GESTIÓN DEL RIESGO BASADO EN CONDICIÓN (CBRM): LA EXCELENCIA EN LA GESTIÓN DE ACTIVOS EN LA SALA DE JUNTAS

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RESUMEN

CBRM es un proceso práctico que combina la información de activos con la ingeniería del conocimiento y la experiencia para cuantificar el riesgo, rendimiento y la condición de activos actuales y futuros. En las tres últimas conferencias de CIRED, han sido presentados documentos [1] [2] [3] que han trazado el desarrollo y aplicación de este proceso. Este papel divulga sobre las últimas mejoras que incluyen: técnicas para perfeccionar la cuantificación del riesgo; optimización financiera de la estrategia de sustitución de activos; y la predicción del efecto de las decisiones financieras o ingeniería. Se presentan conclusiones sobre cómo este enfoque puede utilizarse para influir y mejorar las decisiones de gestión de activos en la sala de juntas.

INTRODUCCIÓN

Aunque la gestión del riesgo ha estado por mucho tiempo en el centro de la buena práctica de ingeniería, cambios en la legislación corporativa ha hecho obligatoria la notificación de riesgo [4], junto con la disponibilidad de una especificación pública documentar mejores prácticas de métodos [5] ha fomentado la adopción de la gestión eficaz del riesgo a los operadores de red.

La gestión de programas de reemplazo de activos tradicionalmente es un asunto para los ingenieros, pero para comunicar eficazmente los riesgos actuales y futuros con los altos responsables de las decisiones a menudo es necesario expresar decisiones Ingeniería en términos de costo/beneficio financiero. Los recientes acontecimientos en CBMR tienen por objeto ayudar esta comunicación, capacitar a ingenieros y tomadores de decisiones por igual con los datos necesarios para conducir una política eficaz de gestión de activos.

ADMINISTRACIÓN DE RIESGO BASADA EN CONDICIÓN

La metodología CBRM, desarrollada por EA Technology, proporciona un eficaz enlace de activo disponible la información, ingeniería de conocimiento y experiencia a los procesos de planificación y ejecución de inversión dentro de una empresa de distribución o transmisión.

Como se detalla en documentos anteriores, un estudio típico comienza por analizar el conocimiento colectivo y experiencia relativa a la degradación, falta, evaluación de la condición, rendimiento y la influencia del medio ambiente, derecho, política operacional y especificación de activos de red del operador de red. Esto puede ser combinado con la experiencia de toda la industria para definir un sólido "índice de salud" y tasa de envejecimiento de cada activo bajo consideración. Datos históricos de fallos y rendimiento entonces se analizan para determinar la relación entre el índice de salud y la probabilidad de que un activo seguirá funcionando correctamente. Esto solo proporciona una poderosa herramienta de ingeniería para permitir la probabilidad existente y futura de la insuficiencia de activos para modelar confiablemente.

Para cuantificar el rendimiento anterior en términos financieros, a menudo es deseable expresar el resultado en términos de riesgo financiero. Se trata de una combinación de:

- la probabilidad de un evento que ocurre; y
- la consecuencia financiera resultante si se produce el evento

La probabilidad de que cada uno de los activos siga funcionando correctamente (o no) ya se ha determinado, por lo que todo lo que queda por hacer es cuantificar las consecuencias del incumplimiento de cada activo. Para ello, es necesario examinar y analizar las consecuencias en términos de cantidades concretas dentro de las categorías (normalmente rendimiento de la red y del medio ambiente, seguridad y consecuencias financieras). Un trabajo anterior [3] se describe un enfoque práctico para la obtención de estos datos.

Para un activo individual en activos del grupo I, el riesgo en cualquier año t puede expresarse como sigue:

$$Risk_{t,i} = PoF_{t,i} \cdot \sum_{j=1}^{m} (CoF_{I,j} \cdot Crit_{i,j})$$

where:
$Risk_{t,i}$ = El riesgo asociado con activo i en el año t PoFt,i = la probabilidad de activo i no en el año t
$CoF_{I,j}$ = la consecuencia promedio *j* de un evento de incumplimiento en el grupo I de activos
$Crit_{i,j}$ = *la criticidad relativa j de activo i*
m = el número de categorías de consecuencia bajo consideración

MEJOR ESTIMACIÓN DEL RIESGO

En estudios previos, se ha estimado riesgo utilizando las consecuencias mensurables probabilidad y promedio de un solo resultado por ejemplo una falla interruptor disruptivo. Sin embargo, el "fracaso" de un activo puede resultar en una amplia gama de resultados posibles, en el ejemplo anterior esto podría ir de "no operar" (con una mínima pérdida consecuente) a través de "falla catastrófica" (que implican pérdidas significativas).

