STRATEGIC ASSET MANAGEMENT OF ELECTRICITY DISTRIBUTION LINES USING ADVANCED HELICOPTER INSPECTION TECHNIQUES

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ABSTRACT

A technique developed by EA Technology for inspecting electricity distribution towers using helicopters and high resolution photography to replace conventional climbing inspections is described. A case study showing the benefits achieved following implementation within CE Electric UK, a UK Distribution Network Operator, is presented.

INTRODUCTION

Electricity Distribution Network Operators (DNOs) are required to inspect, maintain and manage large numbers of geographically dispersed overhead line assets, such as steel towers. Whilst this is essential in order to meet safety, statutory, operational and regulatory requirements, it places a significant burden upon the network operator in terms of resources and cost. In addition, in order to maximize the value of any inspection regime, it should aim to gather as much useful information on the condition of the assets being inspected as possible, rather than just a list of defects. This means the information gathered can be used for strategic decision making and investment planning, instead of merely targeting essential maintenance work.

A previous paper was presented at CIRED 2005 [1] that described the development of a helicopter-based inspection system specifically designed for inspecting electricity distribution pylons or towers using high-resolution photography. It contrasted the new technique against traditional methods and showed how it could replace the need to climb towers in order to perform a detailed inspection. The new technique was faster, safer and less expensive than the traditional methods, as well as producing superior results.

Since CIRED 2005, the helicopter inspection technique has been successfully applied to over 4000 steel towers within 4 out of the 7 UK DNOs. This paper shows how the results of the new inspection method are used to meet the business needs of the DNO. It describes how the information gathered is collated and reported back to the DNO. A link is established between the tower's condition, probability of failure, remaining useful asset life, and the cost implications for refurbishment or deferral of maintenance work. This provides a powerful tool for strategic and investment planning within the DNO.

The paper includes a case study comprising in excess of 400 towers within CE Electric UK, a leading UK DNO that has worked together with EA Technology to successfully implement the system within their own company. It shows how the method has been applied to the refurbishment of 132kV steel tower overhead lines, the benefits that have been gained, and the subsequent changes made to operational policy in the light of the findings.

TOWER CONDITION ASSESSMENT

Figure 1 shows a block diagram of the entire inspection and condition assessment process. The detail of the process has been described previously [1] and will not therefore be repeated here. Instead this paper will concentrate on the outputs from the process and how they are used.

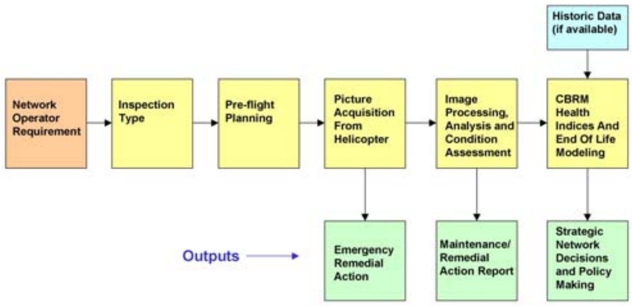


Figure 1. Block Diagram Of The Helicopter-based Inspection And Condition Assessment Process.

Figure 2 shows a typical example of the output from the condition assessment for an entire route that may comprise a few to several hundred towers along the line. In the spreadsheet matrix, each row represents an individual tower and each column represents a carefully chosen condition point that is significant to the tower's overall health. Each cell is colour coded depending upon the numerical Condition Rating (CR) awarded to the relevant component based on the detailed assessment made using the high-resolution photographs captured during the helicopter flight. By convention green represents components in sound condition, orange intermediate condition and red poor condition. Whilst it is not possible to reproduce the detailed contents of the spreadsheet here because of its size, the important feature to note is how the overall condition of the route can be very quickly assessed simply from a visual inspection of the colour pattern produced.

