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Vegetation Management Takes to the Air

BC Hydro pilots the use of LIDAR and PLS-CADD to identify vegetation encroaching on transmission lines.

By Bryan Hooper, British Columbia Hydro

Currently, BC Hydro (Vancouver, British Columbia, Canada) vegetation management field personnel work from the ground or from helicopters when determining what vegetation violates clearance requirements and needs to be removed. This involves a lot of estimating, as the field crews need to predict where the conductor would be under maximum operating temperature or wind conditions. It also requires either estimation or field measurement of trees to determine if they would encroach required clearance zones if the trees fell.

With a generating capacity of 11,500 MW, BC Hydro has 18,000 circuit kilometers of transmission lines that range from 69 kV to 500 kV. This government utility is constantly looking for innovative and low-cost methods to maintain its network. Of course, proper vegetation management is key to keeping its network up and operating.

BC Hydro decided to address the guesswork inherent in vegetation management by combining two technologies now in use in its engineering department. The first of these involved using LiDAR (Light Detection and Ranging) to quickly survey the transmission line, including the vegetation canopy in the vicinity of the line. The second involved using a computer program to accurately model conductor position and movement, and to identify the vegetation that encroached on defined conductor clearance values.

BC Hydro has been using Power Line Systems' (www.powline.com) suite of applications, including PLS-CADD, for transmission-line design and line-rating studies since 1995. BC Hydro has used FE sag-tension analysis for transmission-line rating studies since it became a feature of PLS-CADD in 2001. The FE modeling results in a more accurate prediction of wire behavior in the presence of large span-length variations and steep terrain. Furthermore, the more accurate

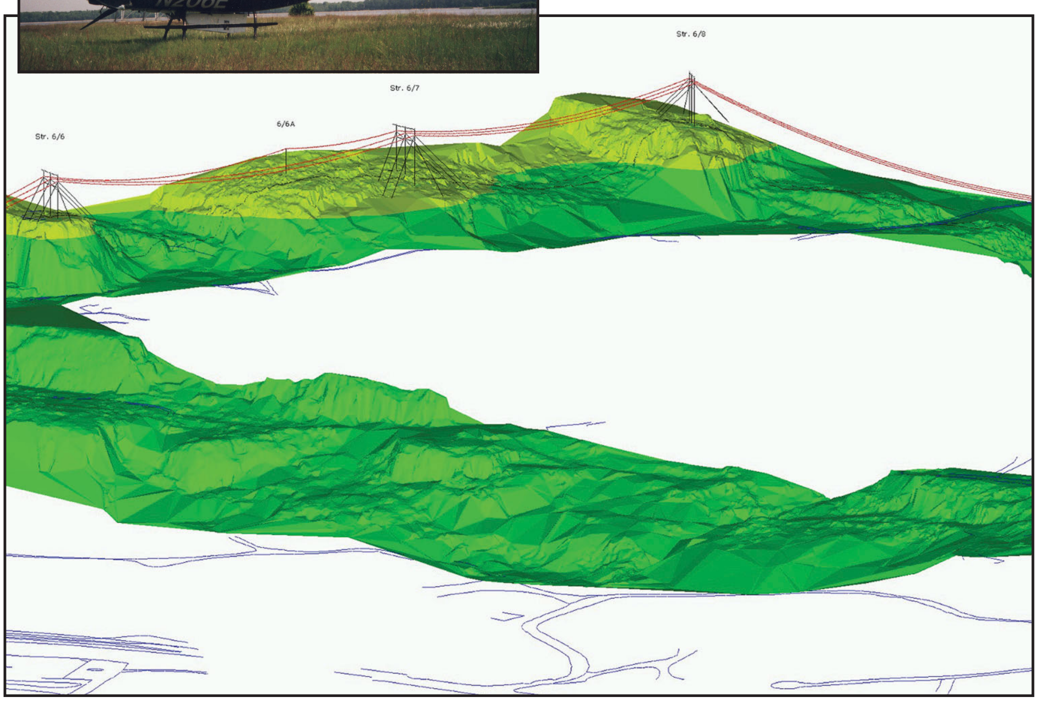


Fig. 1. T/L transmission line ground model.

