CONDITION BASED RISK MANAGEMENT (CBRM), A PROCESS TO LINK ENGINEERING KNOWLEDGE AND PRACTICAL EXPERIENCE TO INVESTMENT PLANNING – AN UPDATE

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ABSTRACT

CBRM is a powerful process that enables companies to use current asset information, engineering knowledge and practical experience to define future condition, performance and risk for network assets. Over the past 2 years development and implementation of the process has continued. This paper concentrates on the quantification of risk and its use in investment planning.

INTRODUCTION

'Asset management' and 'risk management' have become essential processes for distribution companies in recent years. The development and application of CBRM (with major distribution and transmission companies) has been a practical response to this requirement, helping companies deliver effective asset related risk management.

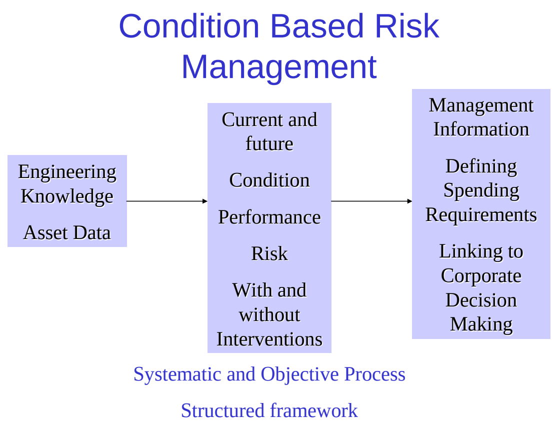
The CBRM process has evolved over a number of years directly as a result of working with distribution and transmission companies to meet specific requirements. The process was described and discussed in papers at the two previous CIRED conferences [1], [2]. The process and its application are continuing to develop. This paper provides an update, highlighting the developments since 2005. The nature of the output and its use to shape, justify and target future investment are illustrated with an example.

CONDITION BASED RISK MANAGEMENT (CBRM)

The essence of CBRM is the creation of an effective link from detailed asset information, engineering knowledge and experience to the investment planning and implementation processes within a distribution or transmission company. There is extensive engineering knowledge and experience relating to degradation, failure, condition assessment, performance and the influence of environment, duty, original specification for network assets. Using this to define current and future condition and performance of these assets is essential to enable effective and economic investment programmes.

CBRM starts by defining the condition of individual assets by a numeric 'health index'. The health index is 'calibrated' against probability of failure (POF). Within the model an ageing algorithm is applied that enables the future condition and POF to be estimated. Risk is then quantified by combining the POF with the consequences of failure and the criticality of the asset.

The current and future condition, performance and risk of individual assets or groups of assets can then be expressed either as numeric values in a table or graphically. The effect of any future investment programme can be factored in.



The ability to define and quantify future asset condition, performance and risk for different investment programmes provides the essential information for investment planning. The process is both objective and transparent, future performance and risk can be directly related back to asset information and engineering knowledge and experience.

DEVELOPMENTS SINCE 2005

By 2005 the essential components of the CBRM system were in place, however continuing application has led to a number of significant developments and improvements. In the earlier applications effort was concentrated on deriving health indices and creating the link with POF. In many cases decisions on future investment plans were based on achieving or maintaining specific failure rates for asset groups.

In the 2005 paper the calculation of risk by combining POF and consequences of failure was illustrated but the applications were limited. Since then major efforts have been applied to developing the risk quantification process and this is described and discussed in more detail in a later section.

Other developments include a redesign of the process to derive health indices and extension and improvement of results presentation to facilitate use in investment planning processes. The original health derivation process was based on identifying, weighting and adding condition related factors. Experience indicated that by combining the condition information with the ageing algorithm more consistent results could be achieved.

Each application of CBRM involves the construction of a 'CBRM spreadsheet' that combines all the asset information, applies the algorithms to derive health indices, POF and risk and presents the results. Building spreadsheets provides a very flexible, transparent and powerful means of reflecting the relevant engineering knowledge and experience. However as these become more complex and sophisticated the need for a more robust final solution is apparent. Updating and adding to CBRM spreadsheets is a relatively complex, manual process. Currently work is underway to produce a robust CBRM software tool that will incorporate the flexibility of the spreadsheets. This will then enable companies to interface CBRM with existing IT systems and use CBRM as a routine asset management tool.

QUANTIFYING RISK

'Risk' is a widely used term but what does it mean? In the case of the CBRM process, risk is defined as 'the possibility of loss or misfortune arising from the failure of network assets'.

The approach taken in CBRM is that risk for an individual asset is the product of the POF, the average consequences of failure (for the asset group) and the criticality of the asset (relative to other assets in that asset group).

It is recognised that consequences (and therefore risk) must be considered in different categories. There has been considerably debate about the relevant categories. This has led to the conclusion that there are four essential categories.

