THE THOR HAMMER TESTER – A STEP CHANGE IN THE MANAGEMENT OF WOODEN UTILITY POLES

Ralph EYRE-WALKER
SP Energy Networks – UK
reyre-walker@spenergynetworks.com

Russell BRYANS
SP Energy Networks – UK
rbryans@spenergynetworks.co.uk

Dr Baraneedaran SRISKANTHARAJAH
Groundline Engineering - Australia
bara@groundlineengineering.com

Catherine DOW
SP Energy Networks - UK
catherine.dow@spenergynetworks.co.uk

ABSTRACT

With over two million wooden utility poles in use across the United Kingdom (UK), assessment and management of wood pole decay has been an issue for many years. Various techniques and approaches exist for this, but each has disadvantages, such as subjectivity in the results, or time implications associated with the test. At present, there is no suitable technique for obtaining an accurate consistent pole health assessment, including below ground assessment, with enough efficiency for mass-scale deployment across the UK networks.

Recently, SP Energy Networks has trialled a new, non-destructive seismic pole tester, "THOR". The device is considered to have great potential, combining an innovative use of technology with real practical application. This paper presents the outcome of the trials to date; considers the device's applicability to the UK networks; and outlines the proposed future development work to integrate the device as a Business as Usual inspection method for the UK industry.

INTRODUCTION

SP Energy Networks manage over 600,000 wooden electricity poles across our networks. Depending upon environmental conditions, a wood pole is expected to remain in service for approximately 55 years. Assessment of pole decay is one of the key parameters that we use to rate the health of the pole as per UK DNO common methodology; through which assets are targeted for replacement based on condition rather than age.

The traditional method for assessing pole condition is to use a simple hammer sounding test. During the hammer test, an experienced linesperson can identify from the sound resonating from the pole whether any internal decay is present and therefore make an assessment of condition. The key disadvantages with this approach are twofold. Firstly, the hammer test is subjective, and while an experienced linesperson can be relied upon, as with any subjective measurement there will be some variability in results, particularly with any borderline cases. This variability could be exasperated as workforce renewal accelerates. Secondly, a particular area of concern for pole decay is just below the ground line, so excavation is required for a full test, disturbing the foundation of the pole.

Various other techniques have been developed over the years in an attempt to overcome some of these problems, with varying degrees of success, the pros and cons of each are well known and include:

1. Mattson Bore or similar: provides an accurate output at point of test but is time consuming and can only assess small areas. Boring risks future pole decay as a result of the hole. It requires excavation for below ground level assessment.

2. Ultrasonic based methods: these can provide a reliable Residual Strength Value (RSV) output at point of test but are time consuming to perform, and have training and application issues. This method requires excavation for below ground level assessment.

3. Microdrill based methods: can provide a reliable RSV at point of test. Fairly time consuming but not excessive. Can provide limited assessment below ground level by drilling down at an angle.

It is clear from the use of these other techniques that there is a requirement for a test method that can reliably determine the extent of internal pole decay, by assessing the whole pole (including below ground level) efficiently and with good practical application.

As a solution, Groundline Engineering has developed a non-destructive seismic pole tester, "THOR". The device has the potential to realise a step change in the way wood pole networks are managed. The practical application of the device will make training and integration into Business as Usual a realistic prospect. The key objective is to remove the subjectivity from the condition assessments – THOR has the potential to be a robust, repeatable scientific condition indicator with minimal variability based on the operator, or other contributing factors such as the weather conditions at the time of test. Repeated tests on a pole over a number of years could then be trended to indicate the rate of deterioration.

Condition monitoring of wood poles is likely to become even more essential in the future as alternative methods of wood preservative to creosote are put into use that may not have the same lifespan as the existing poles. The subject of this paper is to present the initial trials of this device and highlight the potential value to the wider industry.

THOR HAMMER DEVELOPMENT

Over the last ten years in partnership with Industry and Academia, Groundline Engineering has developed the seismic pole tester THOR, capable of non-destructively evaluating the in-situ health of wood poles. To date, much of the development has been undertaken in Australia with the Swinburne University of Technology [1]. With millions of timber power poles sitting in the public domain across Australia, New Zealand, United Kingdom and rest of the world, this paper is set against a background of the many problems faced by utilities as they maintain aging poles under constant degradation modes including rot, decay and termites.

