DLTCAD 2014: Low-Cost Software to be used by High-Voltage OHTL Designers and Teachers.

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Abstract—**This paper presents the applicability of software developed and presently used in Peru for the design of high-voltage overhead transmission lines (OHTL) to be built in the USA and its territories. A review of the basic software tools was performed and they were found to be in conformance with the NESC (National Electrical Safety Code). These results are significant for the following reasons: 1) they open the possibility of the software to be used in states that required that the design of high-voltage overhead transmission lines be performed with tighter specifications than the ones given in the NESC; 2) the software reviewed is very versatile, user-friendly and low-cost. These are attributes that make it ideal for additional use in teaching and training overhead transmission line designers and engineers from the US.**

Index Terms—**High-voltage, Overhead, Power, Transmission**

I. INTRODUCTION

DLTCAD 2014 is very powerful and specialized software to be used for the design of high and medium voltage, electrical power, and overhead transmission lines (OHTL). Due to its versatility the software allows the design of transmission lines within the range of 7.2 kV to 500 kV.

The original version of this software was developed ten years ago in the Spanish language used in Perú in Latin America. In 2014 a version in English was created with the intention of marketing the software among English speaking electrical engineers dedicated to designing high-voltage overhead power transmission lines.

The authors have tested the applicability of the software in the USA and have found that it is very applicable insofar as using it for designing short-length, medium-length, and long-length overhead high-voltage power transmission lines that comply with the US NESC (National Electrical Safety Code) [1].

Due to its versatility and user friendliness, we have also found that the use of the software may be applicable for the design of overhead high-voltage power transmission lines in states where the specifications for designing and building of such transmission lines are tighter than the specifications ruled by the NESC. Due to this characteristic, and because of its low-cost, compared with the higher cost of current transmission line design software presently available in the marketplace, we dare to forecast that organizations such as the Water and Power Resources Service, the Rural Utilities Service and the many electrical utilities and electrical cooperatives, plus the US electrical engineering community, will start soon using the DLTCAD 2014 software. Additionally, this software brings good news for the US colleges and universities who are dedicated to teach and provide overhead high-voltage, power transmission line design training to electrical power engineering students.

II. TESTING EQUIPMENT USED

Minimum Computing Software/Hardware Requirements:

Operating System: Windows XP, Windows Vista, Windows 7, Windows 8, Windows 10 (32b and 64b).
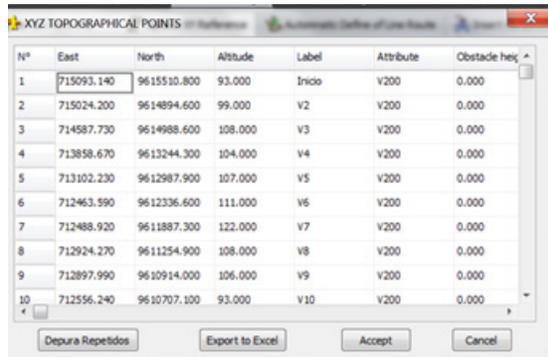
Hardware: Pentium IV or higher, 10 MB hard disk.
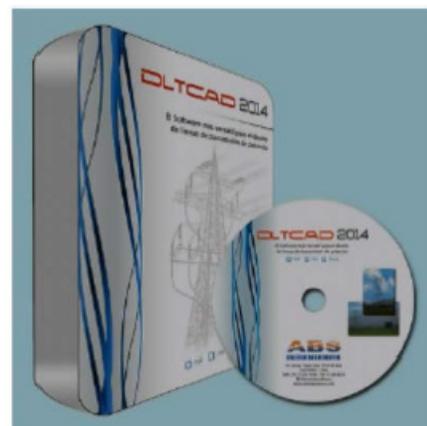
OHTL Software Tested in This Project

III. OHTL DESIGN AND TESTING PROCEDURE.

The following hypothetical transmission line was used:

- Topographical data given in UTM coordinates as shown in the following table:

Nº	East	North	Altitude	Label	Attribute	Obstacle heig
1	715093.140	9615510.800	93.000	Inicio	V200	0.000
2	715024.200	9614894.600	99.000	V2	V200	0.000
3	714587.730	9614988.600	108.000	V3	V200	0.000
4	713858.670	9613244.300	104.000	V4	V200	0.000
5	713102.230	9612987.900	107.000	V5	V200	0.000
6	712463.590	9612336.600	111.000	V6	V200	0.000
7	712488.920	9611887.300	122.000	V7	V200	0.000
8	712924.270	9611254.900	108.000	V8	V200	0.000
9	712897.990	9610914.000	106.000	V9	V200	0.000
10	712556.240	9610707.100	93.000	V10	V200	0.000

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- Power tobe transmitted: 96 MW

- OHTL Length: 7 km, using crossing and non crossing obstacles.