Network Performance – CMLs/CIs
Safety – fatalities and injuries
Financial - £, €, $, etc
Environmental – oil loss, SF_6 loss, pollution from a fire etc

Additional categories such as reputation, regulatory, legal etc have been suggested but these are largely secondary consequences that arise from the four primary categories above.

In each of the primary categories the average consequences of failure for each asset group are quantified by reference to the actual consequences experienced over the past 10 years. For example for 11kV cable faults what are the average number of CMLs and CIs experienced in the last 10 years? How many fatalities or injuries have occurred in the last 10 years? What is the average cost of dealing with a fault?

The consequences in each category are initially expressed in their own units, to compare and combine them it is necessary to relate them all to a common unit. The logical common unit is money. One of the consequences (financial) is expressed directly in monetary terms, for the others it is necessary to value them, what is the value of a CML or CI, what is the value of a fatality or injury, what is the value of an environmental consequence.

Most companies will have some means of valuing network performance consequences (CMLs and CIs), in the UK the Regulator operates an incentive/penalty regime that provides a convenient valuation. For safety consequences various valuations have been published. In the UK the DTI/HSE have published values for fatalities and injuries used originally to prioritise and justify spending on road improvements [3].

Environmental consequences are more difficult. After consultation EA Technology has proposed a scheme for defining and valuing environmental consequences that uses carbon emissions trading values as a reference.

Once the average consequences of failure (for an asset group have been estimated and valued it is necessary to define the criticality (in each consequence category) of each individual asset. The criticality is the importance or significance of the individual asset relative to other assets in that group i.e. the importance of one transformer relative to other transformers.

The criticality is therefore expressed as a multiplication factor: 1 for an 'average asset, <1 for a less important asset, >1 for a more important asset. Defining the individual criticality is relatively straight forward, different factors will be relevant for different asset groups. Typically network performance criticality will depend on the number of customers supported by the asset and some measure of network configuration. The safety criticality may include consideration of the physical location, proximity to people, and type of insulation (for switchgear) oil, vacuum or SF_6. Financial criticality may include the size of the asset (a large transformer costs more than a small transformer). Environmental criticality typically relates to proximity to a water course or other environmentally sensitive location.

In practical terms defining asset criticality and average failure consequences has not been found to be particularly onerous. Once a systematic framework has been established the information requirements are not demanding. In virtually every case the information required (number of customers, proximity to people etc) has been readily available. Certainly the information issues for the consequences and criticality part of CBRM are far less demanding than the initial information requirements for the health index/POF calculations.

THE SIGNIFICANCE OF RISK

The early applications of CBRM were limited to defining current and future condition and performance (health indices and POF). The output was then used very successful to define investment programmes to achieve specific failure rates.

The extension of the process to quantify risk adds two important elements. Firstly, it recognises the concept of criticality, some assets (within an asset group) are more important than others. By defining the relative criticality of each asset in each consequence/risk category this can be catered for. When prioritising assets for replacement the ones in worst condition may not be the ones that carry the biggest risk. Secondly, quantifying risk enables the significance of different asset groups and the cost benefit of investment programmes for different asset groups to be directly compared.

Quantifying risk in this manner involves valuing different consequences (in monetary terms). This requires significant and sometimes difficult decisions. Over the past 2 years EA Technology has applied this process with major distribution and transmission companies in several very different parts of the world and it is important that the values reflect local company or society values. The value of different consequences (cmls/ci, fatalities/injuries, oil loss/SF_6 loss etc) may vary significantly in different places.

Ultimately the test of the model is in the acceptance of the final results. Do the levels of risk estimated for different asset groups reasonably reflect the risk as perceived by the company. Are the absolute values (expressed as a monetary value) reasonable? Are the relative values between groups reasonable?

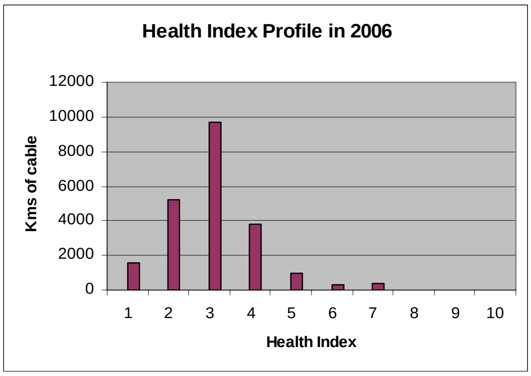
The initial results achieved with the process do appear to be broadly satisfactory, however it is important that these continue to be critically reviewed. The concept of measuring future risk (in monetary terms) with and without specific investment programmes is new to most companies. As the process is rolled out across companies it will be possible to make a better assessment of the outcome. This may then require some adjustment to the values used in the calculations.

