Understanding LiDAR Data - How Utilities can get Maximum Benefits from 3D Modeling

L. J. Chaput, *Technical Marketing Engineer (EIT), WIRE Services*

***Abstract*-- Electrical utilities worldwide are faced with aging and overloaded transmission lines. Due to the challenges of acquiring permits and approvals required to construct new transmission lines many utilities are concentrating on rating and up-rating their existing facilities. This paper will explore the practical benefits of three dimensional transmission line modeling using LiDAR survey technology for the analysis and re-rating of existing power lines. Proper processing and management of LiDAR data is the key to developing a useful analysis tool. Trusting and understanding LiDAR's accuracy and limitations are essential to appreciating the cost effectiveness of merging it with transmission line modeling software. Recognizing the importance of model building choices, analysis criterion and interpretation of results will be explored. Examples of such include, when to string cables using finite element analysis, which design criterion are required to produce viable results and what do the reports really tell you. Various examples of LiDAR's applicability and usefulness in identifying potentially hazardous situations and thermal operating constraints for existing lines are presented. The paper will summarize the methodology used in everyday practice of transmission line re-rating followed by the analysis and upgrade procedures presented in case study format. Examples of processes such as; structure modifications, re-spanning, re-tensioning and re-conductoring will be included.**

***Index Terms*-- asbuilt, laser data, right of way, transmission line, upgrade**

I. Introduction

This paper will explore the practical benefits of three dimensional transmission line modeling using LiDAR survey technology for the analysis and re-rating of existing power lines

II. Global issues surrounding existing Transmission Lines

Given this paper will explore the challenges and solutions of today's transmission lines based on state of the art technologies, it would be prudent if not at least respectful to include a few short and interesting notes on the history and development of the transmission line technology as it continues to shape the world we live in.

This work was supported in part by WIRE Services an Initiative of Manitoba Hydro.

A. Short history

[1] The first recorded transmission line was constructed in Germany, 1882. It was approximately 50km long and energized at 2.4kv DC voltage. The first single phase AC voltage line was constructed in Oregon, USA in 1889 and its success led to a major expansion of transmission line construction across North America. This expansion saw its heights in the early 1930's to early 1960's. We are now seeing a resurgence of line construction or refurbishment as more and more lines become overloaded.

The principles of transmission line design and construction are basically universal; there are different voltages and configurations but typically they all resemble the early designs. [2] The trend over the years has been to increase the voltage when capacity is exceeded; this is why we see systems that contain various voltage groups or families such as 115kv, 230kv and 500kv.

Having the largest portion of our electrical network constructed anywhere from 40 to 70 years ago poses many present day problems that can no longer be ignored. [3] Most Nations have introduced harsh penalties for non-compliance with regards to specific local and national codes. This fact along with the ever increasing liability considerations is forcing many utilities and transmission line owners to take assessment of their current facilities.

B. Aging and overloaded infrastructure

Transmission lines like most other large infrastructure projects are designed to have an extended life cycle. The issue of aging materials and failing components is always a factor when assessing the soundness of any transmission line. Typically, with proper maintenance the overall physical condition of a line is not the leading factor requiring large amounts of capital dollars to improve its performance. Unfortunately like most other types of infrastructure such as buildings, bridges and roads the criteria used during the time of design generally does not allow for the larger than anticipated capacity increases. These large capacity increases are a major contributing factor in the decision to make improvements to an existing line but certainly not the only.

C. Evolving Right of Way Usage

There was a time when utilities could be assured that the right of way they had built on was safe from future encroachments such as buildings, roads and other power and communication lines. This is no longer the fact, since the deregulations of the electrical industry, utility Right of Ways (ROWs) have become fair game for sub-transmission, distribution and communication companies. These companies are using existing ROWs and even existing transmission lines to place their plant. This unregulated construction has caused hazardous conditions which need to be addressed.

Oddly enough the trucking and farming industries have also forced changes in the transmission line world. Equipment used for both trucking and farming continues to grow in size to meet the increasing demands of those industries. This directly influences the clearance height requirements needed from phase to ground for all transmission line voltages. As Farming and trucking equipment gets dimensionally larger, power lines need to have greater line to ground clearance. It’s a fact which forces large capital expenditures for utilities each year.

D. Construction Practices and Sag & Tension Uncertainties

It is interesting to note that if lines are built to the design specifications and criterion used during the design phase there would be few uncertainties in the sag and tension of the conductor. There are tools to predict the tension of the wire after a specific time and loading period, why should there be any concern in regards to what is out in the field? Sag charts are provided, spans lengths are fixed and loading conditions are specified. What could go wrong? More often than not projects in real life are not as they appear on design drawings and this is quite often the case with transmission lines.

The term “asbuilt” was coined for a very specific reason; it means just that, as built in the field. The problems with asbuilt drawings are that they are typically done after the fact and much after construction is completed. Small changes such as structure relocations or height adjustments are easily forgotten but these small changes can have large implications on the sag and tension of the conductor.

Construction practices directly influence the overall performance of the transmission line. Typically we assume that poor construction practices will lead to possible structural failures. This can be the case but those kinds of deficiencies are much easier to catch during the inspections of the transmission line construction.