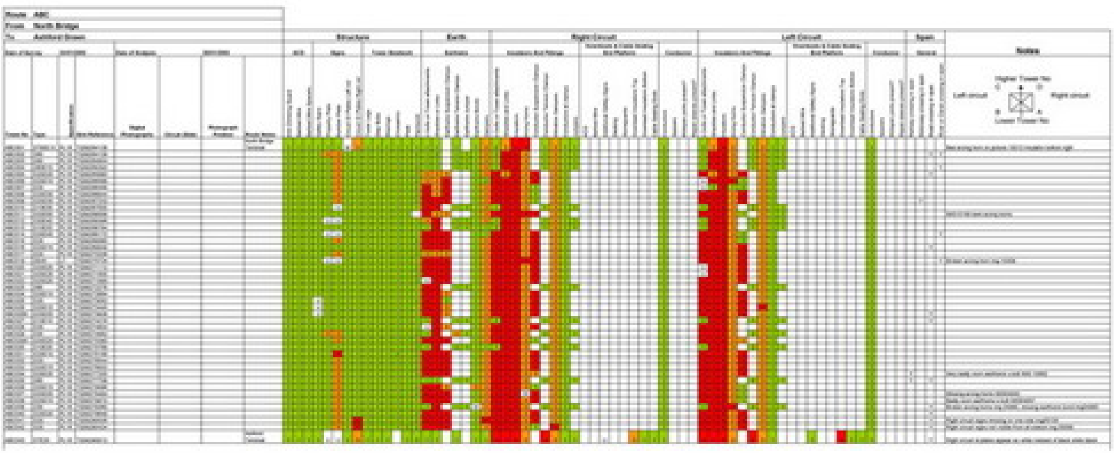


Figure 2. Example Output Format Showing Tower Route Condition Assessment Points

By examining the colour patterns, trends in failing components along the route stand out clearly. Comparisons between different routes can also readily be made by examining the condition assessment spreadsheets for individual routes side-by-side.

To enable the user to see why an individual component has been given a particular condition rating, the condition assessment results sheet contains hyperlinks to provide immediate access to the high-resolution photographs at the "click of a mouse". This allows engineers and asset managers to formulate maintenance strategies based on sound up-to-date condition information that they can readily double check if necessary before commencing work. In addition to the condition assessment spreadsheet, a written report is produced that distils out the key condition information about the inspected towers and makes recommendations for remedial maintenance or refurbishment where necessary, saving the network operator valuable time.

CONDITION BASED RISK MANAGEMENT (CBRM)

CBRM is a process that has been developed over many years by EA Technology. It is a means of combining all available practical and theoretical knowledge and experience relating to a particular asset in order to be able to define its current condition and then use this to estimate its future condition and performance. This is useful for predicting remaining useful life and probability of failure. In doing so, it provides a sound engineering basis for determining far more effective maintenance and intervention strategies based on risk rather than traditional time scheduled programs (i.e. maintenance and refurbishment is performed where and when it is needed, rather than simply because an arbitrary time period has elapsed.) The methodology is well developed and has a proven track record of successful application in practice [2].

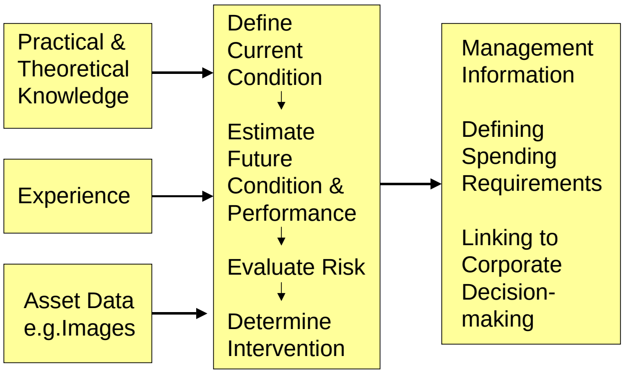


Figure 3. Condition Based Risk Management (CBRM)

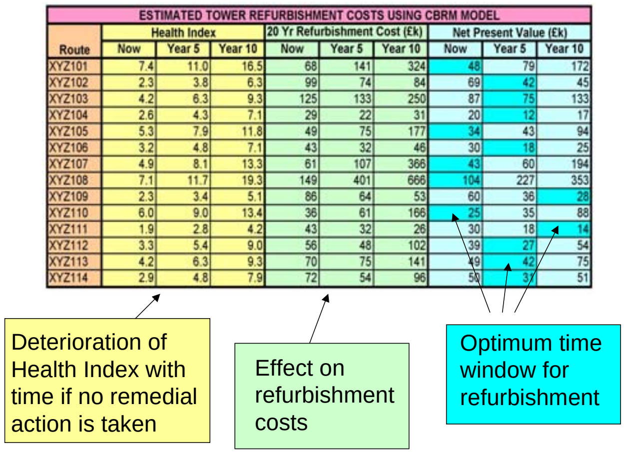
Figure 3 summarises the process. There are three key inputs that are combined within it. These are: (i) **practical and theoretical knowledge** which relates to an understanding of specific component degradation processes and failure modes; (ii) the **unique experience** of DNO staff who have gained an insight into specific localised component failure modes; and (iii) the **asset condition data**, the quality and accuracy of which has a significant bearing on the accuracy of the output from the CBRM model. This is where the helicopter method for gathering condition information in an accurate and consistent manner within a short time period is highly advantageous over other conventional inspection methods.