The concept of the device combines an existing testing methodology with new waveform analysis techniques. The existing technology utilised is Stress Wave Propagation (SWP) techniques. SWP is widely used in the Civil Engineering industry for the evaluation of concrete piles. Typically, the application of SWP in the piling industry is applied in what is the longitudinal direction to the pile, with both the hammer and geophone devices used on the top surface. In the Electricity Industry, the technique has previously been applied in the form of a Transient Dynamic Response test for assessing the condition of the concrete foundations of electricity tower structures [2].

However, applying the technique in the longitudinal direction is not practical for wooden utility poles, therefore the technique needed to be adapted for use with the transverse direction to the poles. Significant research was therefore undertaken to achieve this, including leading edge signal processing techniques, and the practical application to over 600 utility poles in Australia. During this study, a sample of the poles tested were then removed from the field and the results correlated with the decay examined through destructive investigation – with excellent correlation achieved [1].

At present, an on-site field indication is provided on the device, with further detailed analysis undertaken (if necessary and as selected by the operator) manually afterwards by review / assessment of the waveforms obtained. The manual assessment utilises both qualitative and quantitative assessments. Qualitative assessment includes a review of the pole hammer input trace and its velocity (output) response in the time domain. The quantitative assessment of the pole is undertaken using parameters directly obtained from the THOR unit, and once real engineering units are applied, then mechanical impedance parameters such as hammer force input, duration, mobility and dynamic stiffness can be compared against similar pole populations to identify poles requiring further attention or identifying that poles are indeed healthy and sit within a normal admittance range. Poles tested to date have enabled the building of a large database of poles and the establishment of health indices for the various parameters in determining if the pole is an "outlier" or outside of the norm. An example analysis report is provided in Figure 1.

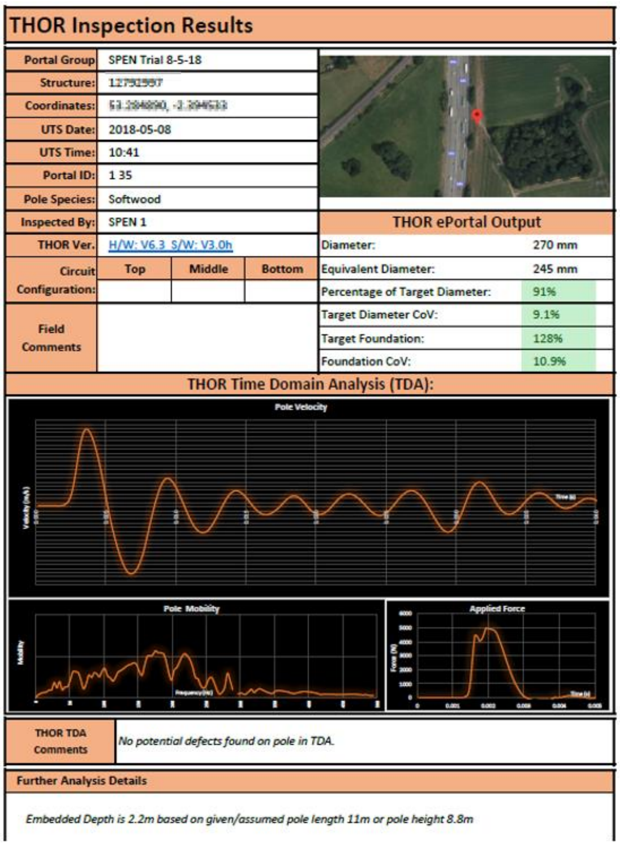

Figure 1: Example analysis report with waveforms visible.

Owing to the large amount of metrics, pole signature and various health scores a system to consistently collate the data was sought. A web portal was developed for this purpose. Encrypted files from the field unit are compressed and uploaded into the portal. The portal then decrypts the files, extracts the information required, tabulates and geocodes the results before presenting in a clear map and tabular format as shown in Figure 2.