It’s the small inconspicuous items such as poor sagging procedures or improper compaction of backfill around structures and guying which can lead to poor performance of the line. A small shift or settling of a structure location can produce large changes in the sag and tension of the conductor, especially when there are short and long spans combined in a specific ruling span.

E. Which span governs the line rating

When a transmission line is given a “rating” defined as the maximum safe operating temperature of the conductor, this rating is the upper temperature limit the line can be safely operated at. This rating generally tends to restrict the original design capacity of the line. Knowing which span(s) specifically are rated below the optimum operating temperature can help transmission line owners develop re-rating programs that can quickly return a transmission line to its original operating temperature or even increase its safe operating temperature allowing for a greater current carrying capacity. The trick is to know what you have in the field so proper solutions can be derived.

F. Dangers of not knowing

Ignorance is no longer an acceptable argument in the court of Law. Harsh penalties against utilities for non-compliance of code have been increasing in numbers over recent years. [4] Governing bodies such as North American Reliability Corporation (NERC) and the [5] Federal Energy Regulatory Commission (FERC) have been given the power to investigate and enforce possible compliance issues. If transmission line owners are found to be at fault in an electrical accident, be it public or private the liabilities attached can be overwhelming.

G. Tying it together

Combining the evolving ROW usage, possible design or construction deficiencies together with new harsh penalties for non compliance transmission line utilities and owners are now forced to conduct asset management studies to develop short and long term maintenance and forecasting programs. This all starts with knowing what exactly you have out in the field.

III. Transmission line Industry Needs

As mentioned in previous paragraphs many transmission line owners are finding themselves needing to study the feasibility of upgrade opportunities on their existing plant. They are also busily assembling up-to-date inventory of their lines for GIS and maintenance programs. Neither of these monumental tasks can be completed as accurately or effectively without the use of accurate digital airborne LiDAR data and orthorectified imagery.

The data and imagery are combined with various modeling software’s that allow for complete line verification and analysis. This provides an effective manner of determining the exact maximum thermal operating limits of a transmission line with respect to minimum ground clearances. Knowing this information allows for efficient cost effective upgrade solutions with minimal social and environmental impact.

The electrical industries requirement takes us directly into the discussion of the benefits of LiDAR and its vast applications. How to manage the seemingly overwhelming data file sizes and produce beneficial information by using the data to reproduce a snap shot in time of a transmission line. How this snap shot can be useful and what kinds of information can be derived from it.

A. What is LiDAR

Before discussing the benefits of this technology, a definition and simple description may ease the understanding and applicability of this technology as it pertains to the transmission line industry. [6] In basic terms, a pulsating laser is directed out of the airborne platform (helicopter) by a multifaceted rotating mirror. When an aerial or earth feature intercepts the laser pulse, energy it is reflected back to the helicopter. Laser pulses reflect off of any solid object below the helicopter such as trees, bare earth, transmission lines and towers, railway beds, roadways, vehicles, buildings etc. The time interval between the laser pulse leaving the sensor and the return of the terrain-reflected-pulse back to the sensor is measured precisely.

In post-flight data processing, the LiDAR time interval measurements are converted to distance and subsequently referenced to the helicopter's Global Positioning Systems (GPS), Inertial Measurement Unit (IMU), and ground based-reference GPS stations. The GPS data is used to accurately determine the helicopter's 3-D position in terms of longitude, latitude, and altitude. The IMU measures the airborne platform pitch, roll and yaw. This data is used to calculate the laser beam exit geometry. By combining the LiDAR, GPS, and IMU data, very accurate 3-dimensional digital terrain model (DTM) of the ground below the airborne platform can be developed.

The DTM combined with laser hits from towers and wires can be incorporated in a software package to develop dynamic 3-dimensional "asbuilt" transmission line models. These models are very beneficial in conducting a wide range of engineering studies and analyses.

IV. Benefits of LiDAR to produce a 3-Dimensional model of your transmission line

Point data used to model the transmission line terrain and conductor sag & tension is gathered by utilizing an aerial LiDAR survey. Millions of points captured on the transmission line and any visible objects (including vegetation layers) within the right of way are post processed into relevant feature code numbers, assigned clearances and modeled in PLS-CADD a line design software from Power Line Systems.

The advantage of employing LiDAR technology is that a "snap-shot" in time of the transmission line geometry is collected very quickly before loading and weather conditions change the conductor sag and tension enough to affect the results .

This quick method of data collections simulates a steady state system in which changes occur slow enough as not to affect the outcome of time dependant calculations. This steady state analysis simplifies conductor temperature and sag and tension calculations.

The steady state of the transmission line and more precisely the conductor cable can be accurately modeled by matching the LiDAR points which represent the actual catenary shape of the wire during the time of survey seen in Fig. 1.