The CBRM process combines all the input information to formulate Health Indices for various components (or groups of components) that comprise each tower. These provide an indication of current condition and can be related numerically to probability of failure. The individual Health Indices can then be compounded in various ways to produce a meaningful overall index for the whole tower, or for a group of towers. For example, an individual electricity tower may have separate Health Indices for each of its electrical circuits, the earth conductor, and its steel structures. These may be combined to produce an overall

Health Index for the whole tower. In turn, the indices of individual towers can be combined to produce an overall route index. The condition of several routes may then be readily compared against each other. The Health Index is calibrated and normalised to give an indication of the current health of the asset, typically on a scale of 1 to 10 with 10 implying worst condition. Broadly speaking, an index of less that 5 implies that no action is necessary at present. A score of more than 5 implies that some action is required and the higher the score, the greater the urgency. This allows the asset manager to develop and select the most suitable intervention strategy.

Having established a numerical representation of the current condition, it is then possible to predict how this will change with time and estimate how each Health Index will deteriorate in the future. The risk of failure due to reduced performance can be estimated and taken into account when deciding on an appropriate intervention strategy. It is also possible to incorporate non-condition related risk into this decision process. For instance, a DNO may take into account the strategic importance of a particular tower route (e.g. the nature and number of customers it supplies) and the consequences of failure when considering the overall level of risk that is considered acceptable.

The model may also take into account the financial costs associated with undertaking various remedial work activities, and how these costs vary depending upon the condition of the component at the time. Figure 4 shows an example of a condition based tower painting refurbishment programme for a steel tower population. The output from the CBRM model signifies the optimum time to carry out painting on specific routes based on economic terms. It is important when developing such models to understand the degradation processes associated with the asset or component for which the intervention strategy is being developed. Figure 4 demonstrates how different tower routes on an electricity distribution network can be compared. Each row represents a different route. The first yellow column shows the current weighted average Health Index for tower condition along the route. In this instance, the Health Indices have been normalised to a scale of 1 to 10, where 10 represents the worst condition. Hence immediately it is possible to compare one route against another. The next two yellow columns show how the current Health Index will deteriorate over the next 5 to 10 years if no refurbishment work is carried out. The green columns use costing information to show what the respective refurbishment costs will be depending upon when the refurbishment work is undertaken. Finally the blue columns express this as a Net Present Value. This allows the optimum time for intervention to be estimated on economic terms, specifically addressing the rate of degradation of the tower steelwork as it approaches the end of its useful life.


ESTIMATED TOWER REFURBISHMENT COSTS USING CBRM MODEL

Route	Health Index			20 Yr Refurbishment Cost (£k)			Net Present Value (£k)		
	Now	Year 5	Year 10	Now	Year 5	Year 10	Now	Year 5	Year 10
XYZ101	7.4	11.0	16.5	68	141	324	48	79	172
XYZ102	2.3	3.8	6.3	99	74	84	69	42	45
XYZ103	4.2	6.3	9.3	125	133	250	87	75	133
XYZ104	2.6	4.3	7.1	29	22	31	20	12	17
XYZ105	5.3	7.9	11.8	49	75	177	34	43	94
XYZ106	3.2	4.8	7.1	43	32	46	30	18	25
XYZ107	4.9	8.1	13.3	61	107	366	43	60	194
XYZ108	7.1	11.7	19.3	149	401	666	104	227	353
XYZ109	2.3	3.4	5.1	86	64	53	60	36	28
XYZ110	6.0	9.0	13.4	36	61	166	25	35	88
XYZ111	1.9	2.8	4.2	43	32	26	30	18	14
XYZ112	3.3	5.4	9.0	56	48	102	39	27	54
XYZ113	4.2	6.3	9.3	70	75	141	49	42	75
XYZ114	2.9	4.8	7.9	72	54	96	50	37	51

Figure 4. CBRM Model Comparing Health Indices and Refurbishment Costs For A Number Of Electricity Tower Routes

CASE STUDY – CE ELECTRIC UK'S EXPERIENCE

All UK DNOs have a statutory requirement to inspect assets with sufficient frequency and detail to identify what actions need to be taken to comply with the Electricity Safety, Quality and Continuity (ESQC) Regulations 2002. For 132kV steel towers in CE Electric UK, routine climbing inspections formed an integral part of this inspection regime. Other traditional methods such as foot patrols and high speed helicopter patrols (including thermal imaging) are also employed; however, it is the output of climbing inspections that has traditionally influenced the decision to carry out major refurbishment work on tower lines.