- Conductors: Three type AAAC

- Guard cable: Two EHS Galvanized steel

- Fiber optic cable One type OPGW

Hypothetical climate and environmental conditions:

- Minimum temperature: 19 degrees C

- Medium temperature: 26 degrees C

- Maximum temperature: 36 degrees C

- Relative humidity; 87%

- Maximum wind speed: 95 km/h

- Average altitude: 100 masl

- Isoceraunic level: 40 days/year

The major findings found during the process of designing and testing the aforementioned transmission line were the following:

IV. USER INTERFACE

Ease of use.

DLTCAD 2014 uses a very interactive and very user friendly interface.

Editing Topographic Profile.

It has been built using a very user friendly graphic environment with graphical icons and pull-down menus for each option. Designers can actually run any task using only the computer mouse.

The major options presented by the user interface are the following:

Editing topographical data: Once these data are loaded in the software, they may be edited and/or corrected by a designer who will be able to add or delete survey points in graphical form or manually via the computer keyboard.

Automatic structure spotting: The software can perform the automatic spotting of transmission line structures and supports, taking into account the NESC minimum clearances to ground and maximum span due to the separation of conductors.

Editing structures: The software helps designers to change the type of structures, support types, add or remove guys, and assign a type of grounding. Changes can be made one by one or automatically for the entire project.

Catenary Editing: It allows separating the treatment of some spans as slack spans, varying the initial EDS tension. It is possible to change the type of conductor for special spans or change the conductor automatically for the entire project.

Options for Manual Corrections: Using the computer mouse, designers can delete, add, and move to a particular point or move and perform structure spotting continuously using the computer mouse. The software facilitates the relocation of supports according to certain considerations, such as: minimum distance to the ground, nearest local topographic point at a certain distance from the current location or side supports.

Presentation of Results at Design Time: Every time an action is executed, the catenary, tensions, support conditions, clearances and other parameters are recalculated by the software, and the new information is displayed simply by bringing the computer mouse to the desired item. For example, placing the mouse on a catenary displays its parameter, weight span, wind span, sag, tensions and others. The same applies when dealing with overhead transmission line supports and structures.

Image Amplification: The following software features allow designers to view the entire transmission line or a specific section of it; it does presentation on screen of the entire project (full zoom), it does selection options of specific areas for scaling (zoom by sections), it also does linear amplification or compression by using the mouse, zoom independent scales on the X axis and the Z axis.

Graphic Alarms: They are used to identify errors occurred during the design of transmission lines. The software provides a different type of graphic alarm for each type of error, and this help designers determine at first glance the type of error that requires correction. The types of errors that are signaled by means of graphic alarms are the following:

- Catenary below the minimum safe distance.

- Tension that exceeds the safety coefficient of conductor.

- Distance between conductors below the regulated limit.

- Negative weight span.

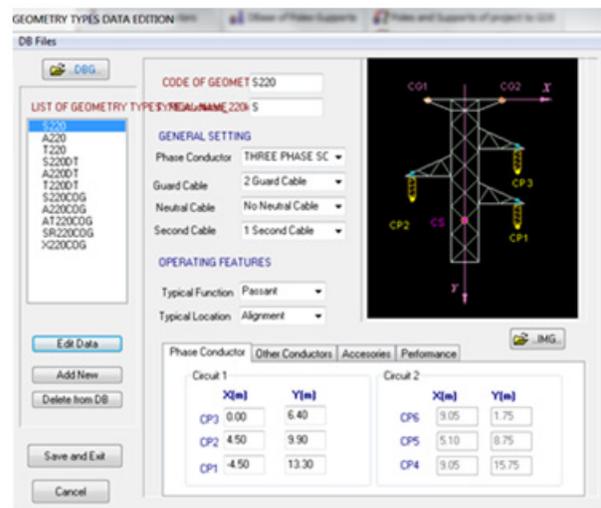- Suspension insulator swing exceeding the limit.

Graphic Indicators that identify design actions are the following:

- Do not move: It indicates that support cannot be moved.

- Has grounding: It indicates that a support has grounding.

- Section not allowed for placing supports.

- Type of support: Different colors for dead end, alignment or angle structure.

- Different colors for conductors:

  Green Lemmon: First three phase conductors.

  Brown: Second three phase conductors/

  Blue: Overhead ground wires.

  Yellow: Neutral conductor.

  Sky blue: Fiber optic cable.