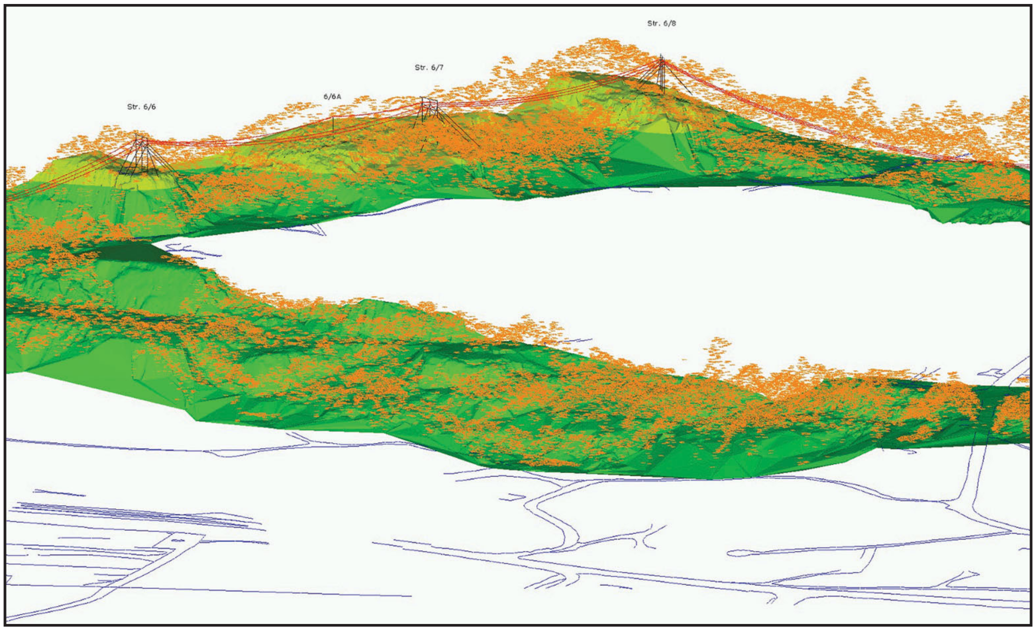


Fig. 2. Ground model with LiDAR vegetation points merged.

analysis generally results in fewer required changes to an uprated line. It also allows the designer to consider situations like unequal ice and clearance improvement techniques such as cutting out conductor or shifting slack between spans.

BC Hydro currently is using LiDAR survey as a cost-effective method for capturing spatial data on 69-kV transmission lines for the purpose of populating its enterprise GIS system.

The utility recently completed a pilot project using this approach to determine vegetation clearance violations on a 230-kV uprating project. The pilot not only delivered on the reduction of guesswork, but also revealed several other advantages encouraging the use of the LiDAR/PLS-CADD combination as part of an on-going right-of-way vegetation management program.

The Project

The project was a 230-kV transmission-line uprating on a 65-km (40-mile) line serving the Greater Vancouver area. The line was originally constructed in 1945 and initially designed for 50°C (122°F) operation, but electric system requirements now call for the circuit to be uprated to a hot operating temperature of 90°C (194°F).

In the first phase of the project, Rudy Rugge and James Peters of BC Hydro's engineering group modeled the line in PLS-CADD. Ground structure positions and conductor tension data were derived for the model using LiDAR survey. Ground clearance checks were run with the conductor at the new required operating temperature, and where additional ground clearance was necessary, the utility employed line modifications such as raising or adding structures. Also, in some areas where increased ground clearance was necessary, small lengths of conductor were removed and insulators re-clipped. The finite element (FE) analysis capability of PLS-CADD made this possible.

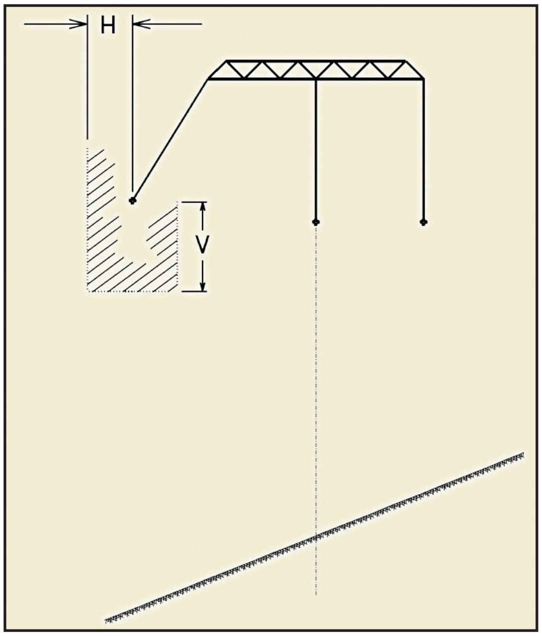
As this transmission line runs through a watershed that supplies the Greater Vancouver area, BC Hydro historically had been extremely frugal in carrying out its vegetation maintenance program, by only removing vegetation perceived to pose a hazard to the safe reliable operation of the circuit. Thus, the uprating of the line had to include vegetation clearance analysis in its scope since the utility could not operate the line at the increased ampacity until it had removed all vegetation identified as a hazard at the new hot temperature. Therefore, BC Hydro began a pilot project that merged vegetation points captured by LiDAR survey to the transmission-line model and then calculated, plotted and reported vegetation-clearance violations to the newly uprated conductor positions from within PLS-CADD.