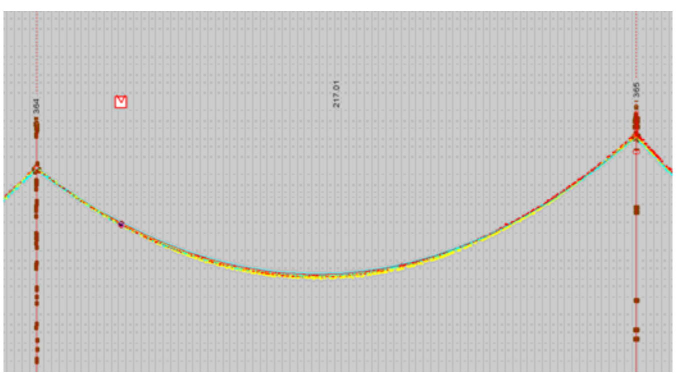

Fig. 1. Conductor cable matching LiDAR points

Along with the recorded electrical loading, meteorological, hardware and conductor data, the transmission lines can be modeled with high accuracy with a software package such as PLS-CADD. The PLS-CADD models are recreations of the survey "snap-shots" of the project transmission lines during the time of survey.

A wide range of future engineering studies and analyses can be performed by using these models. The goal of the analyses is to determine the as-built condition and explore the potential thermal rating issues, if any, of the project transmission lines.

Important features of the model include the ground surface model, structure location, cable location and potential ground and or aerial obstacles. A TIN model or Triangulated Irregular Network is a surface made up of triangles having the terrain points at its apexes. The primary advantage of a TIN model is that it is a surface and not a collection of points. A TIN model rendered with the DTM ground key (digital terrain model) points and other points connected to the ground are attached into the project. The TIN model is useful for graphical interpretation of the transmission line and for ground clearance reporting in the software. This surface can be used to generate accurate center line and side profiles, to find the elevations of arbitrary points or to locate points at the intersection of structure bases with the ground. It is also used to create points in any location whether or not the elevation value is known. The TIN model allows checking to a surface area instead ground survey point data. Thus the quality and quantity of the DTM data is important.

The collection of ground points can quickly and easily overwhelm the capabilities of analysis software to produce a TIN model. Proper filtering of this data is critical to maintain an accurate and manageable data set which will produce a TIN surface area that produces beneficial results. An accurate TIN model will display potential ROW changes which can cause potentially dangerous situations. Changes to the ROW such as new road crossings as seen in Fig. 2, can present hazardous conditions if not designed properly.

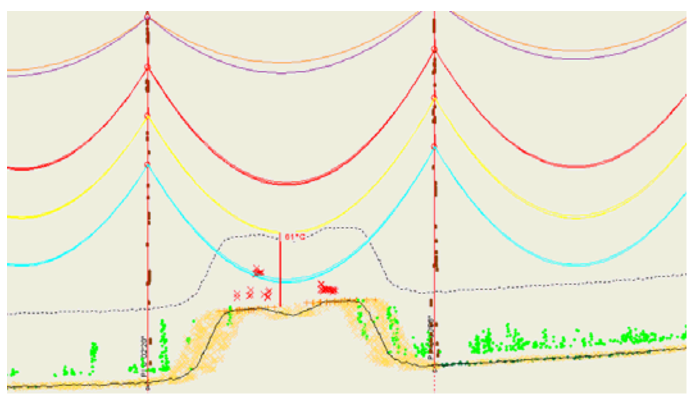

Fig. 2. ROW changes (new road crossing)

V. Applications of a 3-Dimensional model

The objective of the analysis is to determine the thermal rating of the transmission line and identify encroaching objects to the phase conductors including overgrown vegetation contained within the limits of the transmission line right of way.

A. Finite Element applications

Conductor operating temperatures and weather events as specified in national and local standards are checked to the right of way, for any detectable encroaching objects, and vegetation in each span. PLS-CADD can be initialized with any combination of wind and temperature for use in special studies.

The Finite Element (FE) feature for matching individual cables inside the model to actual LiDAR points allows for a comprehensive analysis of the entire line. Historically cable sags are derived using Ruling Span calculations; unfortunately this does not provide an actual representation of the entire line span for span, phase for phase. By separating and classifying individual LiDAR phase hits of each transmission line dead-end section it allows the software to perform multiple span sag and tension calculations which match closely the catenary shape of the conductor at the time of survey for each and every span.

This analysis method produces a much clearer understanding of the potential problem areas when clearance and thermal rating reports are generated. Instead of de-rating an entire line, specific spans and or phases can be focused on to return a transmission line to its desired operating temperature.

B. Structural analysis with asbuilt line specific loading

Having the individual cables inside the model that closely match the LiDAR data using FE produces an as-built line loading table which delivers a more comprehensive structural analysis. Ruling span calculations do not produce asbuilt phase specific loading which are critical for accurate structural analysis. It is especially important to use Finite Element cable sagging in locations where the terrain is hilly or has short and long spans within the same dead end section. Without the actual asbuilt conductor loading, incorrect sag and tension properties can be applied to individual structures which translates into inaccurate structural analysis of the existing transmission line.

