International Journal of Science and Research (IJSR)
ISSN (Online): 2319-7064
Index Copernicus Value (2013): 6.14 | Impact Factor (2015): 6.391

Optimization of Transmission Tower using Genetic Algorithm

Sanah Rose Sony[1], Airin M. G.[2]

[1, 2]SCMS School of Engineering and Technology, Karukutty, Kerala, India

Abstract: ***Transmission line towers constitute about 28 to 42 percent of the total cost of the transmission lines. The increasing demand for electrical energy can be met more economically by developing different light weight configurations of transmission line towers. Therefore, it is very important to find an optimal design for the transmission tower that would give the minimum weight. Optimization plays an important role in structural design, the very purpose of which is to find the best ways so that a designer or a decision maker can derive a maximum benefit from the available resources. The basic idea behind intuitive or indirect design in engineering is the memory of past experiences, subconscious motives, incomplete logical processes, random selections or sometimes mere superstition. This, in general, will not lead to the best design. The shortcomings of the indirect design can be overcome by adopting a direct or optimal design procedure. The feature of the design optimization 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, weight or merit function). In the present study, the weight of the transmission tower was optimized while keeping the base width, height and basic outline of the tower constant. The structure was modeled and analysed in ANSYS 16.2. The optimization method selected was Genetic Algorithm. The optimized value was obtained by interfacing ANSYS with MATLAB.***

Keywords: ANSYS, Genetic Algorithm, Interfacing, MATLAB, Optimization, Transmission Tower

1. Introduction

A transmission tower is a tall structure, usually a steel lattice tower, used to support an overhead power line. They are used in high-voltage AC and DC systems, and come in a wide variety of shapes and sizes. 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 increasing demand for electrical energy can be met more economical by developing different light weight configurations of transmission line towers. Therefore, it is very important to find an optimal design for the transmission tower that would give the minimum weight.

Practical applications of structural optimization methods to civil structures are often hindered by non-quantifiable design objectives such as aesthetics and societal issues. Transmission tower design is an exception since aesthetic appeal is often coupled with functionality. Therefore an opportunity exists for optimization methods to reduce the overall mass of current tower structures as well as the number of members and joints they contain without adversely affecting qualitative criteria.

T. Raghavendra, [1] considered a typical 132-KV double circuit transmission-line tower for optimizing the structure with respect to configuration and different materials as variable parameters while Mohan et al., [2] attempted to make the transmission line more cost effective by optimizing the geometry (shape) and behaviour (type) of transmission line structure. Sivakumar et al., [3], presented a new approach for the optimization of steel lattice towers by combining genetic algorithms and an object oriented approach. Shea et al., [4] applied structural topology and shape annealing (STSA), a structural topology optimization method that combines structural grammars with simulated annealing, to reduce the structural mass of an existing tower and Rajeev et al., [5] presented genetic algorithms (GA)-based methodologies for obtaining optimal design solutions simultaneously considering topology, configuration and cross-sectional parameters in a unified manner.

In this study, a genetic algorithm based optimization is done by interfacing ANSYS and MATLAB to minimize the weight of the transmission tower while keeping the base width, configuration and height of the transmission tower constant. Even though optimization using genetic algorithm is a common method, there are very few instances where GA in MATLAB is coupled with ANSYS. In the instances where coupling is done, very few variables are passed as inputs whereas in this study a large number of variables are passed.

2. Optimization

Optimization is essentially the art, science and mathematics of choosing the best among a given set of finite or infinite alternatives. It refers to finding one or more feasible solutions which corresponds to extreme values of one or more objectives. In the simplest case, an optimization problem consists of maximizing or minimizing a real function by systematically choosing input values from within an allowed set and computing the value of the function. The generalization of optimization theory and techniques to other formulations comprises a large area of applied mathematics. More generally, optimization includes finding "best available" values of some objective function given a defined domain (or a set of constraints), including a variety of different types of objective functions and different types of domains.

It is fairly accepted fact that one of the most important human activities is decision making. It does not matter what field of activity one belongs to. Whether it is political, military, economic or technological, decisions have a far reaching

Licensed Under Creative Commons Attribution CC BY

influence on our lives. Optimization techniques play an important role in structural design, the very purpose of which is to find the best ways so that a designer or a decision maker can derive a maximum benefit from the available resources.