Methodology

For those unfamiliar with LiDAR, the survey is carried out by a helicopter, equipped with sophisticated equipment, flying over the subject area. The equipment consists of a precise navigation system and a scanning laser. The laser transmits light pulses (about 10,000 Hz) and measures reflection times. Distances to objects are calculated and then combined with the precise positional data from the navigation system. This provides the LiDAR survey points with their coordinate values accurate to ±0.25m absolute and ±0.15m relative. The LiDAR supplier, in this case Terra Remote Sensing Inc. (www.terraremote.com), classifies the survey points into several categories such as ground, structure, conductor and vegetation in a post flight process. The survey points are provided for client use as ASCII files.

In late 2002, BC Hydro approached Power Line Systems with a request to develop new PLS-CADD features exclusively for conductor to vegetation clearance analysis with a view using LiDAR supplied vegetation points. PLS-CADD already had the ability to establish conductor positions under a variety of wind and temperature conditions. It also already had the ability to perform clearance analyses to an assortment of categories of survey points each with unique conductor clearance requirements. In discussion with Power Line Systems and BC Hydro's vegetation professionals, the companies agreed that PLS-CADD could be used as an effective vegetation management tool with the addition of:

- A method to identify vegetation grow-in violations. These are vegetation points that violated designer prescribed horizontal and vertical clearance to conductor values.
- A method to identify trees that would come within a



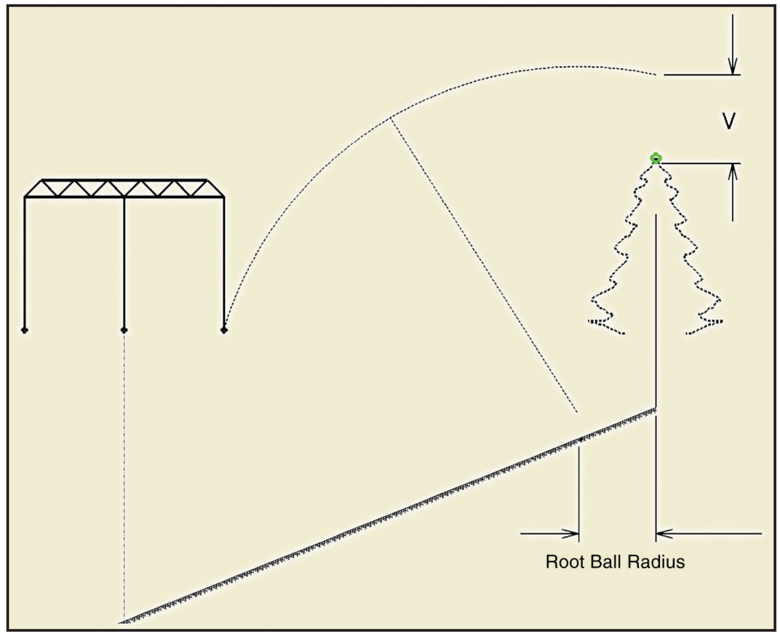


Fig. 3. Vegetation grow-in clearance requirements. **Fig. 4. Falling tree clearance requirements.**

designer prescribed clearance value if the tree were to fall.

- A means to present the above results in a manner that would be easy for field crews to use.

BC Hydro was able to detect vegetation grow-in violations in PLS-CADD, as previously noted, because the program already had the ability to assign a required horizontal and vertical clearance for each type of survey point (road, ground and vegetation). Typically the vegetation clearances would be comprised of the required electrical clearance, an allowance for vegetation growth and an additional safety margin. In Figure 3, the values of *H* and *V* represent the safe clearances values specified. Vegetation points that encroached this zone were identified as grow-in violations.

For those unfamiliar with LiDAR, the survey is carried out by a helicopter, equipped with sophisticated equipment, flying over the subject area.