C. Vegetation survey and management programs

Clearance to vegetation analysis is performed quite easily using classified LiDAR data. Various options exist to perform this function; generally the number of data points dictates which method of analysis is chosen. The LiDAR collection technology has become such that the number of vegetation points much like ground points can quickly overwhelm the software memory capacity. An easy solution exist to lesson the vegetation report generation times and prevent memory allocation errors. PLSCADD has a point filter imbedded in the software which allows for filtering of points to varying criterion.

While performing vegetation studies it is beneficial to use varying degrees of wind intensity to ensure the conductor clearance to vegetation is analyzed at its resting position as well as during blow out condition. An example of the varying degrees of wind intensity as it relates to conductor blowout is shown in Fig. 3.

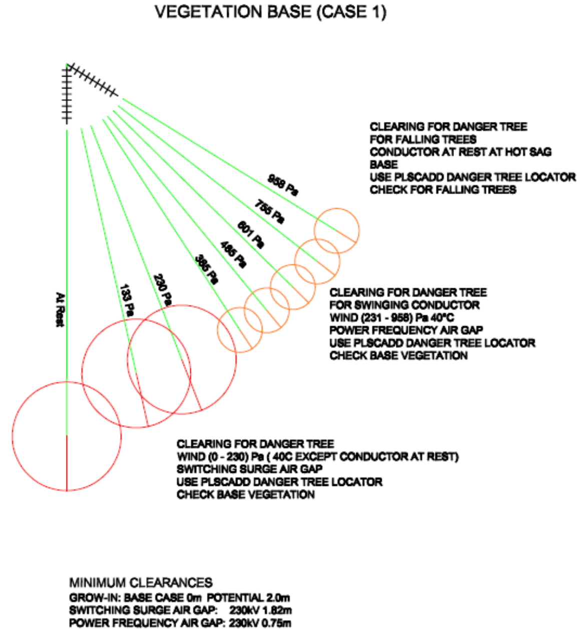

Fig. 3. Conductor blowout in relation to wind intensity.

A potential growth simulation can also be performed by increasing the required clearance from cable to vegetation point with a forecasted growth rate for various tree species. The simulated growth rate can be viewed in Fig. 4, It is also useful to use the falling tree option inside PLSCADD, this option checks the to see if the arc distance created by a falling tree (data point) will encroach the required absolute clearances set out in the feature code table.

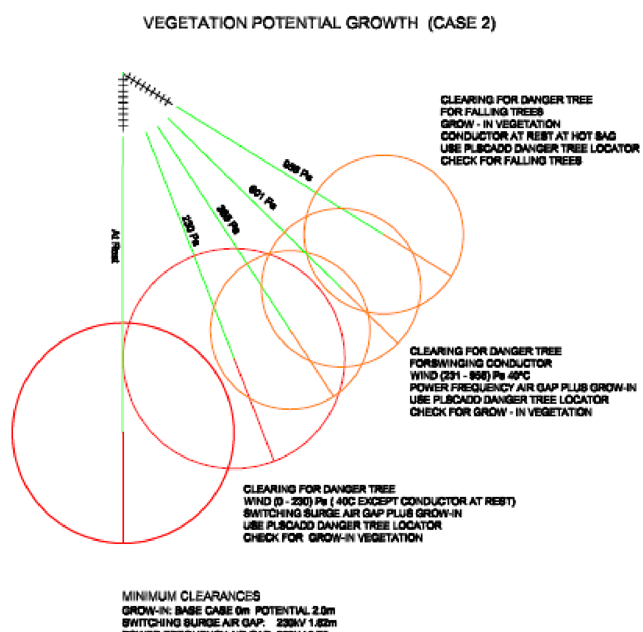

Fig. 4. Vegetation potential growth simulation.

VI. Importance of Criterion and Engineering Assumptions

As in every engineering problem the complete solution may not be known upfront but as you start to pick away at the pieces you gain a better understanding of how the entire solution should turn out. The same goes for 3-Dimensional modeling which of course is just a tool used in the bigger picture of creating a solution to the problem. For most reactions there are predictable equal and opposite reactions. The key is predictable reactions. When data and criteria are input into an analysis tool such as PLSCADD, the output results should never be a complete surprise to the user. In saying this if you want accurate results from you analysis tool you need to input accurate and relevant criterion.

If we acknowledge the idea that our LiDAR data is accurate, the next important inputs for the model would include but not be limited to the clearance and loading criteria, the conductor base temperature calculation and the offset distances used during the analysis.

At first glance clearance and loading criteria seem to be the most critical inputs into the model and of course they do directly affect the results of clearance reports, thermal ratings and sag and tension reports. Most times these values are easily obtained from local or national standards and are calculated and input correctly.

The analysis results in the various engineering reports are based on these inputs but it is the next few inputs this paper will discuss that can alter analysis results in such a fashion that an inexperienced user may not fully understand and or appreciate. Without a proper understanding of the affects of changing certain input such as offset clearances and conductor base temperatures there is potential for confusing and erroneous output from the model which can lead to costly and potentially dangerous situations.