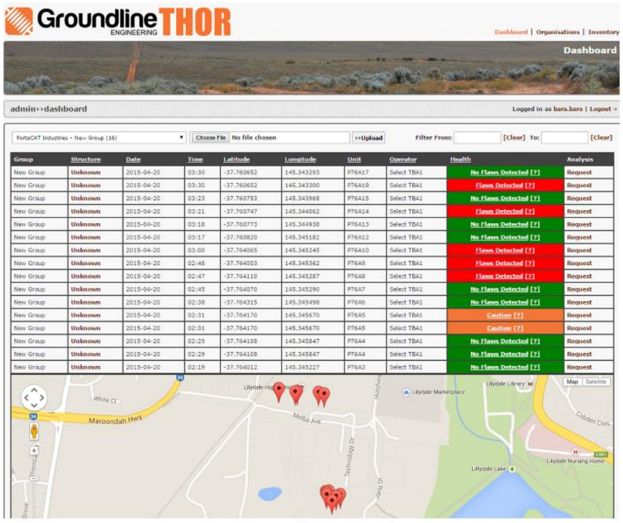

Figure 2: Screen shot of the THOR web portal

INITIAL DEMONSTRATION

An initial demonstration trial was first undertaken to demonstrate the device on SP Energy Network's southern network. Four poles were tested with the device, one of which was tested twice. A key issue identified at the outset was in how to make use of the results. The value output by the THOR instrument (percentage of equivalent diameter) is different to the industry recognised value of remaining Residual Strength Value (RSV). RSV is widely used to understand condition within existing asset management practices. Whilst there will be a general correlation between the two, the key additional factors considered by the RSV are:

1. As a wooden pole is cylindrical in shape, the greatest percentage of the pole's strength is in the outer 20% (approx.) of the pole thickness.
2. The reduction in cross-sectional area strength is then related to the reduction in bending strength [3].

It was recognised at this stage that the capability to reliably relate the THOR's output to a remaining RSV is preferred for the wider application across the UK electricity industry and should be considered during future developments. An approximate relationship between the two values was required in order for the initial trials to continue. By comparing THOR test results against an experienced linesperson's condition assessments for a limited sample set, initial thresholds were able to be assumed for this purpose. It should be noted that future work is still required to robustly map the RSV as a condition indicator into the UK DNO Common Network Asset Indicies Methodology (CNAIM), noting that this test is only one aspect of the condition assessment for a wood pole asset – this work will become worthwhile should a suitable method for obtaining a RSV on a wide scale basis across the network be identified.

Using the above thresholds, the comparison between the results obtained is illustrated in Figure 3. Good correlation between the Condition Based Assessment (CBA) Health Index (HI), obtained using existing testing methodologies, and the THOR HI was demonstrated, particularly with poles that were clearly HI5. In addition, tests 1 and 2 were both of the same pole and both resulted in a HI5, demonstrating consistency, albeit with a very limited sample set (note: a Health Index for a pole would normally be formed from several condition indicators, with HI1 being as new and HI5 approaching end of life. The CBA and THOR HI values within this paper consider only the internal pole condition indicator to ensure a like-for-like comparison).

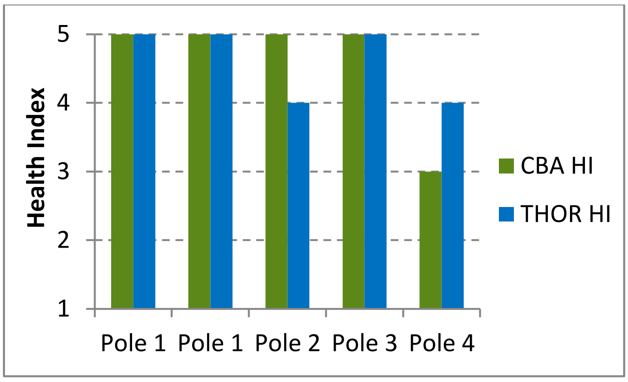

Figure 3: Comparison of HI values obtained during initial trial. Two measurements were carried out at Pole 1.

LARGER USAGE CASE TRIAL

Following the work outlined above the trial was extended to assess a further 43 pole across disparate locations. The main purposes of the extended trial were:

1. To determine over a larger sample set whether THOR has the potential to provide a practical, repeatable scientific test methodology while also producing results that are broadly in line with existing practice;
2. To assess the device's pole embedment depth measurement capability. On poles with a scarf mark present, if available the total pole length was noted. This provided a comparative reference for the measured embedment depth recorded by the THOR device.