Identifying falling trees that could come within a safe operating distance of the conductors is a bit more difficult and required the utility to make some conservative assumptions. BC Hydro wanted to consider a tree falling, rotating about the base of its trunk at the ground line and swinging through an arc with a radius equal to the tree height. The utility also wanted to include an option to address the fact that trees often pivot about a root ball rather than pivoting about the base of their trunks.

BC Hydro decided on the strategy that assumed every vegetation point represented the top of a tree. The height of this tree is calculated by PLS-CADD as the distance between the vegetation point and the ground surface directly beneath it. The designer defines the optional root ball radius at the time of the analysis as a percentage of the tree height. The tree is assumed to sweep out an arc centered about the base of the tree (or optionally, the root ball) with a radius equal to the tree height plus a designer-supplied clearance requirement. If the assumed treetop, when swept towards the conductor positioned at any of the specified temperature and wind conditions, comes within the specified clearance distance of the conductor, it is identified as a falling tree violation (Figure 4).

To provide an effective way to present the results so they would be useful to the field crews, BC Hydro decided to use the traditional PLS-CADD plan and profile sheets. This was the best way to graphically present the information, as it was a format that provided everything necessary to locate and identify the vegetation to be removed. The vegetation points deemed as grow-in or falling tree violations are indicated on both the plan and profile portion of the plan and profile sheet with different symbols and colors. This enables the field crews to distinguish between grow-in and falling tree violations. In addition to the drawings, a report that lists each vegetation clearance violation, its position and geometric details can be produced and either printed and exported to a spreadsheet or database file for further manipulation.

The utility had assumed it could simply merge the LiDAR vegetation data to its PLS-CADD line model and run the vegetation clearance analyses. While this worked on small sections, BC Hydro found that for longer lengths of line, the volume of LiDAR vegetation data overwhelmed the computers memory and resulted in prohibitive run times. This was particularly problematic when the analysis included the falling tree-analysis option.

Working with its LiDAR supplier, Terra Remote Sensing, and the survey and photogrammetry department of BC Hydro, the utility developed methods for reducing the data volume to a size manageable in PLS-CADD, while still keeping the points that accurately represented the critical

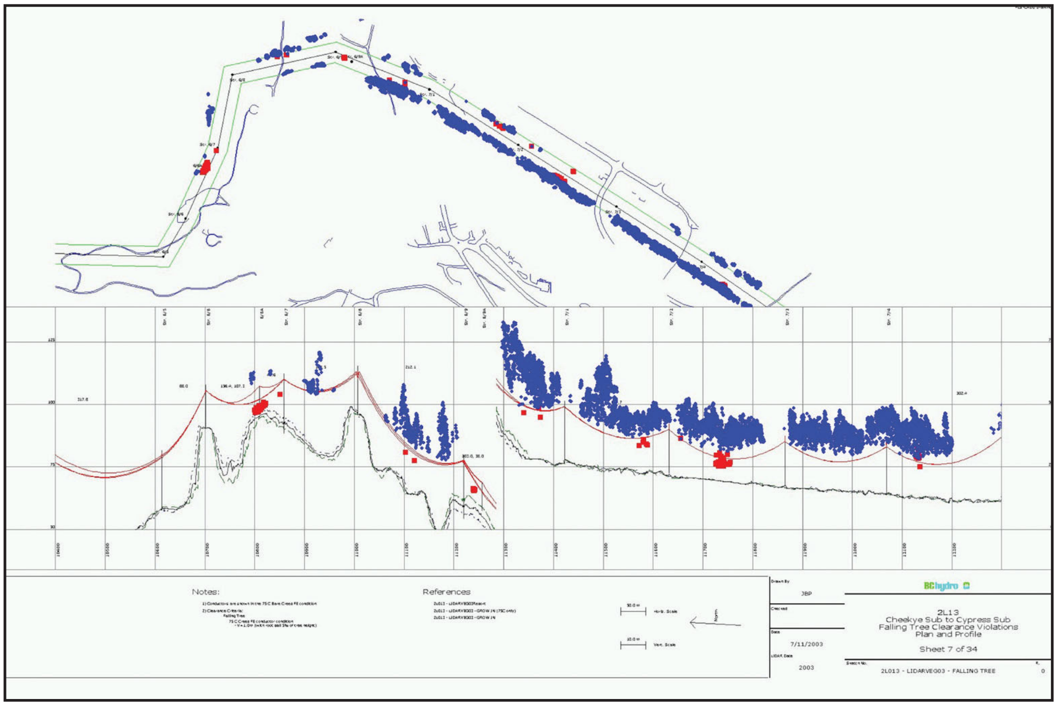


Fig. 5. Plot of vegetation clearance violations produced directly from PLS-CADD.

position of the vegetation canopy. These included removing all vegetation points that are within a meter of the ground.