During 2005 CE Electric UK undertook a joint project with EA Technology to address the difficulties highlighted in [1] arising from conventional climbing inspections. A trial inspection of 420 132kV towers (comprising 14 different routes and a total route length of 116 kilometres) was performed in the north east of England. The routes were specifically selected to meet the evaluation requirements of CE Electric UK to ensure optimum results.

It was evident from initiation of the project that a bespoke condition assessment proforma was necessary to maximise the quality and consistency of data to be gathered, and thereby increase the company's asset intelligence for its tower asset class. Consequently, a proforma was developed by CE Electric UK, incorporating lessons learnt from the implementation of previous data capture methods. A colour coded, four level Condition Rating (CR) convention was adopted in line with CBRM techniques. The condition assessment was performed in accordance with criteria laid down in the condition proforma. Three distinct Condition Rating categories were defined; tower furniture (signing and guarding), tower steelwork and circuit condition (phase and earthwire conductors and fittings).

Up to 30 images were captured for each tower position. These images were examined by engineers at EA Technology in conjunction with CE Electric UK staff. This partnership proved invaluable in order to calibrate the Condition Ratings, defining what constituted a CR of 1 to 4. To aid this iterative process, a good practice guide was developed to maintain consistency across the range of towers inspected. A set of Health Indices was formulated for each circuit based on the Condition Rating data, allowing a prioritised list of lines for refurbishment to be produced. Using CBRM it was to possible to define, justify and target future investment in 132kV tower lines. The benefits derived from the approach included an improved understanding of asset risk, which increased confidence in the prioritisation of tower lines for refurbishment. The results of the inspections influenced CE Electric UK's short, medium and long term asset renewal plans.

The effective utilisation of condition ratings 3 and 4 was key to the success of refining maintenance and investment strategies. Remedial maintenance activity was planned and coordinated in a timely manner to ensure effective prioritisation and compliance with the ESQC Regulations. In addition, the inspections have advanced the refinement of CE Electric UK's overall strategy for 132kV tower lines and helped contribute towards capital delivery targets.

The case study demonstrated that the helicopter technique offers considerable operational benefits over that of conventional climbing inspections at a comparable cost. The only material disadvantages is the loss of expertise of staff climbing towers and associated working methods (e.g. earthing methods and safe climbing techniques). However, such disadvantages are not considered detrimental to the long term asset management of the overhead line tower population and the benefits far outweigh those derived from legacy climbing inspections. For 132kV tower lines, CE Electric UK's change in philosophy to a high resolution imaging helicopter inspection regime has provided the following key benefits:

- A credible, proven alternative to conventional inspection methods
- A solid link can be made between asset condition and asset health for defining 'End of Life'
- An auditable, permanent record of condition is produced
- Increased confidence in the quality of condition data to aid robust decision making
- Aids investment appraisal to define, justify and target future investment at a strategic level
- Improved safety and reduced continuity risks arising from operational activities

CE Electric UK has now integrated the helicopter inspection technique into its inspection and maintenance regime for steel tower lines. CBRM and Health Indices have also been adopted into the investment appraisal decision making process. The successful use of this innovative technique clearly demonstrates the need for DNOs to re-appraise inspection methods to meet future challenges and the investment planners' needs.

CONCLUSION

This paper has shown how aerial inspections of electricity distribution towers from a helicopter using high resolution imaging can be combined with condition assessment and Condition Based Risk Management (CBRM) to provide a complete and unique solution to tower asset management within the electricity industry. The reasons for using such a system and the benefits it has to offer have been described. This has been clearly demonstrated through the CE Electric UK case study. Acquiring accurate and timely condition information and combining this with a sound engineering knowledge of degradation and failure mechanisms is the key to estimating future performance and operational risk. The method described provides both a powerful maintenance tool as well as enhanced strategic planning and investment decision making capabilities.

The study shows how Health Indices can be produced for various components on the tower route, or for the route as a whole, and used to compare the condition of different circuits in order to prioritise remedial maintenance programmes. The Health Indices can be related to probability of failure or useful remaining life and used as the basis for a risk analysis using EA Technology's Condition Based Risk Management (CBRM) process. The model takes account of future degradation rates and, when combined with refurbishment cost information, can be used to predict the optimum time for component replacement. This provides a powerful tool for strategic planning and investment within the DNO.

REFERENCES

[1] G. Earp, 2005, "Condition Based Risk Assessment of Electricity Towers Using High Resolution Images From A Helicopter", *Proceedings 18th International Conference on Electricity Distribution*. CIRED.

[2] D.T. Hughes, 2005, "Condition Based Risk Management (CBRM) – Enabling Asset Management Condition Information To Be Central To Corporate Asset Management Decision Making", *Proceedings 18th International Conference on Electricity Distribution*. CIRED.