V. TESTING OF DLTCAD 2014 FEATURES

Units.

The software allows designs of overhead, high-voltage power transmission lines in two types of units: SI base units and English base units.

Topographic Data Management.

These data are the basic information needed to develop an overhead transmission line design using DLTCAD 2014. This software accepts data in UTM coordinates (X, Y, and Z), and also in X, Y format (cumulative, altitude, angle, label). Either topographic data can be used to trace the line route and to develop the line profile.

General Data Bases.

There are tables of overhead transmission line structures, conductors and supports used by the software. The information in these tables is editable and reusable. When a new project is started, the designer can retrieve from the general data bases, any data deemed to be necessary and copy it to the tables of the project. In the project data base the designer can add new items, update data, and delete unwanted items without affecting the data stored in the general data bases.

Major tables provided by the software are the following:

Tables of structures: Three phase, biphase and single phase structures.

Tables of supports: Wood, concrete, metal and steel supports.

Conductor tables: ACAR, AAAC, ACSR, ACCC.

Insulator tables.

Terrain types tables.

Obstacles type tables.

Grounding types tables.

Foundation types tables.

Structure S220 Used for Testing DLTCAD 2014

Environmental Conditions.

These are the hypothesis of state required for designing overhead transmission lines. The software can handle up to ten hypotheses and a designer can define the number of scenarios needed to work by adding or removing a hypothesis according to the specific design requirement for conductors. The data or name in each hypothesis can be easily edited and/or modified; moreover, the software allows a designer to work with five types of conductors per span as follows:

- First overhead three phase circuit

- Second overhead three phase circuit

- Overhead ground wire

- Overhead neutral cable

- Overhead Fiber Optic Cable

Mechanical Calculations for Conductors.

These calculations take place in two separate phases as follows:

General calculations phase:

Automatic calculations performed in this phase generate Final EDS tables, tensions and sags for horizontal and uneven spans as defined by the designers. The calculation results can be applied to predict additional results such as the evaluation of support performances, and the preparation of diagrams of mechanical loading prior to attempting the spotting of structures.

Design development phase:

Automatic calculations performed in this phase generate results for the horizontal wind pressure on the projected area of conductors, the catenary, the spans, the sags of conductors, and the current-temperature relationships, the initial and final EDS used in a particular hypothesis as well as the effect of permanent elongation (creep) of such conductors [2]. For the calculation of the final EDS the software uses the polynomial stress-strain characteristic of conductors [2]. For the calculation of the catenary and conductor tensions the exact hyperbolic equations are used, applying finite numerical methods for solving some of these equations [2]. For the calculation of conductor ampacity and for the calculation of current-temperature relationships of bare overhead conductors, the method from IEEE 738-2012 Standard is used. [3]. The software also provides for different methods of designing adequate grounding for the high-voltage structures, the allocation of required guys for all types of supports, and the allocation of wind dampers on conductors.

Clearance Calculations.

Vertical distance to ground:

DLTCAD 2014 evaluates the vertical distance to ground from all the catenary points, with reference to the limit value set by the designer according to the NESC safety considerations. It also includes options for setting different safety distances for special cases, such as for crossing of roads, streets, rivers, and other obstacles. During design, the software evaluates vertical safety distances for all points entered in the topographical profile. It generates graphic alarms when a catenary is below the established limits, thus alerting the designer to take corrective actions.

Distances between conductors:

At each mid span the software evaluates existing distances between conductors of different phases, and for each case it calculates actual clearances according to the geometrical configuration of the transmission line structures. Then, these distances are compared with the permissible values specified by the NESC. When spans do not meet the minimum safety clearances, the software generates graphical visual alarms.

Suspension Insulator Sideswing Calculations.

For each structure used in a transmission line project, the software helps designers to calculate and meet the clearances allowed by the NESC for transverse oscillations caused by the wind on suspension insulators. If needed, counterweights can be added to the design and a recalculation is performed. A status report of the angles of oscillation per each structure can be generated and this report includes the number of counterweights designed.

Vibration Analysis Due to Conductor Galloping.

The software can be used to evaluate the spatial displacement of conductors due to the galloping effect. This is accomplished by simulating the area that could be affected by the aforementioned effect.

Conductor Sag Calculations.

These calculations can be performed under two conditions.

Conductor on sheaves:

The software develops the sag calculations when a conductor is lying on the pulleys for chain suspension, according to the actual locations of the supports. In this situation, the software determines the deflection angle of the chains and the conductor offset in each support. Following this method, a conductor sag table can be generated for a configurable temperature range required by a particular transmission line project.

