

# A Software Programme developed to assist High Voltage Transmission Line Design “TowerPLUS”

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**Abstract** - The project was to develop a Transmission line Tower Spotting software, which was the specific requirement of the Ceylon Electricity Board transmission design branch. This paper contains details of the existing process of tower spotting & the advantages of TowerPlus as a more effective tool. We have further given the distinct benefits available and how we have automated the existing manual process using a procedure we developed. TowerPlus has been developed using Visual Basic, AutoCAD and MatLAB as background applications. The principle purpose was to create solutions with better economic feasibility.

## 1.0 INTRODUCTION

The software programme “TowerPlus” is geared towards designing and spotting of High Voltage (132 V and 220 V) transmission lines. The CEB is the sole client for whom we have designed the product and it is a tailor made solution and not a generic model.

The Objective of TowerPlus is to develop cost optimized transmission line layouts, which are fully technically feasible and also maintain the highest safety standards acceptable by the CEB and other authorities.

In brief TowerPlus undertakes an input of a terrain, which consists of a start and end point giving further details of the ground profile and also the current economics of equipment, labour and other costs involved. The software consists of databases of required technical specifications relevant to the spotting of towers such as clearance limits, tower specifications, foundation types, cable types etc. A sound algorithm to tackle the optimization problem has been devised for our software. This has been with close consultancy and approval from our lecturers and the CEB transmission design engineers.

We have taken extra care for the software to be user friendly. The numerous options given to the user

helps to even modify basic solutions and gives opportunity for manual adjustments where necessary. Other commercially available models of this nature cost over US \$90,000 (approx) and thus our achievement in developing a low cost high performance substitute.

## 2.0 THEROTICAL BACKGROUND

The catenary curve is assumed by a cord of uniform density and cross section that is perfectly flexible but not capable of being stretched and that hangs freely from two fixed points. [1]

Let  $L$  be the length of the conductor POQ, suspended between the supports P and Q at the same level. Let O be the lowest point of the catenary,

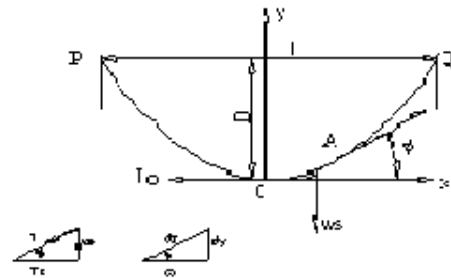


Fig. 1 Catenary Curve

- $W_s$  -Weight of the conductor per unit length.
- $T$  - Tension at any point A of the conductor.
- $T_0$  -Tension at point O of the conductor
- $Z$  - Length of conductor OA
- $l$  - span AB

Catenary Equations

$$Y(x) = C \cdot \cosh(x/C) \text{ where } C = T_0 / w_s$$

$$Y(x) = x^2 / 2C \text{ -----(1)}$$

If the Span length is denoted by  $l$ , then  
 $x = (l/2)$  and substituting to (1)  
 Sag of Span  $D = (w_s \cdot l^2)/8 T_0$ ----- (2)

Total length of the Conductor  
 $Z = C \cdot \text{Sinh}(x/C)$   
 $L = 1 + [(l^3 \cdot w_s^2)/(2^4 \cdot T_0^2)]$ ----- (3)

By considering only the first 2 terms parabolic equations are derived; using which the SAG TENSION equation is determined. [1], [2], [3]

### 3.0 EXISTING MANUAL PROCESS OF TOWER SPOTTING

1. The route is divided into straight-line sections as determined by the ground profile. The distinct sections are taken one by one to spot the required towers.

2. Initially when spotting towers in one section, one has to decide on a basic span (on average the initial guess is 300m for 132KV lines, 400m for 220KV lines), and this is the first value used to create the sag template (which in turn is used to evaluate the clearances when spotting towers in the particular section).

The sag template is a celluloid frame containing the hot curve (curve at 75 °C), cold curve (curve at 7 °C) and ground clearance curve of the cable between two towers for a particular basic span. The curve is approximated to a parabola, but actually it's a hyperbola (due to simplicity of the parabolic equation). Placing this template on the map and fixing one end to the starting tower of the section and ensuring that the ground clearance curve doesn't go below the ground profile one can witness the hot curve and the cold curve pattern for the particular equivalent span. The designer can now spot the next tower of the section at a feasible distance from the first considering the clearances. Here the wind span and also the weight span of the first tower are also checked. If these are also satisfied the designer has successfully spotted the second tower of the section. This process goes on till the end of the section, where the towers are spotted step-by-step using the sag template also varying tower extensions.

3. But, since templates of standard sizes are used for a range these may not give the exact solutions and also when using a template for a section the designer is still uncertain whether the template used was accurate. To check the accuracy of the template

used the designer then calculates the ruling span (RS) for the section. This must be within a range of -25 and +75 of the basic span for feasibility.

$$RS = \sqrt{\frac{a_1^3 + a_2^3 + a_3^3 + \dots + a_r^3 + \dots + a_n^3}{a_1 + a_2 + a_3 + \dots + a_r + \dots + a_n}}$$

$a_1$  - distance from initial terminal tower to first suspension tower.

