PLS-CADD AS TOOL FOR DETERMINING THE AIR CLEARANCES IN TOWER WHEN VOLTAGE UPGRADING

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Abstract: Statnett is busy upgrading 1500 km of 300 kV lines with duplex configuration to 420 kV using the current towers. One of the challenges during this process is the determination of actual air clearances in towers. For the modelling of the overhead transmission line and the calculation of the air clearances, the software TOWER™ and PLS-CADD™ have been selected. Studies have been made towards the uncertainty of PLS-CADD™ and the uncertainties between drawings and that what actually is built.
When modelling, at first the line model is made for the situation before upgrading, i.e. as the line is today. To fulfil the insulation coordination requirements existing strings comprising 14 or 15 insulator units are extend to 17 units. Structure clearances are checked for four load cases. In case of critical clearances different insulator string configuration or solution are tried until the problems have been solved.
This paper will focus on the how these problems are handled and overcome, and how PLS-CADD™ and TOWER™ are used successfully as tool when voltage upgrading.

1 INTRODUCTION

To be able to meet tomorrows demand on the power grid, Statnett is busy upgrading and rebuilding a large part (5000 km) of its 300 kV network to 420 kV.

There are basically two different types of line configurations that are of interest for upgrading: the simplex lines (ca 3500 km) and the duplex lines (ca 1500 km). The problems that both line types have in common is the insulation coordination challenge.

The insulation coordination challenge comprises different parts. Those different parts that amongst others can be identified for voltage upgrading are:

- the length and type of the insulator strings,
- the air clearances,
- the lightning performance,
- the switching overvoltage profile and performance,
- the actual wind load for the different load conditions,
- the clearance to ground [1].

One important task for voltage upgrading is the determination of the actual air clearances using a particular insulator configuration in each tower, this is the main topic of this paper.

2 DESCRIPTION OF A TYPICAL 300 KV OVERHEAD LINE WITH DUPLEX CONFIGURATION

2.1 Transmission towers

Statnett has about 15000 towers in operation on 300 kV level in its transmission system. There are in basic few structure types which were design in the 60´s and 70’s under different criteria and wind mappings.

A typical suspension tower is illustrated in Figure 1. The tower legs have generally a spacing of around 9,5 m. The length of the cross arm is 18 m.

Figure 1 Showing a suspension tower in 300 kV, duplex line (picture comes from [4])

2.2 Insulator and string types

The standard insulator used in Statnett's 300 kV lines is a glass cap and pin insulator with a diameter of 280 mm and a construction length of 170 mm.

There are few types of insulator strings used. One of them is a single suspension string with 14 or 15 insulators in the string as it is shown in Figure 2. Statnett uses also double suspension strings and V-strings.

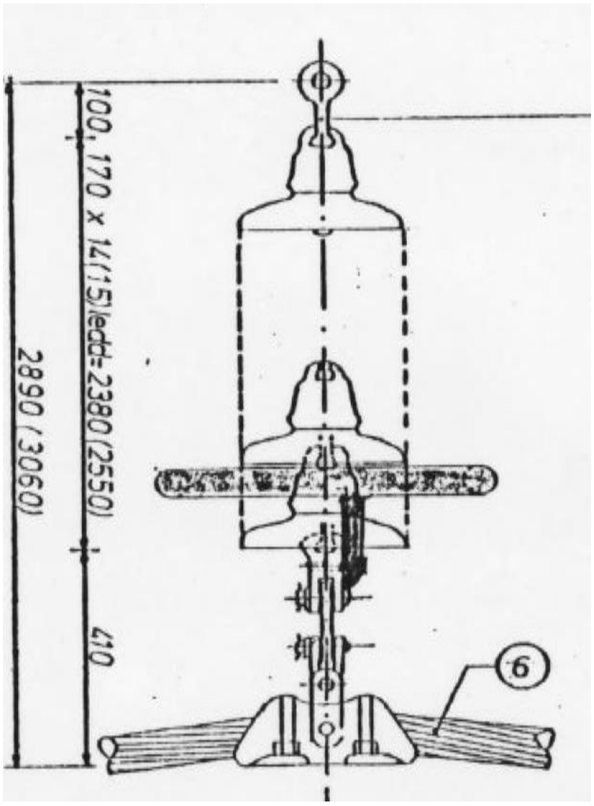

Figure 2 Configuration of typical suspension string for 300 kV OHTL [6]

