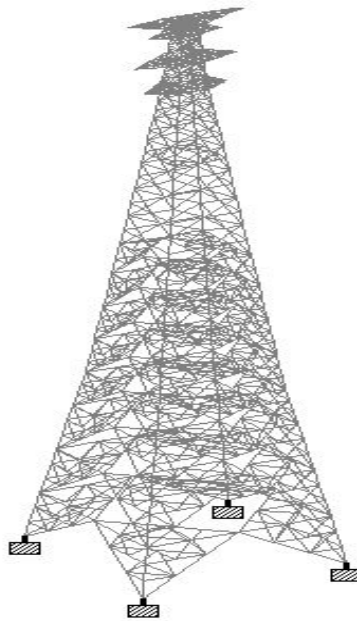


Figure 1 ISOMETRIC VIEW OF 2587 BAR TRANSMISSION TOWER

The tower shown above has totally 976 nodes and 2587 members. These members are grouped into 43 groups for the purpose of optimization. The total number of angle sections considered is 72. The tower configurations are listed in table 1, the parameters for the transmission line and tower components are listed in table 2

Table 1 CONFIGURATIONS OF 2587 BAR TRANSMISSION TOWER

Sl.N o	Configuration	Square tower (mm)
1	Base width	16500
2	Height till L.C.A level	61500
3	Height till M.C.A level	65100
4	Height till U.C.A level	68700
5	Total tower height (from G.L)	70800

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6	Horizontal spacing between ground wire	9300
7	Vertical spacing between conductor	3600
8	Vertical spacing between conductor and ground wire	2100
9	Horizontal spacing between conductor (L.C.A)	6600
10	Horizontal spacing between conductor (M.C.A)	8200
11	Horizontal spacing between conductor (U.C.A)	5700

Table 2 PARAMETERS FOR TRANSMISSION LINE AND TOWER COMPONENTS

Line voltage	400 kV	Max temperature	75° C
Tower type	Suspension	Min temperature	0° C
No of circuit	Double	Everyday temperature	32° C
Cross arm	Pointed	No of ground wire / Phase	ONE
Deviation	0° – 2°	No of Conductor / Phase	ONE
Tower Configuration	Vertical Conductor	Design Wind Pressure	1520 N/m ²
Wind Zone	V	Length of ground wire attachment	2000 mm
Tower Geometry	Square Base	Insulator type	Suspension
Wind span	1572 m	Size of insulator disc	280 X 170
Basic wind speed	50 m/s		

Loads and Load cases

STAAD pro has been used for the analysis and design. The three dimensional analysis of the tower considering all the members of the space truss as primary members has been used in STAAD pro. The load and loading combinations criteria on the ground wire, conductor and the towers are found using IS: 802. The loading calculations on tower due to conductor and ground wire in reliability condition as well as broken wire condition considering transverse as well as longitudinal direction. The tower loadings are determined on the basis of wind pressures, temperature variations and broken wire conditions. The factors of safety adopted in the designs have a great bearing on the cost of the structures and they have to be chosen so that the structures prove economical as well as safe and reliable. The load combinations for the reliability, safety, and security conditions are considered for per code provisions of IS : 802 (Part 1 / Sec 1) -1995. The over load factors considered for dead load is 1.3 and for wind load is 1.0.

VI. RESULTS AND DISCUSSIONS

TOWER

The initial weight and the optimized weight of the 2587 bar transmission line tower obtained from STAAD pro and meta-heuristic algorithm are given in table 3. The PSO algorithm gives minimum weight for the tower.