$a_2$  - distance from first suspension tower to second suspension tower.

If RS is violated the designer begins the whole process from the beginning using a sag template with a higher value.

### 4.0 TOWERPLUS - OPTIMIZATION PROCESS

Step 1 : The full route is separated into straight line "sections"

Step 2 : For each section the programme calculates minimum number of suspension towers required to satisfy Wind span. Section corner towers are Angle or Terminal towers.

Step 3 : Evaluates all possible tower location options on the section which satisfy Wind span. A combination is referred to as a "string"

Step 4 : For these considering various tower extension possibilities we evaluate the strings for Weight span compliance. Thus a new set of strings is formed satisfying both Wind and Weight spans.

Step 5 : Thereafter for each string we validate the compliance of maintaining required clearances. This is done using the "ground shifting curve" and the hot curve of the cable. The strings complying with the clearance requirement is taken forward.

Step 6 : Now the strings where towers may lie on dead areas are filtered out. i.e., we have technically feasible sections when this process is done for all sections on the route.

Step 7 : Now strings of each section are compared with adjoining sections for common "joint" points, where we can develop larger strings for the full route by combining sectional strings which have common heights at section joint points.

Step 8 : The strings derived for the full route are taken in and the Wind and Weight span compliance

of Angle towers are evaluated. Thus the strings that result are fully technical feasible line layouts.

Step 9 : Now these technically feasible options are ranked according to the number of tower extensions on each strings, where we first consider the string with the least possible extensions. If there are many, further ranking is done by costing the equipment used for each string. Thus cost optimized solution can be arrived at. The result is shown on the two output views.

Step 10 : The AutoCAD output can be developed. To make any changes again, an option is given for the user to start from the beginning, making the relevant changes.

The plan and end elevation views with objects in the right of way is seen as follows.