The basic idea behind intuitive or indirect design in engineering is the memory of past experiences, subconscious motives, incomplete logical processes, random selections or sometimes mere superstition. This, in general, will not lead to the best design. 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, weight or merit function).

3. Genetic Algorithm

In the field of artificial intelligence, a genetic algorithm (GA) is a search heuristic that mimics the process of natural selection. This heuristic (also sometimes called a meta-heuristic) is routinely used to generate useful solutions to optimization and search problems. Genetic algorithms belong to the larger class of evolutionary algorithms (EA), which generate solutions to optimization problems using techniques inspired by natural evolution, such as inheritance, mutation, selection, and crossover.

3.1 The GA principle

Genetic Algorithms have three characteristic operators, namely *selection*, *crossover* and *mutation*. In each iteration, or *generation*, these operators are applied on a population of possible solutions, or *individuals* in order to improve their *fitness*. Each individual is represented by a *string*, and these strings remind very much of the natural chromosomes, hence the name genetic algorithms. Initially, the population is created randomly, and the breeding continues until a stopping criterion is reached, e.g. the exceeding of a certain number of generations, or the absence of further improvements among the individuals.

3.2 Optimization problems

In a genetic algorithm, a population of candidate solutions (called individuals) to an optimization problem is evolved toward better solutions. Each candidate solution has a set of properties (its chromosomes or genotype) which can be mutated and altered; traditionally, solutions are represented in binary as strings of 0s and 1s, but other encodings are also possible.

The evolution usually starts from a population of randomly generated individuals, and is an iterative process, with the population in each iteration being called a *generation*. In each generation, the fitness of every individual in the population is evaluated; the fitness is usually the value of the objective function in the optimization problem being solved. The more fit individuals are stochastically selected from the current population, and each individual's genome is modified (recombined and possibly randomly mutated) to form a new generation. The new generation of candidate solutions is then used in the next iteration of the algorithm. Commonly, the algorithm terminates when either a maximum number of generations has been produced, or a satisfactory fitness level has been reached for the population.

A typical genetic algorithm requires:
1) A genetic representation of the solution domain,
2) A fitness function to evaluate the solution domain.

A standard representation of each candidate solution is as an array of bits. Arrays of other types and structures can be used in essentially the same way. The main property that makes these genetic representations convenient is that their parts are easily aligned due to their fixed size, which facilitates simple crossover operations. Variable length representations may also be used, but crossover implementation is more complex in this case. Tree-like representations are explored in genetic programming and graph-form representations are explored in evolutionary programming; a mix of both linear chromosomes and trees is explored in gene expression programming.

Once the genetic representation and the fitness function are defined, a GA proceeds to initialize a population of solutions and then to improve it through repetitive application of the mutation, crossover, inversion and selection operators.

4. Optimization by Interfacing ANSYS and MATLAB

Optimization in ANSYS is done using the Direct Optimization Toolbox. In the project setup, design optimization requires identification of input and output parameters. The input parameters are typically geometric parameters that are optimized to be optimized. Output parameters are typically expressive values evaluated post simulation. Based on the identified input and output parameters, parameter correlations can be determined which identifies strong and weak correlations between sets of input and output parameters. In the optimization properties, one or more objectives with or without constraints can be set.

In MATLAB, the command ‚ga" implements the genetic algorithm at the command line to minimize an objective function. In this work Optimization toolbox is used to implement genetic algorithm to minimize the objective function.

4.1 Outline of the Algorithm

The following outline summarizes how the interfacing between ANSYS and MATLAB using genetic algorithm works:
1) The algorithm begins by creating a random initial population. The initial population is stored as a text file which becomes the scalar parameter input for ANSYS.
2) The ANSYS log file is then made to run from MATLAB in batch mode and produces output files.

Licensed Under Creative Commons Attribution CC BY

3) The results from ANSYS which are required for constraint check is read from text files to MATLAB. The value of constraint is then checked.
4) If the check is satisfied, then the volume is read from the ANSYS result, else returns an invalid value.
5) The algorithm then creates a sequence of new population. At each step, the algorithm uses the individuals in the current generation to create the next population.
6) The algorithm stops when one of the stopping criteria is met.