Además de considerar la importancia relativa de los activos, por lo que puede ser beneficioso para la gama de posibles situaciones de fallas. Esto se hace tomando la consecuencia promedio de cada modo de falla y ponderación según la probabilidad relativa de cada modo de falla. La consecuencia de promedio de *j*, de un suceso de falla en activo grupo *I* se convierte entonces en:

$$CoF_{I,j} = \sum_{k=1} PoF_{I,k} \cdot CoF_{I,k}$$

Where:
PoFI,k = la probabilidad relativa de una falla en el modo k de un activo en el grupo I
CoFI,k = la consecuencia de una falla en el modo k de un activo en medio del grupo I
n = el número de modos de falla diferentes bajo consideración

Using this approach, it is possible to take a wide variety of failure modes into account. In practice, sufficient data is unlikely to be available for all failure modes. It has been found that acceptable results can be obtained by limiting the number of failure modes under consideration to a few broad categories (e.g. “minor repair”, “disruptive failure” and “catastrophic failure”).

PRESENT VALUE RISK OPTIMIZATION

The above method enables the highest-risk assets to be clearly identified. However, the degree of asset replacement is usually a matter of budget and policy; this is commonly based on past experience, rather than on a forward- assessment of the level of risk. The question remains: is the level of proposed investment the correct one?

As risk is now defined and quantified in monetary terms, it is possible to make a direct assessment of the financial value obtained from different proposed investment programs by considering the investment cost against risk on a present value (PV) basis. This can be used to determine the financially optimum (i.e. lowest PV) replacement program.

Investment

The PV of the investment required to replace an asset can be calculated for future years by compound discount of the current replacement cost. In any future year *t* this is calculated as follows:

$$PV_{investment} = \frac{Inv_0}{(1+r)^t}$$

Where:
Inv0 = the current replacement cost (year 0) of an asset
r = the discount rate

This results in a decreasing investment cost with time.

Cumulative risk

The optimum year for the replacement of a given asset is determined on the basis of “delta risk”. This represents the difference between the future risk associated with an asset and the risk associated with a new asset and can be written as follows:

$$\Delta Risk_t = Risk_t - Risk_{new}$$

where:

$Risk_t$ = *the risk associated with a given asset in year t*

$Risk_{new}$ = *the remaining risk following replacement of the asset*

In any future year *t*, the total delta risk over *t* years is calculated; i.e. the summation of discounted delta risk in each year *m* over the given period. The cumulative PV can be expressed as follows:

$$PV_{\Delta RISK} = \sum \frac{\Delta Risk_m}{(1+r)^m}$$

Using the CBRM model, the risk associated with an asset increases year on year, once the health index reaches a specified value (denoting the onset of end-of-life). The cumulative discounted delta risk increases accordingly.

Replacement

For a given asset, the total cost of replacement in year *t* is the summation of its PV investment cost and PV cumulative delta risk:

$$PV_{replacement} = \frac{Inv_0}{(1+r)^t} \sum_{m=0} \frac{\Delta Risk_m}{(1+r)^m}$$

A minimum occurs in the year when the increase in asset risk exceeds the reduction in cost by not replacing the asset. This is the financially optimum replacement point for the asset.

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EXAMPLE RESULTS

The following snapshots show results from this process, using source data taken from a sample population of 916 11kV circuit breakers.

Health Indices

Figure 1 shows a typical profile of existing health indices. In this example, new assets are deemed to have health indices. In this example, new assets are deemed to have a health index of 0.5 and those at end-of-life (i.e. presenting an unacceptable probability of failure) have a health index of 7. It can be seen that there is a typical distribution of relatively few new assets (HI <1), with a larger number assets in ageing but serviceable condition (HI 3-6)

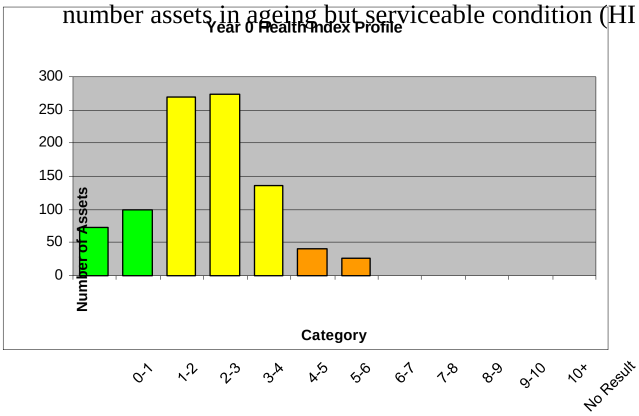


Figure 1 Example health index profile (year 0)

Using the calculated ageing factors for each asset, we can look forward into the future to see how the health indices will change. Figure 2 shows the health indices for the same assets in 10 years' time with no investment.

