Overhead line analysis and measurement with a smartphone or tablet

By C Rathbone, Linesmarts Ltd

Many of the design resources which are taken for granted in the transmission industry are unavailable, cost prohibitive or impractical for use on distribution lines. For many distribution utilities the feasibility of generally adopting a detailed approach to design will hinge on the availability of practical alternatives.

LineSmarts is an app for Android smartphones and tablets that enables remote field analysis and measurement of overhead power lines and structures. It takes advantage of the emerging ubiquity of smart device technology to deliver a tool for overhead line assessment, which can be accessible to anyone. LineSmarts supports the following direct measurements for overhead line assets:

- Span length
- Conductor tension, catenary constant and attachment loads
- Conductor sag
- Pole lean
- Structure horizontal and vertical dimensions (including pole height, pole diameter, hardware and equipment dimensions)

LineSmarts also supports a range of analyses based on user defined load case scenarios. The app is able to report individual load case and maximum summary results for:

- Conductor tension, catenary constant and attachment loads
- Conductor utilisation
- Conductor sag
- Conductor blow-out

Process

The LineSmarts measurement process works by firstly capturing a photo of the overhead line being assessed and then asking the user to enter distance information for the power line supports contained in the image. From that point the user can immediately process the results or move on to another measurement and process the results later.

The photograph and the distance inputs are combined with information from device sensors to understand how to scale measurements from the image. Users identify defining points on the image through the device touch screen interface to perform the measurements. For example, to measure pole lean or height, points are selected at the top and bottom of the pole. From this information the measurement and analysis results are automatically processed and displayed. The development of LineSmarts pioneers a brand new method of overhead line measurement. This method has been made possible through the advent of the modern smart device and the systems that have evolved in support. LineSmarts relies on the processing capability, high definition touch display, GPS, accelerometers, gyroscopes, compass, internet connection and the camera all being integrated into the one device.

Smart device

By using a smart device as its platform, LineSmarts is able to take advantage of the innate strengths of these devices. Measurements made by LineSmarts are recorded digitally and so can be readily copied and communicated using the various available electronic communication channels. The ability to digitally communicate results generally facilitates potential improvements to efficiency and information integrity. Ultimately it provides an opportunity to directly export results to corporate systems and databases. Other advantages of the smart device platform mean that LineSmarts can be easily accessible to a broad range of users. Smart devices are made to be affordable, richly featured, of good quality and user friendly for the highly competitive, volume driven, consumer market to which they are targeted. This is in stark contrast with tools specifically made for the electricity sector, which are relatively low volume, specialist and expensive.

For smart phones especially, the platform offers the advantage of always being to hand. The result is that measurements can be made where they otherwise would not be, or might require a repeat site visit to perform. Smart devices also offer software distribution advantages. Apps can be easily found, downloaded and automatically updated via the Google Play store. This means that tools hosted on smart phone devices can be continually improved, in many cases without any action being taken by the user.

Measurement and analysis

Utilising remotely captured images as a basis for measurement and analysis yields improvements to safety and efficiency, and potentially can reduce landowner disruption. The technique avoids operation at heights, operation in the vicinity of electrified wires, the operation of heavy equipment or proximity to or disturbance of mechanically loaded assets. In some cases the technique may be used as a substitute for methods which would otherwise require an outage to be taken. Typically measurements can be completed within minutes of arriving on site and in some cases will allow entry to private property to be avoided.

Immediacy

Results can be viewed immediately in the field without requirement for post-processing or additional analysis. Generally assessments can be made from a single image. This means that an image captured on LineSmarts can be returned to repeatedly for new measurements without having to revisit the site.

Calibration requirements

Like any measurement tool, LineSmarts is subject to calibration requirements and its level of accuracy and precision can change as a function of host device qualities, measurement type and the specific situation in which it is used. For some smart devices users may need to perform a one-time calibration before LineSmarts will return accurate results. Detailed information on calibration and factors that influence LineSmarts accuracy are provided on the LineSmarts website.

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Advantages

Many of LineSmarts' features provide significant advantages over equivalent conventional measurement techniques. However, the effect can be greater than the simple increase in efficiency, safety or convenience. These advantages can change the result of value judgements made to determine whether a measurement or analysis is worth the effort. For some organisations LineSmarts may reduce the effort required to perform a measurement or analysis, below the potential for derived benefit. This could therefore make it possible to justify increasing the rigour and quality of engineering practice.

For many distribution organisations, not measuring tension is an example of a pragmatic judgement to accept a reduced level of quality control or information rather than incur the cost of measurement. Especially at the lower voltages it can be common practice to install conductor without measuring tension, or only measuring tensions from the pulling end. Similarly in line design it is not uncommon for designers to assume installed tension based on estimates or historic records. The validity of any design or assessment is predicated on the accuracy of the information on which it is based. Therefore the cost of such assumptions can be the expensive and unnecessary replacement of structures, or non-conservative design outcomes. In the past, these risks have been offset by the significant cost and inconvenience of measuring overhead line tension.

If dramatic reductions are made to the cost and time required to capture tension measurements, it should lead to an increased practice of measuring tension. Assessment of how line tensions change is another area where opportunities offered by LineSmarts may facilitate an improvement in engineering practice. These assessments are performed to identify vulnerability of conductor systems to vibration, mechanical overloading and clearance encroachments. LineSmarts is able to use its conductor measurements as a basis from which to automatically assess tension under a set of user defined load cases. The resulting tensions are able to be automatically compared against vibration and mechanical load thresholds to report the utilisation percentage.