The inspections were carried out while accompanied by a trained, experienced Condition Based Assessment (CBA) linesperson. As mentioned earlier, a full HI for a pole is made up of several different condition points, including external damage such as vertical splits, or pole top rot. THOR is not designed to identify these defects as it is a tool for detecting the extent of internal decay, and therefore a visual inspection would always be recommended as part of the patrol. Recognising this, the linesperson used their experience to report a HI score specifically from the hammer sounding test alone, to allow correlation with the THOR results post-analysis.

Two measurements resulted in errors in the waveforms, most likely due to the presence of an unusual metallic pole protection wrapping around the base of those particular poles – this issue will be explored in later trials. With these results removed, the comparison between the remaining 41 results is presented in Table 1.

	Agree	Disagree	Agreement %age
HI1 - 3	28	2	93%
HI4 - 5	7	4	64%
Total	35	6	85%

Table 1. Comparison between HI score obtained from hammer sounding test and THOR test

Overall, correlation was 85% between the two inspection methods. For healthy poles, correlation was very high with a 93% agreement. Closer analysis of the six that did not agree revealed the following:

- In two cases the THOR test detected potential anomalies (HI4) whereas the sounding test did not.
- Two results were very close to each other, with a HI4 reported by the linesperson and a HI3 reported by THOR.
- In two cases the sounding test detected potential anomalies (HI4 or HI5) whereas the THOR test did not.

It is debatable what conclusions can be drawn from the four poles for which only one detection method detected anomalies – without further investigation or destructive examination, it is not possible to determine which is the correct result in each case. However, it is clear that the overall correlation shows good promise at this stage.

The overall results comparison in Figure 4 illustrates that in general and using the existing thresholds, the THOR test identified more HI1-3 scores, and slightly less HI4 or HI5 scores. If the THOR results are shown to be the more precise at a later date, this indicates potential cost savings are possible using this technology, as replacement could potentially be delayed on poles with a reduced HI.

Comparison of pole length information, which will ultimately provide pole embedment depth by using the measured height of the pole above ground, also yielded positive results, as presented in Figure 5. In this case, it was only possible to compare results for the 30 poles for which the scarf mark was visible, and the pole length mark was legible. For these poles, 80% of the THOR measured results were within 1% (approximately 10cm) of the expected length taken from the scarf. Just one measurement was out by more than 5% (approximately 50cm).

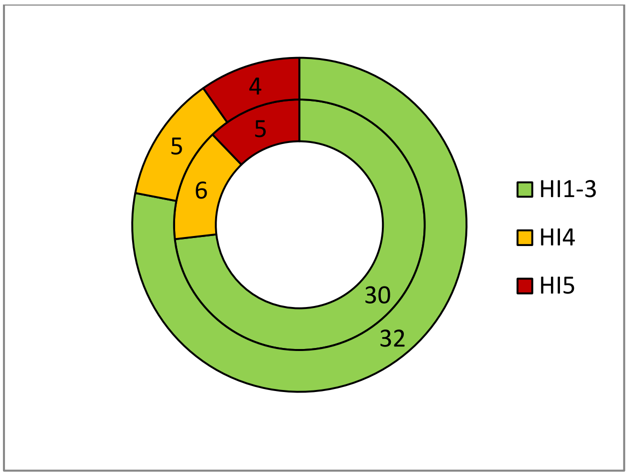

Figure 4: Comparison of total numbers of each condition rating obtained. Outer circle is THOR HI, inner circle is CBA HI.

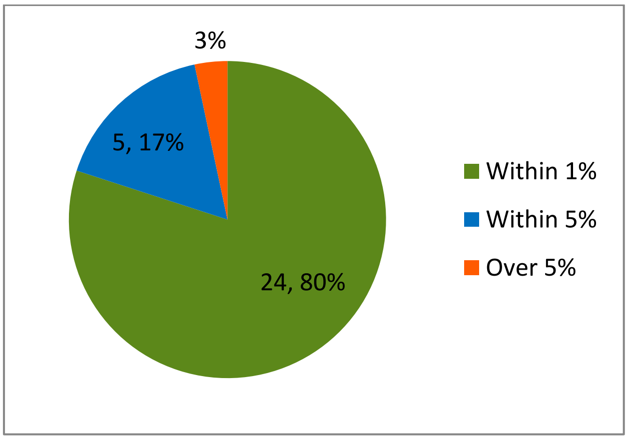

Figure 5: Comparison of THOR pole length measurements with scarf mark information.