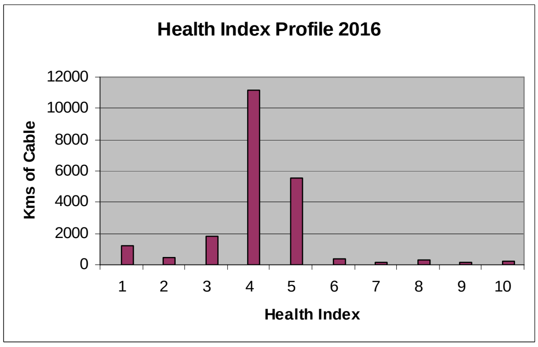
What we have demonstrated so far is that the approach is practical, it can be applied to a wide range of assets, covering both discreet substation assets (transformers, switchgear) and linear assets (OHLs and cables). It has been successfully applied to assets from LV to 500kV.

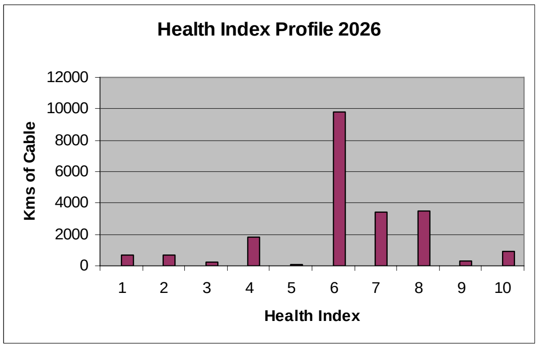
AN ILLUSTRATION OF CBRM RESULTS

The CBRM spreadsheet created for each asset group in each application can produce condition, performance and risk results for any future year with any intervention. It is therefore difficult to demonstrate the full range of results and applications in a short paper.

As an illustration some results are presented for a population of 11kV cables. Starting with the health index profiles that summarise the condition over the next 20 years







The current health index profile (2006) shows a population (21,925kms of cable) with the majority of cables having low health indices. The profile by 2016 shows a relatively small change, but by 2026 there has been a significant shift to higher values. These changes are reflected in the projected failure rates.

The current condition relates to the current failure rate of 0.040 per km (877 faults per year). The estimated fault rate for the 2016 profile is 0.044 per km (964 faults per year) i.e. a modest increase if no cable replacement is undertaken. However by 2026 the estimated fault rate will have more than doubled to 0.093 per km (2039 faults per year), again assuming no cable replacement.

The changes in risk further reflect the condition and failure rates. The annual risk expressed in monetary terms and split into the 4 categories is summarized for the 3 years in the table below.

Year	Network Perform	Safety	Financial	Environmental	Total
2006	13.52M	0.59M	3.70M	0.24M	18.05M
2016	14.88M	0.65M	4.76M	0.26M	20.55M
2026	32.58M	1.34M	10.41M	0.54M	44.87M

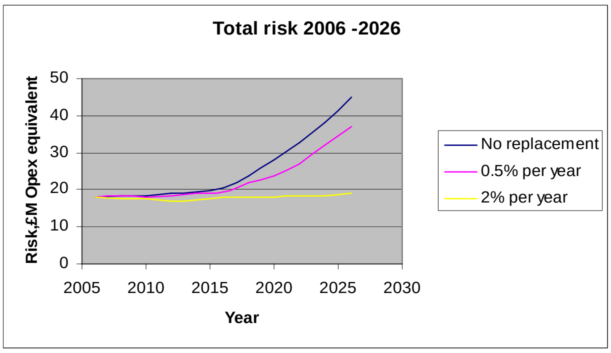
Table 1, Summary of risk, expressed in £, for 11kV cables with no replacement

The risk broadly mirrors the fault rates with a modest increase in 2016 and a major increase by 2026. The main contribution to the overall risk is the network performance component, accounting for approximately 75%. The £19m increase in network performance risk between 2006 and 2026 represents an extra 46M cmls and 1M cis!

We can then factor in different intervention programmes (different cable replacement regimes). Currently this company replaces approximately 0.5% of these cables each year.

The current replacement rate (0.5% per annum) will maintain the current risk/fault rate for the next 10 years, but after that the risk/fault rate will increase significantly. 2% replacement per annum (over the whole 20 year period) is required to maintain the risk/failure rate at the current level up 2026. If the current 0.5% replacement rate is continued up to 2016 it will be necessary to increase the replacement rate in period 2016-2026 to 3.5% per annum to prevent a significant increase in risk/failure rate (cmls, cis etc).

The effect of 2 specific replacement programmes over the next 20 years are shown below.



CONCLUSIONS

Over the past 2 years development of the CBRM process, through implementation with major distribution and transmission companies, has continued. The algorithms used to derive current and future health indices and POF values have been reviewed and refined to give more consistent results. The process to quantify risk has been strengthened, tested and successfully applied to a wide range of assets from LV cables to 500kV transformers.

The great strength of the process is the link it creates between the future condition, performance and risk and current asset information and engineering knowledge and experience.

The ability to quantify future risk (with and without interventions) in terms that relate directly to KPIs is a major advance in the pursuit of effective asset management..

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