Likewise, calculation of site specific tensions under design load case scenarios enables assessment of conductor sag variation. Many utilities measure conductor ground clearances to ensure that their statutory ground clearance requirements are maintained, without having the means to determine the extent to which the conductor is likely to sag beyond its surveyed position. This means that utilities are at risk of not identifying clearance encroachments, applying inadequate treatments to low spans or, conservatively identifying spans as having encroachments when they do not. LineSmarts provides a viable method of determining site specific potential for sag change. Leaning poles indicate potential footing issues, and therefore risk, which tools like LineSmarts can be used to systematically monitor and manage. If pole verticality is measured, subsequent pole lean can be identified. Preferably the verticality should be assessed immediately after a pole has been installed. Routinely monitoring pole lean as part of a periodic condition assessment programme can assist with identifying lean, quantitatively tracking rate of lean or establishing whether poles have stabilised.

Conclusion

These are some examples of activities where LineSmarts has reduced the associated effort to an extent that organisations might reasonably consider increasing the level of engineering rigour they apply. These increases to engineering rigour may take the form of additional one-off measurements and analyses, through to the systematic incorporation of new or improved assessments into a general asset inspection programme.

Reference

[1] AS/NZS7000. 2010. Overhead line design. Detailed procedures.

Some background

The need for a tool like LineSmarts became apparent to its creators following the 2010 publication of AS/NZS7000 [1], the Australia and New Zealand Overhead line design standard. AS/NZS7000 [1] is a limit state standard that specifies a level of rigour for distribution design which, prior to its publication, had largely been reserved for transmission line design.

Many of the design resources which are taken for granted in the transmission industry, such as LIDAR, finite element

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modelling software, site specific soil investigations and skilled professional engineers are unavailable, cost prohibitive or otherwise impractical for use on distribution lines. It was realised that for AS/NZS7000 [1] to be fully implemented on distribution networks, practical alternatives would be required for:

- Line design (software)
- Line route survey
- Soil investigation
- Footing design
- Tension measurement
- Technical engineers

LineSmarts was conceived of in the first instance as a practical and efficient method to fill the tension measurement requirement. However it was quickly realised that it could be developed as a tool to assist with aspects of line design, line survey and technical engineering assessment. Perhaps the most significant gap exposed by the introduction of AS/NZS7000 was a general absence of engineering capacity in the distribution sector with which to implement the standard.

The big organisations originally required to build the electricity network in New Zealand had largely completed the task by the early 1970s. The installed networks remained relatively new and so a comparatively inactive period persisted in the industry for the next few decades. The consequence of this was that the large utility design offices that had once existed dwindled, in many cases to nothing. Utility internal design capability was cut to basic functionality and remaining structural engineering requirements were largely outsourced to consultants, who in many cases only serviced the industry on a part time basis. This is a pattern familiar to many countries.

When AS/NZS7000 [1] was introduced, the majority of New Zealand distribution designs were non-technical or developed in accordance with legacy design systems and standards. A large proportion of design work, especially at the lower voltages, was being undertaken by experienced, but non-technical staff, who did not have the skills, systems or equipment required to assimilate the new standard into their established design processes.

Non-technical design involves specification of design based on rules of thumb and the experience of the designers, who frequently have a field background. The advantage of this approach is that the designers are able to efficiently create practical designs.

By inspection, insufficient numbers of technical engineers are available within New Zealand's electricity industry to expand current detailed design activities to cover all distribution design activity. Nor would that necessarily be a good solution if it were an option. It would be relatively inefficient and risk losing the qualities that experience based designers bring to design. It was recognised that an alternative solution might be to develop tools that could be used by existing designers to complement their practical skills and demonstrate design compliance with AS/NZS7000. That alternative solution has been pursued, with various tools and systems being developed.

LineSmarts is one such tool. It allows non-technical operators to perform various measurements and certain engineering analyses. It takes calculations which were formerly the domain of engineers with expensive desktop computer modelling packages and allows them to be performed in the field with greater efficiency and accuracy. This empowers existing non-technical designers to apply rigour to technically complex assessments while relieving them of the need to become involved in the technical detail.

With further development the range of engineering assessments that can be performed using LineSmarts can be extended. One of the challenges, as increasingly sophisticated analyses are added to LineSmarts, is to keep the tool efficient, simple and accessible for non-technical users. Ultimately LineSmarts could be developed for non-technical designers to validate their structure and line designs. This would make it possible to have the consistency associated with design to a standard, without losing the efficiency and practical input of field based designers, while freeing up technical engineers to perform more complex tasks.

LineSmarts developers aspire to contribute a technology based solution to address the industry challenge of increasing engineering requirements of standards, at a time of constrained structural and mechanical engineering resource.

Carl Rathbone graduated from the University of Canterbury in 2002 with a degree in civil/structural engineering. He has worked in the electricity industry since, spending approximately equal amounts of time working in the UK, Australia and New Zealand, specialising in the design and asset management of Transmission and Distribution overhead lines. Carl is an active member of the Standards Australia/Standards New Zealand Committee EL-052. He is a Chartered Professional Civil/Structural Engineer and currently works for PowerNet Ltd as a Senior Lines and Structures Engineer. Carl recently co-founded LineSmarts Ltd to develop overhead line engineering software solutions.
Enquiries: Email carl@linesmarts.com