A. The importance of setting a proper off set clearance distance

When a transmission line model is created in software such as PLSCADD, there are certain parameters the user is expected to input to define the analysis requirements as to obtain useful and beneficial results. To aid in this task the user defined parameters such as “Maximum Offset for Survey Points and Tin Model” have typical values pre-defined. The danger in not understanding how these values affect the output can lead to trouble. The maximum offset clearance value refers to the distance on either side of each wire the model will check for clearance violations.

The example in Fig. 5, shows a transmission line with 8m phase spacing. If PLS-CADD is set to only analyze points 1 m to the left and right of the conductor, a total of 6 m between phases is left unchecked. A high point or obstruction under the line could create a clearance violation but would not be flagged under this scenario. Conversely if PLS-CADD is set to check 6m to the left and right of the conductor and there is a large side slope which starts at 13.5m from the center line than there may be a clearance violations reported which in most scenarios could be ignored.

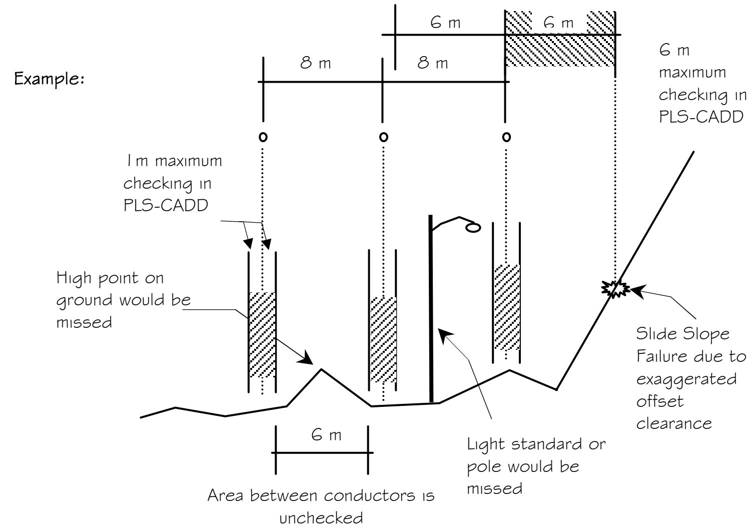

Fig. 5. Offset clearance example.

The ideal situation for checking wire to ground and aerial obstacles would include an offset distance which covers the entire area between phases and does not extend too far past the outside phases as to unfairly penalize the rating. Depending on terrain conditions this can sometimes be achieved with one report but in many cases this must be performed with separate reports; one report covering the area between outside phases and one checking the zones from the outside phases to a distance deemed adequate towards the edge of the right of way.

Another important offset distance to watch for can be found in the user input parameters of the “Survey Point Clearances Report”. Again this report has default values pre set but these values are not always the best choice for each analysis situation. Always ensure the project profile terrain widths are set to a distance that will at minimum encompass the horizontal distance from wire chosen to analyze in the Survey Clearance report. Always ensure the terrain width for the entire project is set wide enough to encompass larger ROW sections due to line angles.

B. Base temperature calculation

Calculations of conductor temperatures at the time of the LiDAR survey are performed using the meteorological and electrical loading data as per; [7] IEEE 738-93 “Standard for Calculating the Current-Temperature of Bare Overhead Conductors”.

The weather assumed to be acting on the transmission lines during the time of survey is the average of the weather values only for the time that the survey equipment is being flown above the transmission lines. Since the total time the LiDAR unit has spent over the line is very short, any changing weather conditions will not affect results measurably.

The conductor temperature is calculated assuming the average wind speed, ambient temperature, wind direction relative to the line orientation and the electrical loading. All of these inputs are critical to performing an accurate base temperature calculation. Fig. 6, depicts the change in temperature calculation when one variable (amperage) is changed. The parameters for the temperature calculation are as outlined below, the figure shows an increase of approximately 34 degrees Celsius when the line loading is increased from 0 to 600 amps. All other variables are held constant in the example.

IEEE Std. 738-1993 method of calculation PLS-CADD Output

- Air temperature is 0.00 (deg C)
- Wind speed is 0.61 (m/s)
- Angle between wind and conductor is 90 (deg)
- Conductor elevation above sea level is 20 (m)
- Conductor bearing is 90 (deg)
- Sun time is 11 hours (solar altitude is 75 deg. and solar azimuth is 112 deg.)
- Conductor latitude is 30.0 (deg)
- Atmosphere is CLEAR
- Day of year is 172 (June 21) (day of the year with most solar heating)
- Conductor description: 556.5 kcmil 26/7 Strands DOVE ACSR
- Emissivity is 0.5 and solar absorptivity is 0.5
- Solar heat input is 11.751 (Watt/m)
- Radiation cooling is 7.045 (Watt/m)
- Convective cooling is 43.056 (Watt/m)