3 VOLTAGE UPGRADING PROCESS

Statnett has in average 3 towers per km. Upgrading 1500 km of overhead lines, implies that one has to investigate clearances around 4500 towers. Each tower has three phases and the clearances need to be determined for four load cases, for three configurations, so it means that 162 000 clearances have to be determined. Therefore manual evaluation of the clearances is not feasible, and a search was started to suitable software to support the engineers. It was clear that an automated method was needed, and if not available it needed to be developed. After some investigations, Statnett selected the software PLS-CADD™ and TOWER™ from Power Line Systems Inc. to support their needs.
One of the reasons for selecting those particular programs was that these programs meet most parts of the designing of an OHTL. They can be used to check capacity of individual structures and also the whole line structure. The result is then shown graphically which makes some of the designing phases much easier to work on. One of the advantages of these programs is that the line model can be used later on as some kind of a database for maintenance.

3.1 Establishment of the model representing the situation before upgrading

The upgrading process for each line starts with LIDAR scanning of the existing line and the terrain in a corridor around the line. Then the geometries of the insulator strings and towers are modelled in TOWER™. After that the terrain and towers are put into PLS-CADD™ and a computer model is fully created by stringing conductors and earth wires between the towers. With help of old documentations, pictures from line inspection and information from line master, an inventory of the line is taken. All input data like weather and ice loadings, geometry definitions and load definitions are established and checked. The first PLS-CADD™ model is then a computer model of the current situation before upgrading. This process is shown in the flow graph in Figure 3.

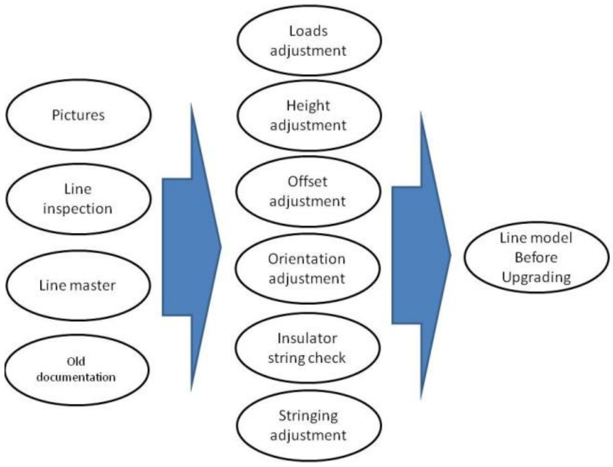

Figure 3 Establishment of the first PLS-CADD model representing the situation before upgrading

3.2 Establishment of a proposal for voltage upgrading

The existing overhead lines, which are operated at 300 kV, are equipped with strings of 14 or 15 cap-and-pin glass insulators. Voltage upgrading means that existing insulator strings need to be extended to strings of 17 units to withstand the higher service voltage under pollution or icing conditions. The TOWER™ software is used as a tool to perform this task. To extend the number of insulators every tower needs to be edited one by one. At the same time, the available clearances in the tower top must be utilised in an optimum way to avoid reducing insulation performance of the upgraded line. This is crucial especially for the suspension towers, where available air clearances between conductors and tower legs or guy wires will decrease as a result of extending the insulator strings [2]. The example of a tower model before and after extension of the insulator string is shown in Figure 4.