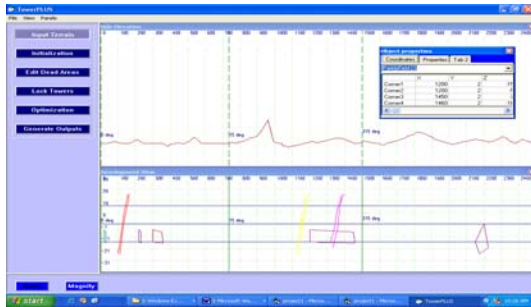
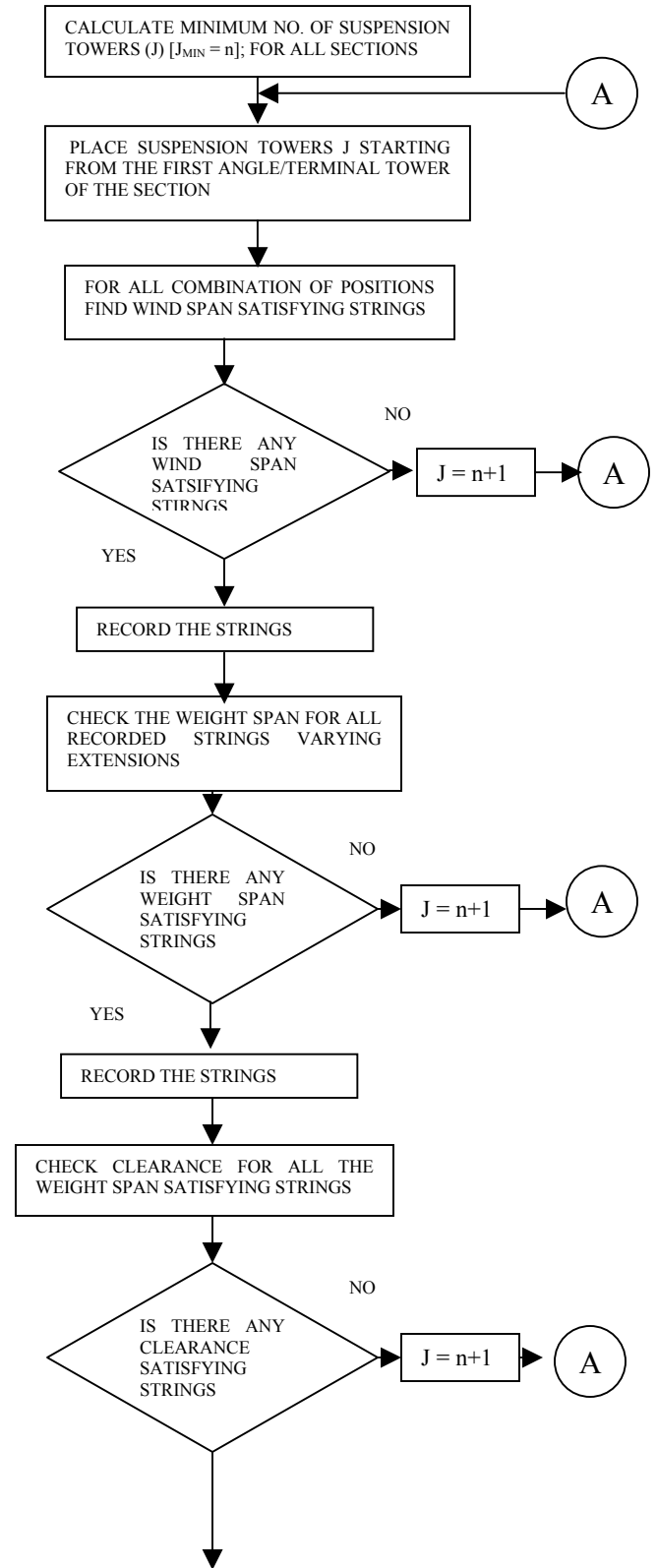
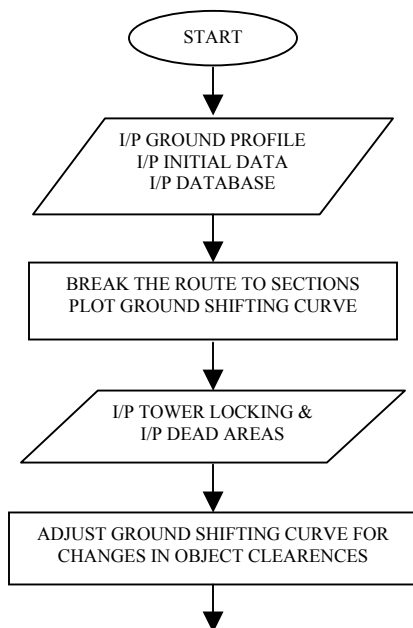
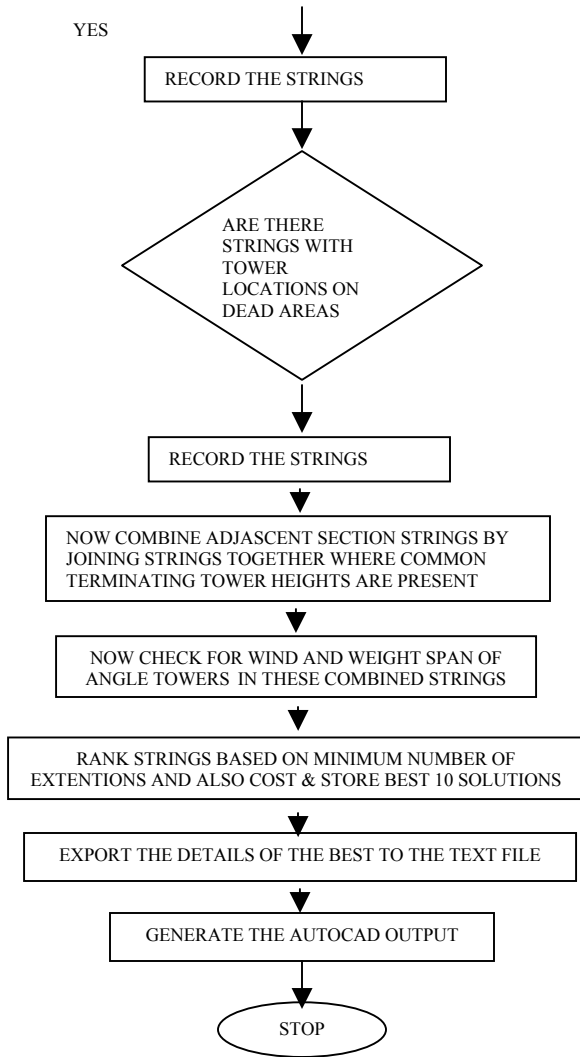


Fig. 2 Plan & End views of Ground Profile

## 5.0 TOWERPLUS - MAIN ALGORITHM





## 6.0 FUTURE DEVELOPMENTS

Possible input methods, of using AutoCAD and a data logger. The proposed tower locking feature, a key development towards more control and flexibility for the user. Ground profiles by Arial coordinates (using satellite imaging and GPS features for remote sensing). TowerPlus is an object oriented software and can easily be converted to any other language. E.g. visual.net, Java, C++ etc.

## 7.0 CONCLUSION

This project has been very challenging from the inception for all the group members. The decision to select this project was that there was enormous

practical benefit from successful completion. Since it was client based, we had to work as a team to achieve a practically useful solution rather than a hypothetical one, created better motivation and enthusiasm amongst us. We feel that there are still further improvements that can be made, but given the resources and time limitations we could not attain these.

## ACKNOWLEDGMENTS

Finally we would like to thank Dr. Thrishantha Nanayakkara our supervisor, the senior lecturers of the department and also very importantly the CEB transmission design branch engineers for their immense support and encouragement.

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