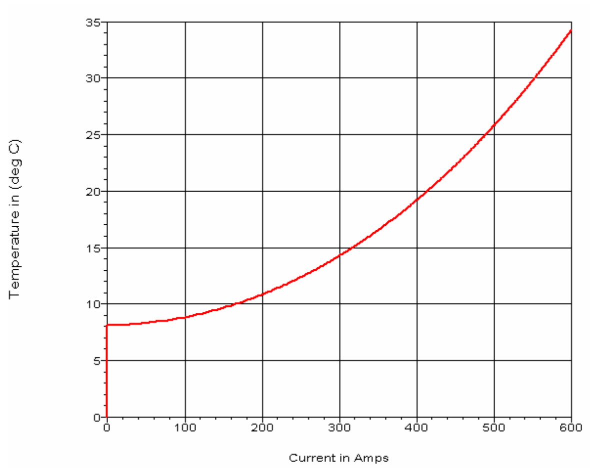

Fig. 6. Conductor temperature vs. current diagram from PLS-CADD software

Fig. 6, displays a considerably large range in conductor temperature due to changing a single variable, the calculation is based on more than 15 variables. The overall thermal rating of the line is based on this temperature. A range of 34 degrees in this simple example is not an acceptable error tolerance thus the importance of proper input is critical for accurate results.

C. Understanding the output

Once the model is complete and you are positive the data is accurate, there are many different engineering analysis tools within the software to locate potential problems in regards to clearance, sag and tension and structural analysis. These reports can be very beneficial but in some cases quite confusing to interpret.

As mentioned during the offset clearance discussion earlier on in the paper the results produced in the thermal rating and survey point clearance reports are based on user inputs; such as offset widths, temperature, loading criteria and clearance requirements.

The various reports found in PLSCADD do not all use the same criteria as each other or do they conduct the analysis in the same fashion or even to the same parameters. This does not mean that the results are wrong they are just specific to a certain application.

An example would be comparing the “Survey Point Clearance” report to the “Thermal Rating” report. Intuition would tell you that if temperature and off set distance parameters of both studies are set equal, violations should be reported at the same location in each span. This is not the case, due to varying parameters in each of the reports.

The Thermal Rating report checks to the TIN model, where the Survey Point Clearances report does not. This allows for varying clearance violation locations due to terrain inconsistencies and small holes in the data along the line.

Another difference is that the Thermal Rating report does not consider loading conditions such as wind and ice where the Survey Point report does. To gain an overall better understanding of the line dynamics both reports should be run and interpreted along side each other.

The varying reports do not all depict clearance violations in the same fashion, some display the violation distance as an excess clearance, which means how much extra clearance you have over and above the required clearance. Other reports display the actual violating distance in horizontal, vertical and absolute measurements. The user needs to be wary of which report produce’s which result and interpret them correctly.

The thermal rating report displays the violation location as “Critical Station” which relates to the lowest thermal rating along the line, positive or negative. The “Critical offset” violation location is reported as the positive or negative offset from the offending phase wire. The user must remember that in the first section of the thermal report only the worst violation in the span is reported. There can be many locations within a span where the clearance requirements are violated; the user must dig deeper into the report to view all the span violations.

In situations where there are many side slope violations the Thermal Report may report the violations at the offset distance set by the user as discussed earlier in the paper. This can be misleading because there can be larger violations outside the bounded area which go unchecked but may require further examination.

VII. Benefits of a 3-Dimensional Model

Having a dynamic 3-Dimensional model of your transmission line can prove to be a safety, time and cost saving benefit. The model allows for a multifaceted analysis options where problems and solutions can be discovered and remedied in a quick and efficient manner. Examples of situations discovered using the LiDAR data in conjunction with a transmission Line software such as PLS-CADD are best describe with images.

Images of grain silos (storage bins) located on a farm in western Canada with a 138 KV transmission line directly overhead. The profile view of Fig. 7, displays the LiDAR points at the time of survey; note the red colored phase hits are approximately 1.5m above the top of the Silo. The solid colored lines represent the conductor at 100 degree Celsius; note the red phase wire at 100°C combined with a slight side wind would make contact with the Silo. This situation was remedied before any accidents occurred.

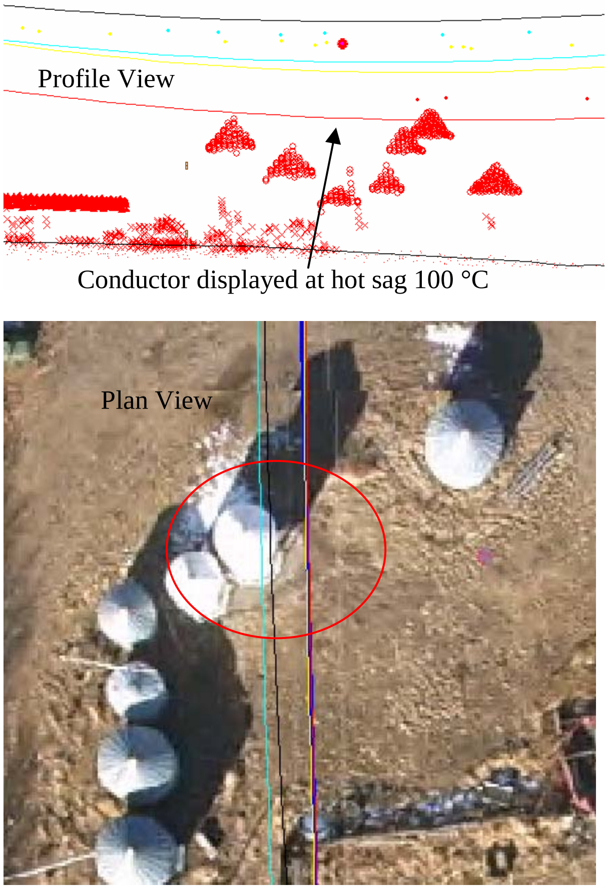

Fig. 7. 138 KV transmission line encroachments to silos.