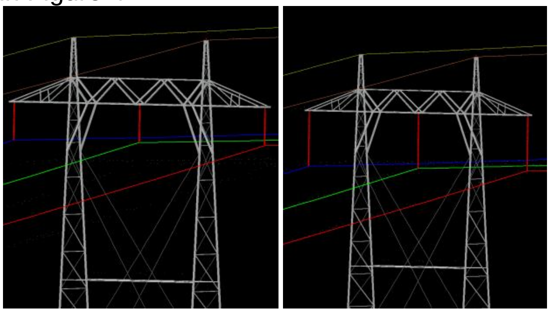

Figure 4 Tower model with insulator strings before and after extension

After extending the insulator strings in the computer model the order Structure Clearance is run. Resulting air clearances are checked, tower by tower, if they fulfil the basic clearance requirements under conditions of still wind and most critical loads on the line (for lightning overvoltage), 3-year wind (for switching overvoltage), and 50-year wind (for service voltage) [3]. Figure 5 shows 50-year wind from both sides affecting a tower model in PLS-CADD^{TM}. The software automatically identifies clearance violations between energized portions of the bundle conductors and the tower construction. PLS-CADD^{TM} takes into account the voltage of wires and the required clearances as defined in its' criteria box. Distances smaller than required are shown in red[5]. Clearances for tension towers with support insulators in jumper loops cannot be calculated by PLS-CADD^{TM} and for that a special program was developed in Excel.

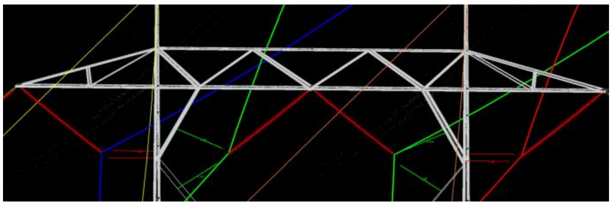

Figure 5 Identification of tower with critical clearances 50 year wind

3.3 Final proposal for upgrading

Due to variations of tower design, it is not always possible to fit strings of 17 units in the middle phase. It is also sometimes not possible for the outer phase in towers with line angle. It means that different solutions should be checked. One option is to reduce the insulator length to 16 units in centre phase. Another option is to install V-strings instead of present I-strings. All possible solutions are checked in PLS-CADD^{TM} and TOWER^{TM}, both according to strength capacity of structure and to distances in the tower. Then all clearance calculations are made once again for all weather cases (see Figure 6).

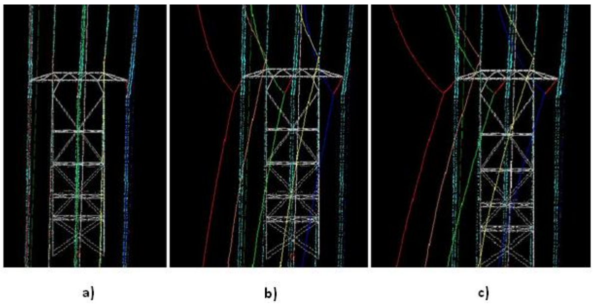

Figure 6 Three load cases used in PLS-CADD: a) still air condition (max. temperature and max. ice load), b) three year return time wind condition and c) 50 year return time wind condition

4 ACCURACY OF SOFTWARE

When starting a large-scale project like this it is important to be confident that programs used and methods are accurate especially when electrical boundaries are utilized to the utmost. For that reason accuracy of TOWER^{TM} and PLS-CADD^{TM} were examined in starting phase of the project.
The main factor that effects the clearances in the tower is the movement of the insulator chains. The difference between reality and the modeling was checked for both TOWER^{TM} and PLS-CADD^{TM} because both the programs use simplified models regarding to this. The main difference between the two programs is that in TOWER^{TM} it is only possible to look at the allowable outswing in 2D: In PLS-CADD^{TM} this is possible in 3D, but it is not possible to define the size of the hardware in the lower parts of the chain. In TOWER^{TM} it is possible to define live hardware in the chain like described in Figure 7.