5. Transmission Tower Optimization

The dimensions of the transmission tower is taken from the reference of T. Raghavendra[1]. The overall height of the tower is 30m. It consisted of a tower body height of 18.2m, cross arm length of 2.527m, cage height of 8.95m and peak height of 2.85m. The dimensions of the tower are given in Fig. 1. The tower is fixed at its base. The material properties of the tower are given in Table 1.

Table 1: Material Properties

Property	*Values*
Material Density	7850 kg/m^3
Young"s Modulus	2.1 x 10^5 N/mm^2
Poisson"s Ratio	0.3

The optimization problem is formulated as the minimization of the weight of the lattice tower. The objective of the optimization is the total mass under a constraint of maximum permissible stress. In the optimization process, the height, base width and overall configuration of the tower are considered fixed, the optimization parameters being the dimensions of the angle section used for each member. The members are grouped into 12 groups as shown in Table 2.
ANSYS is executed from MATLAB by means of the command line specified in Fig. 2. If another type of finite element software is employed, then the first part of the command line must be substituted by the appropriate executable route file.

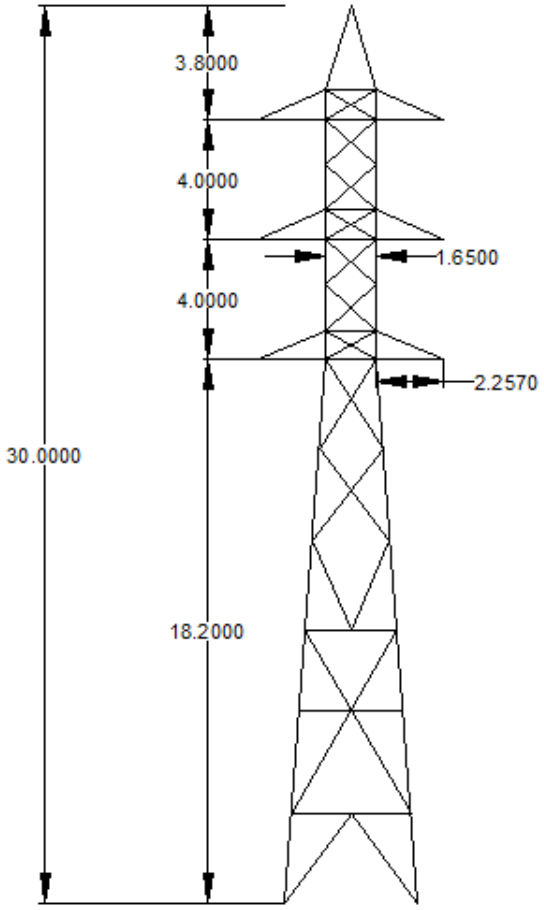

Figure 1: Dimensions of Transmission Tower

Table 2: Parameters and their bounds

Parameter Name	*Description*	*Allowed Bounds*
T1 – T12	Thickness of angle sections	5 – 8mm
W1 – W12	Width of angle sections	40 – 200mm
Stress	Maximum Principle Stress	Permissible Stress

```
!"C:\Program Files\ANSYS Inc\v162\ansys\bin\winx64\ANSYS162.exe" -b -p -i TrussModel.inp -o Output.txt
```

Figure 2: Command line to run ANSYS in Batch mode

The „*-b*" in the command makes the software run in batch mode. Batch mode allows the software to be run under system without specifically opening it by providing an input text file in which the finite element model is programmed. The last part of the code specifies the file route that points to the input finite element model text file in which the finite element model is programmed.

The optimization was carried out under the constraint of maximum stress equal to yield stress. With this constraint the optimum results are obtained in the genetic algorithm toolbox as shown in Figure 3.