Many other analysis examples can be discovered during routine analysis of a 3-dimensional model based on accurate LiDAR data. Vegetation encroachments either in blowout or grow-in conditions as displayed in Fig. 8, are used to prepare management programs to ensure compliance with the new NERC regulations regarding reliability and safety.

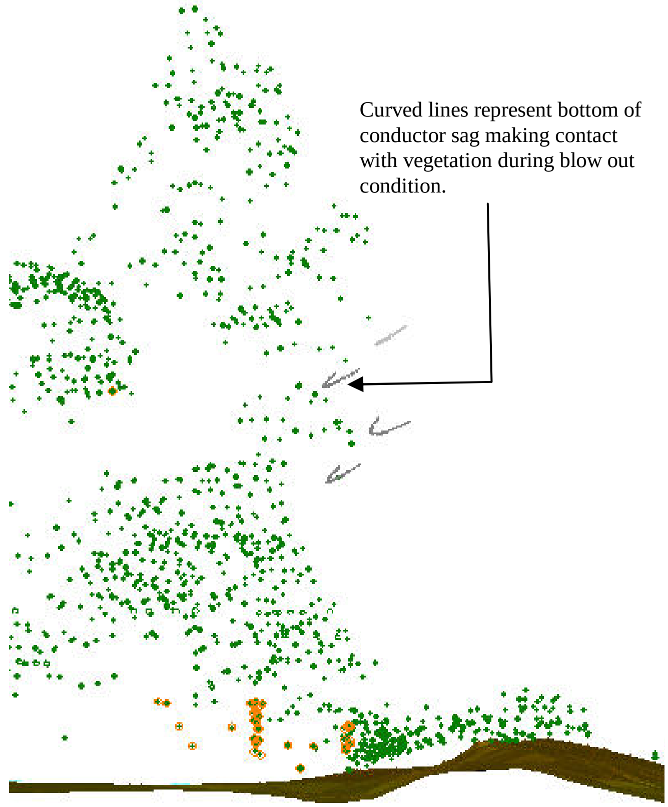

Fig. 8. Cross sectional view of vegetation encroachments to Transmission line.

As previously mentioned in the structural analysis section the benefit of using as-built line loading derived from the finite element cable sagging provides a more comprehensive structural analysis tool. Overloaded structures such as this tight running angle shown in Fig. 9, can be identified easily. By improving the failing components, solutions to the dangerously overloaded structure can be derived. The components shown in red represent greater than 100% usage of allowable design strengths.

Cost effective solutions can generally be determined prior to catastrophic failures which can lead to large outages and costly repairs.

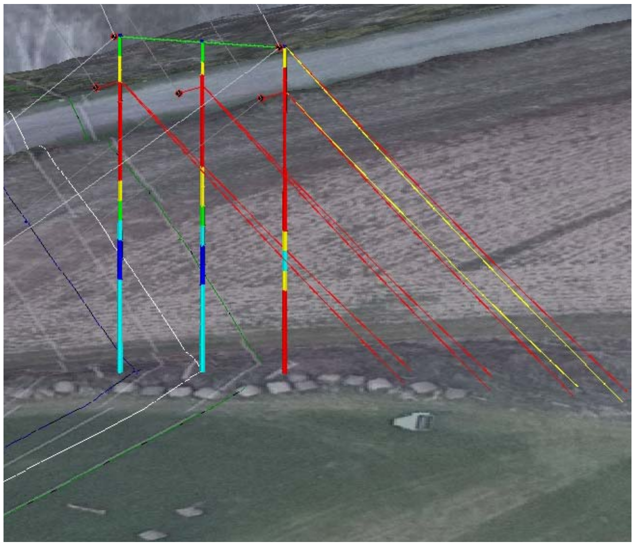

Fig. 9. Structural analysis display of overloaded components.

VIII. Upgrading methods and Solutions

Utilities are quickly accepting the idea that it is generally more cost and time effective to upgrade existing transmission line facilities than build new. This idea lends itself very well to LiDAR technology.

Historically utilities have designed transmission lines to predetermined capacities. The actual asbuilt capacity was never questioned until power demand rose and a larger capacity was required. At this time an upgrade scenario was developed and implemented over the entire transmission line, regardless of the actual existing rating. Granted most transmission lines have some problem spans but due to the conservative nature in which older lines were designed however, there are many situations were portions of a line exceed the original design capacity. These situations need to be taken advantage of and the only way to do so is to have completed a thermal rating of the “asbuilt” existing line prior to commencing an upgrade scenario.