Clamped conductor:

In this case the software generates a conductor sag table considering rigid type of insulators that do not originate offsets due to tension. Following this method the results are presented in tables with temperature ranges required by a particular transmission line project.

Tree of Loads Calculations.

For each type of structure considered in a transmission line project, the software can generate a tree of loads. It does this by calculating the mechanical stresses caused by the conductor on the structure in underload conditions and overload conditions. The software selects the most critical loads based on the defined hypothesis chosen for the type of conductor.

Transverse Profile Analysis.

This software feature is very useful and especially important when overhead transmission lines are located in areas where the steep transverse profile presents significant slopes. In these cases it is necessary to analyze the vertical clearance of the catenary points but in the axis lateral to the line profile. DLTCAD 2014 incorporates a data table of lateral profiles which when edited by the designer, it allows up to three lateral profiles parallel to the axis of the transmission line. Using these profiles the designer can control conductor clearances during project design time.

## VI. OUTPUTS AND RESULTS

Plan Drawings.

The software automatically generates and displays at various configurable scales, the data entered for either the polygonal transmission line in UTM (X, Y, and Z) coordinates or in X, Y coordinates. Additional data that is displayed are support numbers, type of structures, and span lengths. This drawing can be printed in A1 format paper and it can also be exported in DXF format.

Profile Drawings.

The software automatically generates and displays at various configurable scales, the profile cut plan, the vertical scale cuts, the horizontal scale cuts, the angle cuts, strip scale, deflection angles, all supports and standardized symbols. This drawing can be printed in A1 format paper and it can also be exported in DXF format.
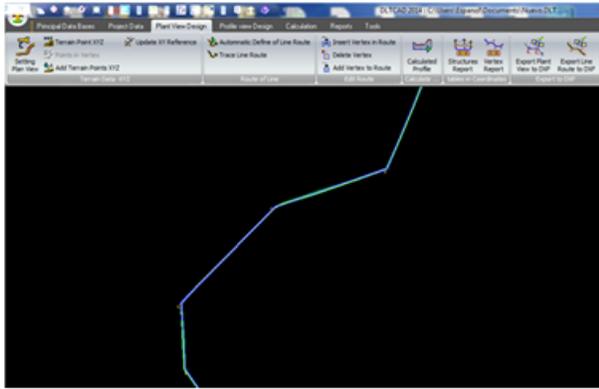
OHTL Plan Drawing
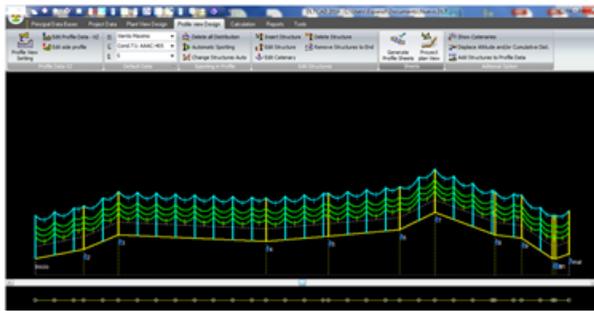
OHTL Profile Drawing

Reports.

All the following reports which are generated by the software can be exported to Excel or stored in text files.

- Table of Structures: It provides all necessary project details regarding types of structures, support types, number of guys, deflection angles, grounding types and many others.

- Conductor Sag Table: It provides a detail table of project sags and tensions for different temperatures according to a configurable range of variation. This table may be generated for clamped conductors and also for conductor on sheaves. The latter also calculates the conductor offset.

- Bill of Materials: It provides a complete summary of the main materials involved in the design of an overhead power transmission line. It lists by type the following items: number of assemblies, number

of carriers, number of groundings, number of conductors, and number of retainers.

CUSTOMER SERVICE

The software developer offers prompt online delivery services as well as user's training for installing and managing the software.

WARRANTIES

The software developer ensures its optimum operation based on ten years of existence in the power engineering communities of Latin American countries.

CONCLUSION

The authors have found that DLTCAD 2014 is a very versatile, feature rich, low-cost, interactive, and user friendly software that can be used in the USA for the design of overhead high-voltage power transmission lines to be build according to the NESC safety rules. We recommend its use to the English speaking electrical power professional engineers and to all of the electrical power engineering students in North America.

REFERENCES

[1] National Electric Safety Code, IEEE Standard C2-2012.
[2] USDA, Rural Utilities Service, RUS [Online], Available: http://test.secvitel.com/TLDMA.pdf
[3] Standard for Calculating the Current-Temperature Relationship of Bare Overhead Conductors, IEEE Standard 738-2012.

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