Licensed Under Creative Commons Attribution CC BY

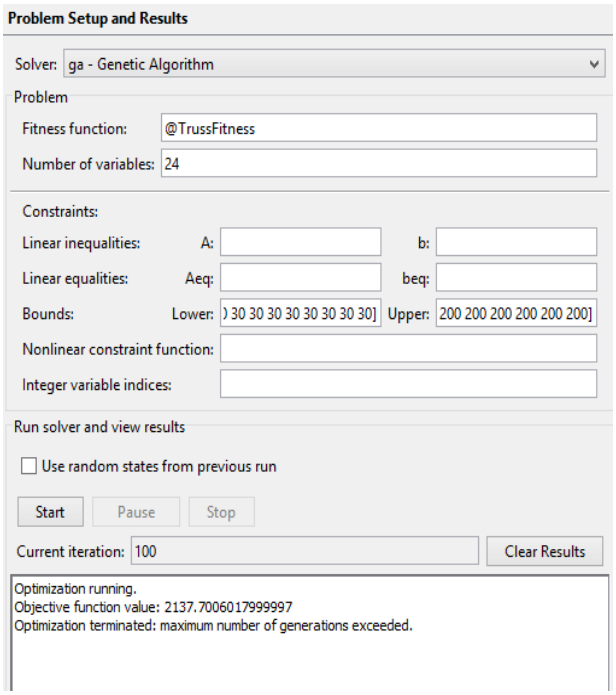

Figure 3: Genetic Algorithm Toolbox in MATLAB

The generations versus fitness value graph obtained from MATLAB is shown in Figure 4.

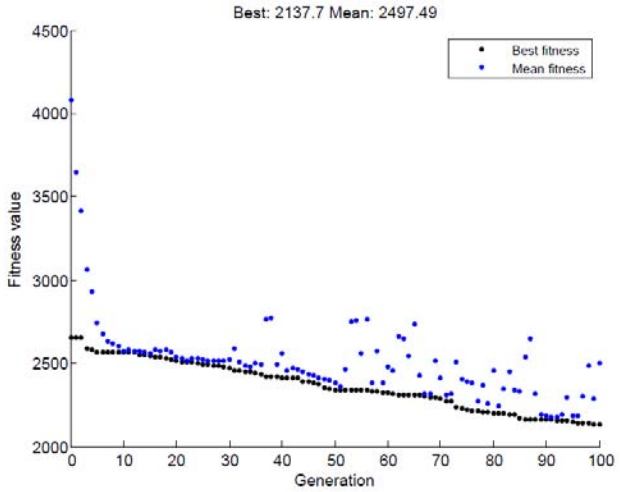

Figure 4: Generations versus Fitness Graph

The optimized values obtained from ANSYS and MATLAB is shown in Table 3. The reduction in mass in the case of ANSYS Workbench optimization is 69.46% and for optimization by using genetic algorithm in MATLAB, the reduction is 78.66%. From the above results it can be seen that coupling of ANSYS and Genetic Algorithm gives better optimization results.

The direct optimization by ANSYS 16.2 was done by creating 100 design points by screening and finding the optimum from the design points. The computation time taken was about 75 minutes to find the optima. When ANSYS was interfaced with MATLAB, the GA toolbox was specified with a population size of 20 and number of generations as 100 which would result in 2000 samples. MATLAB took around 140 minutes to find the minimum mass. Therefore optimization by interfacing of ANSYS with MATLAB by GA is an effective method of finding the optimum result from a large search space in less time.

Table 3: Optimized Values

Parameter Name	*Stress (MPa)*	*Mass (kg)*	*Percentage Variation*
Initial Values	64.295	10,018	
Optimized Values from ANSYS	238.25	3,059.4	69.46%
Optimized Values from MATLAB	230.86	2,137.7	78.66%

6. Conclusions

Gas are efficient techniques of optimization, which have wide application in structural optimization. They are non-traditional optimization algorithms suitable for engineering structures of large design space and discrete optimization problems such as lattice towers. The GA uses a random search algorithm, which is powerful and robust. The GA applies the survival of the fittest among the string structure to form a search algorithm. The search procedure uses random choice as a tool to guide the search through parametric space. In the present study Genetic Algorithm is implemented by interfacing ANSYS and MATLAB. This optimization can be done easily with simple coding. The conclusions drawn from the study are

1) When the transmission tower was subjected to size optimization, Genetic Algorithm provided better value of mass.
2) The mass was reduced by 78.66%.
3) Computational time was reduced by nearly 90.7%.

5.1 Scope for Future Work

1) The study can be extended to simultaneous topology, shape and size optimization of the tower.
2) This study dealt with a 2-D model of the transmission tower. This method of optimization can be applied on a 3-D model.
3) Instead of GA, a modified Non-Dominated sorting GA can be applied where, once the population is initialized, it is sorted based on non-domination into each front.