Another successful strategy involved the selective thinning of data by eliminating all but the highest vegetation point within a square-meter area. Between these methods, performance improvements Power Line Systems made and the upgrading of BC Hydro's computer's RAM, the utility now had the ability to run vegetation clearance analyses in a manageable time.

The benefit of this method lies in the simple fact that guesswork by field personnel is completely eliminated. They no longer have to estimate the conductor at its maximum sag, or at its wind blown swung positions.

Identifying Vegetation Management Work

Plan and profile views with violating vegetation points highlighted were plotted and provided to the vegetation managers for action. Violation locations were investigated and confirmed in the field. Crews removed the trees or vegetation using the PLS-CADD generated drawings as working documents. Figure 5 is an example of the plan and profile view sheet plotted for field use. On this example vegetation points are shown as red squares for grow-in violations, and blue dots for falling tree violations. An additional tabular report provided any necessary precise positional data plus information on the extent of the violation. BC Hydro used this information in prioritizing the vegetation removal.

One of the most encouraging results of the pilot was the positive response received from the field vegetation managers. Thomas Bailey, vegetation manager for the Lower Mainland area within which the pilot project line is located, stated that, "The LiDAR/PLS-CADD combination has the potential to become the most significant development in right-of-way vegetation management since the invention of the chain saw."

Acceptance by field personnel was also encouraging. They found the plan and profile plots easy to understand and use for the identification and removal of violating vegetation. The benefit of this method lies in the simple fact that guesswork by field personnel is completely eliminated. They no longer have to estimate the conductor at its maximum sag, or at its wind blown swung positions. Furthermore, they no longer have to estimate the distances between these critical conductor positions and vegetation.

The following three points validate the value of the LiDAR/PLS-CADD combination by providing transmission-line management that is:

- More reliable, because the risk of missing points that violate clearances standards are substantially eliminated.
- More economical, because only vegetation that is a violation is removed. This is obviously more environmentally acceptable as well.
- Safer, because there is less likelihood of hazardous vegetation being overlooked.

Additional aspects of human error eliminated or reduced include: fatigue caused by long helicopter flights, viewing perspective, lighting or shadow hindrances, and difficulties of winter patrols.

The utility saves time and money by identifying areas with vegetation to be removed prior to field inspection. Knowing exactly what needs cutting in advance has advantages in meetings with the public and environmental resource agencies, and allows for better planning and more effective use of the field personnel involved in vegetation removal. This is especially significant in the rough terrain and remote areas of British Columbia. Also, as roads into and along rights-of-way are seeing increased scrutiny, as well as environmental and regulatory opposition, practices that reduce reliance on ground access are beneficial.

Technologies Yield Success

BC Hydro considers its pilot project to be a success. It worked to address the issues of LiDAR survey data volume and now has it at a manageable level. The next generation of LiDAR laser scanners and their increased pulse rates (40,000 Hz) and "multi-return" process will further increase the accuracy and confidence of the survey data.

BC Hydro is now undertaking a similar project on the two major 500-kV supply lines to Vancouver Island. Last winter the utility experienced an outage as a result of unequal ice loading bringing the conductor into contact with trees on the right-of-way. LiDAR survey vegetation points analyzed with PLS-CADD FE will identify trees and vegetation that violate flashover clearances under this unbalanced conductor load condition. These can then be identified and removed eliminating this kind of event as a potential operating concern.

With a library of transmission lines already modeled in PLS-CADD, it is easy to imagine an annual vegetation maintenance program that uses LiDAR survey vegetation data. Depending on the growth rates of the predominate species, cycles for LiDAR survey could be optimally established. These might vary from three years up to possibly 10 years in harsh growing environments. A growth allowance aligned with this cycle could be applied to the PLS-CADD vegetation clearance analysis. This has the potential to reduce inspection costs in the scale of hundreds of thousands of dollars per year in just the Vancouver Lower Mainland area alone. This would not eliminate the need for annual inspections, but it could greatly reduce them. This savings combined with greater reliability and increased public safety make the LiDAR/PLS-CADD combo a potential winner for vegetation management for some utilities.

Bryan Hooper is the transmission project manager with BC Hydro, where he has worked for 30 years in transmission engineering and maintenance positions. BC Hydro is currently in the process of separating the transmission planning, operation and maintenance functions to a separate government Crown Corp., British Columbia Transmission Corp. (BCTC). Hooper will then work within the asset program management group of BCTC.

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