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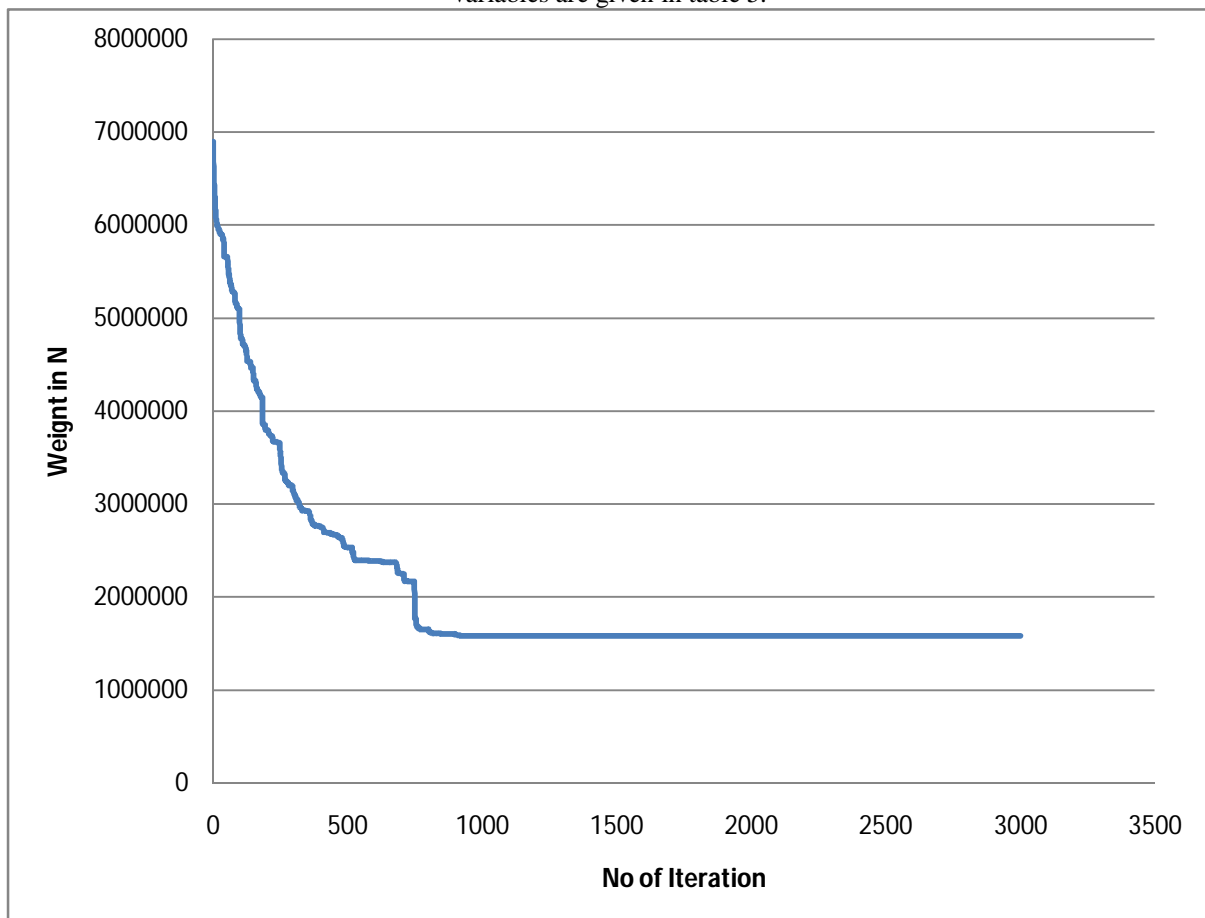
Optimization using meta-heuristic algorithm is effective when compared to the optimization performed using STAAD pro. The optimum results found shows the effectiveness of the meta-heuristic algorithm for optimizing transmission line tower structures.

TABLE 3 OPTIMUM WEIGHT OF 2587 BAR TOWER

Initial Weight of the Tower (kN)	Optimum Weight of 2587 bar transmission line tower (kN)	
	STAAD pro	PSO
3033.341	1728.58	1587.371

Optimum Weight from PSO

The optimized weight of the transmission line tower obtained from PSO according to IS: 802. The iteration history for PSO algorithm is shown in figure 4.1. The best weight is found after 919 iterations. The optimum design variables are given in table 5.



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**TABLE 5 OPTIMUM DESIGN VARIABLES FOR 2587 BAR
TRANSMISSION TOWER FROM PSO**

Design variables	Optimum Angle Sections
1	ISA90X90X10
2	ISA90X90X12
3	ISA130X130X10
4	ISA90X90X10
5	ISA130X130X10
6	ISA75X75X10
7	ISA75X75X10
8	ISA110X110X8
9	ISA60X60X8
10	ISA90X90X12
11	ISA60X60X5
12	ISA60X60X5
13	ISA75X75X10
14	ISA55X55X8
15	ISA80X80X12
16	ISA55X55X6
17	ISA50X50X6
18	ISA70X70X5
19	ISA70X70X5
20	ISA75X75X10
21	ISA110X110X8
22	ISA90X90X10
23	ISA 90 X 90 X 12

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24	ISA 90 X 90 X 10
25	ISA70X70X5
26	ISA130X130X15
27	ISA70X70X5
28	ISA200X200X25
29	ISA55X55X8
30	ISA50X50X6
31	ISA35X35X3
32	ISA75X75X10
33	ISA40X40X3
34	ISA25X25X4
35	ISA30X30X3
36	ISA25X25X4
37	ISA25X25X4
38	ISA70X70X5
39	ISA35X35X3
40	ISA25X25X4
41	ISA25X25X4
42	ISA25X25X4
43	ISA55X55X6

VII. CONCLUSION

The 2587 bar transmission line tower (400 kV double circuit transmission line tower) with 43 design variables are analysed and optimized to check the effectiveness of the Particle Swarm Optimization algorithm. The PSO algorithm gives a best solution which was better than the previously reported best optimum solution by STAAD pro. The simplicity of implementation along with the lower number of setting parameters makes PSO algorithm an ideal method when dealing with the large scale structures like transmission line towers.

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