References

[1] Raghavendra, T. “Computer Aided Analysis and Structural Optimization of Transmission Line Tower.” International Journal of Advanced Engineering Technology, Vol. III, Issue III, pp. 44 – 50, 2012.
[2] Mohan, K. J., Preeti, C. “Analysis of Transmission Towers with Different Configurations.” Jordan Journal of Civil Engineering, Vol. 7, No.4, pp. 450 – 460, 2013.
[3] Sivakumar, P., Rajaraman, A., Knight, G. M. S., Ramachandramurthy, D. S. “Object-Oriented Optimization Approach Using Genetic Algorithms for Lattice Towers.” Journal of Computing in Civil Engineering, 18(2): pp. 162 – 171, 2004
[4] Shea, K., Smith, I. F. C. “Improving Full-Scaled Transmission Tower Design through Topology and Shape Optimization.” Journal of Structural Engineering, 132(5): pp. 781 – 790, 2006.

Licensed Under Creative Commons Attribution CC BY

[5] Rajeev, S., Krishnamoorthy, C. S. "Genetic Algorithm-Based Methodologies for Design Optimization of Trusses." Journal of Structural Engineering, 123(3): pp. 350 – 358, 1997.
[6] Rajeev, S., Krishnamoorthy, C. S. "Discrete Optimization of Structures using Genetic Algorithms." Journal of Structural Engineering, ASCE, 1185(5): pp. 1233 – 1250, 1992.
[7] Mahbob, M. R., Mahmud, J., Azlan, M. A. M., Jumahat, A. "Finite Element Analysis of Telecommunication Mini Mast Structure". Procedia Engineering 68, pp. 258 – 264, 2013.
[8] Júnior, P. A. A. M., Rios, I. G., Ferreira, T. S., Júnior, A. C. D., Filho, O. A. D., Soares, P. H. D. "Design of Lattice Wind Turbine Towers with Structural Optimization." International Journal of Engineering Research and Applications, ISSN: 2248-9622, Vol. 4, Issue 8(Version 5), pp. 38 – 51, 2014.
[9] Gurugubelli, S., Kallepalli, D. "Weight and Deflection Optimization of Cantilever Beam using a modified Non-Dominated sorting Genetic Algorithm." IOSR Journal of Engineering (IOSRJEN), ISSN: 2250 – 3021, Vol. 4, Issue 3, pp. 19-23, 2014.
[10] Hultman, M. "Weight Optimization of Steel Trusses by a Genetic Algorithm – Size, Shape and Topology Optimization according to Eurocode." Master"s Thesis, Department of Structural Engineering, Lund Institute of Technology, Sweden, 2010.
[11] Madugula, M. K. S., Wahba., Y. M. F., Manforton. G. R. "Dynamic response of guyed masts". Engineering Structures, Vol. 20, No. 12, pp. 1097 – 1101, 1998.
[12] Madugula, M. K. S., Wahba., Y. M. F., Manforton. G. R. "Evaluation of the non-linear analysis of guyed antenna towers". Computers and Structures, No. 68, pp. 207 – 212, 1998.
[13] Madugula, M. K. S., Wahba., Y. M. F., Manforton. G. R. "Effect of icing on the free vibration of guyed antenna towers". Atmospheric Research, No. 46, pp. 27 – 35, 1998.
[14] Barsoum, I., Barsoum, F. "Structural Analysis of a New Generation of Guyed Telecom Mast with a Wind Turbine." International Journal of Engineering and Technology, Vol. 2, No. 9, pp.1518 – 1528, 2012.
[15] Gencturk, B., Attar, A. "Optimal Design of Lattice Wind Turbine Towers". 15WCEE LISBOA, 2012.
[16] Guo, H. and Li, Z. "Structural Topology Optimization of High-Voltage Transmission Tower with Discrete Variables," Structural and Multidisciplinary Optimization, 43(6), pp. 851 – 861, 2011.
[17] Harikrishna, P., Annadurai, A., Gomathinayagam, S., Lakshmanan, N. "Full scale measurements of the structural response of a 50 m guyed mast under wind loading". Engineering Structures, No. 25, pp. 859 – 867, 2003.
[18] Hensley, Gregory M., Plaut Raymond H. "Three-dimensional analysis of the seismic response of guyed masts", Engineering Structures, No. 29, pp. 2254 – 2261, 2007.

Licensed Under Creative Commons Attribution CC BY