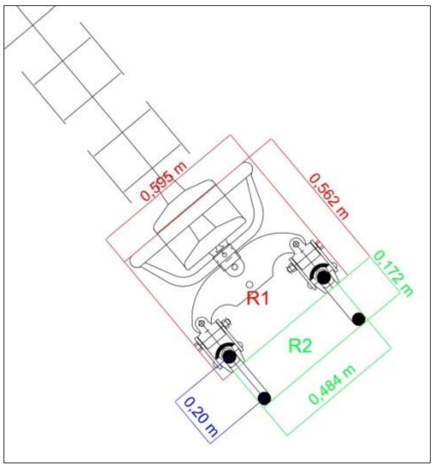

Figure 7 Example of hardware in lower live part of a hanging string, defined in TOWER^{TM}

Now it was interesting to investigate what the simplifications of both programs means towards the accuracy. In TOWER^{TM}, the definition of hardware is not precise and the allowed swing angle used is given a rounded to the nearest whole number, but the outcome, compared to an identical model in a 2D drawing program, is very similar. The difference between the drawing program and TOWER^{TM} was between 0,0-3,5 cm [7].

For the centre phases, a 2D check is not good enough for Statnett's type of towers because of the sag in conductor that influences the air clearances to guy wires. Therefore the air clearances have to be calculated in 3D in PLS-CADD^{TM}. For this purpose manual sag calculations for a line were compared to the ones obtained from PLS CADD^{TM}.

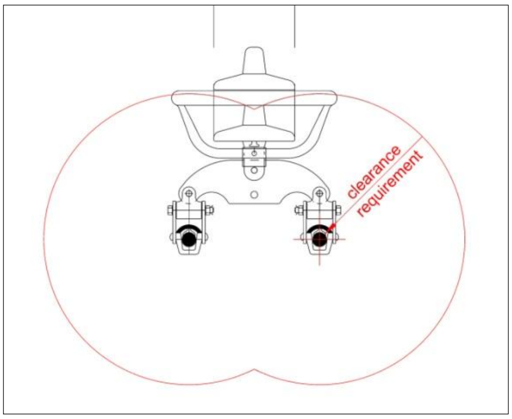

Figure 8 Definition of live part in a hanging string, defined in PLS-CADD^{TM}

The difference the manual calculations, that were performed with help of a drawing program, and the calculations performed in PLS CADD^{TM} was between 1 and 8 cm or up to 2,7% of the clearance within the towers [7]. The results obtained by PLS-CADD^{TM} model were on the safer side.

5 CONCLUSIONS

Because of the large scale voltage upgrading, it was necessary to find and develop methods for checking huge number of air gaps in overhead line towers. Statnett has selected the PLS-CADD^{TM} and TOWER^{TM} software developed by Power Line System Inc. Madison, Wisconsin, to support their needs.

One of the major advantages when using computer programs for the huge number of towers in Statnett's power systems that have to be upgraded, is that it saves a lot of time compared to manual evaluation. Another advantage is that by using these software one can reduce the number mistakes.

A further advantage of computer evaluation is that clearance violations are clearly marked in the both the clearance report and in the 3D view. This allows fast identification of critical towers and the phases where problem appear.

As one can see from check from chapter 4 both software are quite accurate, that make that calculations are more precisely.

One of another advantages of using automation of this work is amongst others that the some of the data can be exported for further dimensioning use, for instance as input for programs like LPE (Line Performance Estimator) [1], [8].

After the design work of voltage upgrading the PLS-CADD^{TM} model can be used as some kind of a database for maintenance department later on.

One of disadvantages is that tension towers with support strings can't be dealt with in PLS-CADD^{TM}.

Another disadvantage is that it takes some time to learn the programs in and out, and that one has to be very careful when defining the load cases and other relevant input data. A small mistake will have large consequences, since the available margins when voltage upgrading are so small.

6 ACKNOWLEDGMENTS

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7 REFERENCES

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