FUTURE DEVELOPMENT PLANS

During the trials, it was demonstrated that a key value of this device is its simplicity of use. The test was significantly quicker to perform than Mattson Bore, Ultrasonic or Micro Drill tests; and in some cases it was quicker than a basic sounding test as THOR requires less vegetation clearance around the pole to complete the test satisfactorily.

In addition, the following outputs are possible:

1. Presence and extent of any internal decay, including below ground level without excavation
2. GPS-tagged measurement results provide

confirmation of measurement location for auditing purposes
3. Predicted life remaining for refurbishment investment planning
4. Measurement of pole embedment depth

Further development is required, and currently being planned, to automate the detailed pole waveform analysis – preferably on-site at the time of test. This could be achieved with a machine learning approach.

It is critical that the results are repeatable and can be relied upon. A method statement will need to be developed, suggesting a suitable number of tests required at each pole to achieve this reliability.

A further application is with the instrument's ability to assess the stiffness of the ground surrounding the pole foundation. This has value for post installation audits, to ensure that linesmen have sufficiently compacted the ground during the backfill process.

A cross-DNO development project, funded under the Network Innovation Allowance, is currently at the proposal stage and aims to achieve:

- Refine what is / is not acceptable in terms of residual strength and how measurements obtained can be mapped to CNAIM condition indicators
- Use the THOR device over a large, UK based sample set of poles to statistically derive confidence levels
- Develop the capability to provide the result data on the spot at the time of test
- Method statement for usage on UK electricity network

If the above objectives are achieved successfully, the quality of information that the THOR hammer will be capable of providing, combined with the practical and efficient application of the device, will enable deployment across UK electricity networks. This would result in the ability to obtain a reliable RSV, with minimal subjectivity, on a scale that has not previously been possible. This has significant benefits to an industry that is striving to improve data quality relating to network assets, and in particular would provide a highly consistent condition input for the Common Network Asset Indices Methodology (CNAIM), the framework recognised by the UK Regulator for the assessment, forecasting and regulatory reporting of asset risk.

CONCLUSIONS

At present, there is no suitable technique for obtaining an accurate pole health assessment, including below ground assessment, with enough efficiency for mass-scale deployment across the UK networks.

Initial demonstrations and small scale trials of a non-destructive seismic pole tester, THOR, have shown promise. This device uses Stress Wave Propagation (SWP) techniques to measure residual pole strength and embedment firmness and depth.

These early tests have shown the capability of the technology to provide consistent, repeatable tests broadly in-line with existing practices.

Further trials and developments are planned to prove and enhance the technology. A cross-DNO development project, funded under the Network Innovation Allowance, is currently at the proposal stage and aims to facilitate integration into business as usual.

Once fully proven, this technology promises to eliminate the industry reliance on the largely subjective nature of the traditional hammer sounding test, and will enable methods for industry wide common approaches to wood pole testing. This will facilitate development of more efficient asset replacement / refurbishment programmes, saving both money and resources.

Beyond these benefits, the THOR hammer device has been demonstrated to be at least as efficient to use as the traditional hammer sounding test. It provides additional valuable information including embedment firmness, accurate measurement of burial depth and GPS-tagged measurement results. The combination of all of these points together make the THOR hammer device a unique, and exciting, new solution to wood pole testing.

As the wood pole networks move into a period of increased uncertainty, with a ban on creosote treated poles on the horizon, pole decay management will become more complex and more pressing.

REFERENCES

[1] B. Sriskantharajah, 2016, *Timber Pole Integrity Testing*, PhD Thesis, Swinburne University of Technology, Australia.

[2] R Eyre-Walker, G Howarth, et al, 2014, "Application of Advanced Condition Assessment and Asset Management Techniques on Steel Tower Overhead Line Electricity Networks", 2014 IAM/IET Asset Management Conference.

[3] British Standard, "Wood poles for overhead power and telecommunication lines, Part 1", BS 1990 : Part 1 : 1984