Due to the software’s flexibility it is easy to determine which sections of the line meet the required capacity and which do not. This allows the designer to develop upgrade scenarios based on actual conditions. Many large capacity upgrades have been completed by modifying a small number of site specific structures to gain ground clearance and allow for higher operating temperatures which translates into greater capacity.

Other upgrade scenarios include conductor change outs which can easily be done inside the software. Having the asbuilt line configuration allows the designer to quickly check ground and aerial clearance requirements as well as complete a comprehensive structural analysis ensuring the new conductor does not overload the existing structures.

An upgrade solution called re-engineering is becoming increasingly popular. Re-Engineering is when the original design criteria are analyzed and it is determined if certain criteria can be altered safely to allow for greater capacity. Examples of re-engineering include increasing the average wind velocity the line should experience on a daily basis. By increasing the assumed wind, a line will experience more convective cooling of the conductor thus more loading can be applied to the line.

These types of assumption changes should only be applied to a thermally checked transmission line with trusted software. Unless this thermal rating is completed using asbuilt conditions which are easily determined using accurate LiDAR survey data, one cannot assume that the line is operating in a safe manner at its existing condition. Once the overall rating of the existing line is determined then small operating assumptions can be altered using sound engineering judgment. By changing small operating assumptions such as wind or ice loading criterion, utilities can gain considerable capacity increases with little capital expenditure.

IX. Why LiDAR INTEGRATED with Transmission line software

The integration of technologies such as LiDAR and 3-Dimensional computer analysis has proven to be an effective way to complete comprehensive asset evaluations. LiDAR surveys can be conducted in a fraction of the time of a conventional survey. The data gathered is considerably more comprehensive which allows the user to create dynamic 3-dimensional computer models of existing transmission lines to conduct thermal analysis studies. These studies form an integral part of a complete asset management program. Without the knowledge of actual as-built conditions of each transmission line, utilities cannot efficiently forecast potential safety concerns and capacity problems.

The ongoing revisions of the computer models with regards to field or engineering modifications allows for an accurate cataloging system of assets. This electronic cataloging system can be accessed quickly to aid in the development of programs such as vegetation and ROW management. With a proper understanding of the software, the computer models can be used to answer engineering concerns pertaining to new ROW issues such as road access, new distribution or communication cables as well as clearance requirements to public and or private infrastructure.

Proper interpretation of the results derived from the multitude of analysis reports than can be generated in PLS-CADD is critical to ensuring the overall maximum benefits of combining LiDAR with a 3-dimensional software is achieved.

X. Acknowledgment

The author gratefully acknowledges the contributions of: Eric Peyrot, PLS-CADD Power Line Systems, Tony Tubman, Art Silver, LiDAR Services International, Jason Wowryk, Gerald Proteau, James Koop, Ralph Will, Anita Altinis, W.I.R.E Services/Manitoba Hydro, in preparation of this document.

All document Images were obtained using orthorectified imagery supplied by WIRE Services and LSI and displayed in PLS-CADD.

XI. References

[1] Jan P. Reynders, Raymond Lings, Rober G. Sephen, Lori A. Nielson, Andrew C. Ludwig. EPRI AC Transmission Line Reference Book -200 kV and Above, Third Edition. EPRI, Palo Alto, California, 2005, p. 1-3.

[2] Jan P. Reynders, Raymond Lings, Rober G. Sephen, Lori A. Nielson, Andrew C. Ludwig. EPRI AC Transmission Line Reference Book -200 kV and Above, Third Edition. EPRI, Palo Alto, California, 2005, p. 1-5

[3] Compliance Monitoring and Enforcement Program [Online} National American Electric Reliability Corporation http://www.nerc.com/

[4] National American Electric Reliability Corporation, Compliance Monitoring and Enforcement Program Standard FAC-003-1 Transmission Vegetation Management Program April 7, 2006 [Online] http://www.nerc.com/

[5] Western Electricity Coordinating Council, WECC, Reliability Standards, PRC-STD-005-1- Transmission Maintenance, *Proposed*, http://www.ferc.gov/industries/electric/indus-act/reliability/cip.asp

[6] T. Tubman P.Eng**.,** - *President and Managing Director LiDAR Services International, LSI* "A note on what is LiDAR," tony.tubman@lidarservices.ca

[7] *IEEE Standard for Calculating Current-Temperature Relationship of Bare overhead Conductors*, IEEE Standard 738-1993, June. 1993.

XII. Biographies

L. J. (Luke) Chaput is the Technical Marketing Engineer (EIT) of WIRE Services, an initiative of Manitoba Hydro in Winnipeg Canada. Mr. Chaput graduated from the University of Manitoba in 2005 with a Bachelor of Science Degree in Civil Engineering. He is a registered engineer in training with the Association of Professional Engineers and Geoscientist (APEGM).

His employment experience includes PowerLine Journeyman's certification (1993) as well as his engineering degree (2005). He has over 17 years experience in the construction and design of transmission and distribution lines. He has been responsible for the coordination of large construction projects involving both the engineering and construction aspects. His interest in LiDAR and transmission line design began in June of 2004 when he spent the summer working with the Transmission line Studies department of Manitoba Hydro. He has been working solely for WIRE Services since May of 2007.