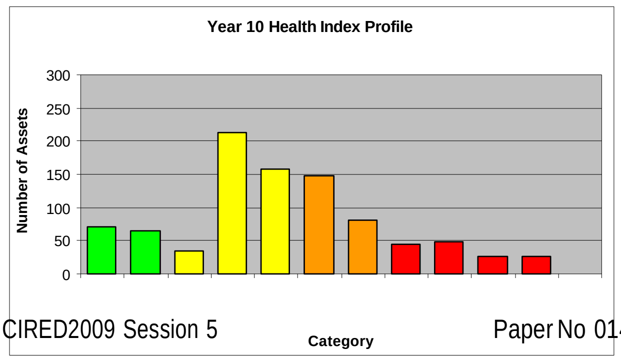
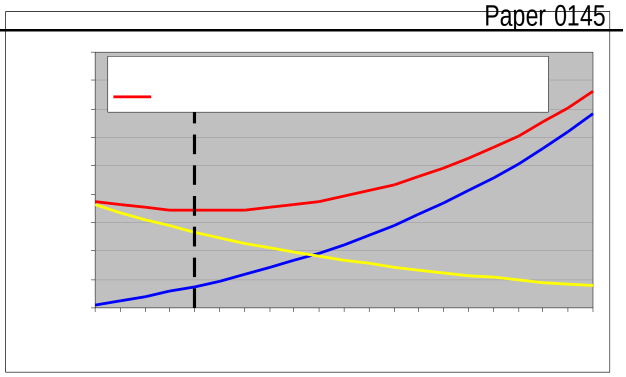


Figure 2 Example health index profile (year 0)

Risk profiles

It is clear from the health indices that a number of assets will require replacement before year 10. As a first pass, the

$1,800,000
$1,600,000
$1,400,000
$1,200,000
$1,000,000
$800,000
$600,000
$400,000
$200,000
$0



Discounted delta risk Discounted investment Total cost of replacement

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20

Year

CBRM model can be used to determine the required replacement rate in order to keep the overall level of risk constant. In this example, the rate was calculated to be 2.9% (or just over 26 units per year, representing 1-2 complete primary switchboards per year). The resulting annual risk profile is compared with “no investment” and “reduced investment” (1.5% replacement rate) options in Figure 3.

It can be seen that at the proposed replacement rate the risk is maintained at a fairly constant level throughout the time period, despite a considerable number of assets reaching their end-of-life. The effect of any proposed variation from the optimum level of replacement (e.g. the reduced investment scenario) can quickly be assessed.

It should be noted that Figure 3 shows the annual risk, and the effect of prolonged risk is cumulative. To determine the actual difference in cost of the different scenarios, a PV analysis can be performed.

Figure 4 PV analysis of switchgear near end of life

While the investment cost falls with time, the condition- related is approaching the end of its life, the lowest replacement cost occurs wi his switchgear would result in greater overall cost.

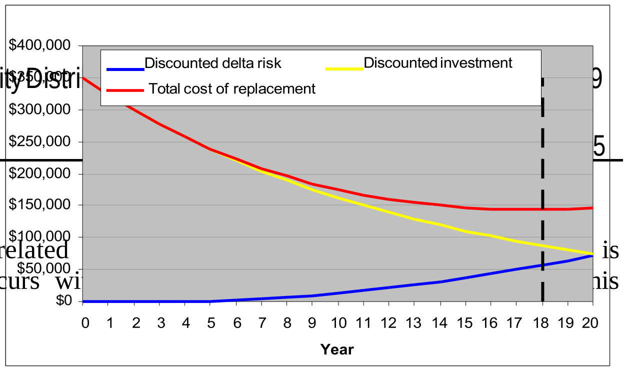


Figure 5 PV analysis of switchgear with life remaining

The profile for another substation is shown in Figure 5. In this case, the switchgear still has a useful amount of remaining life; the minimum overall cost is achieved by replacement in year 18.

Finally, the above individual optimisations can be combined to recommend the lowest overall cost investment programme, taking risk into account. Such a programme is shown in Figure 6.

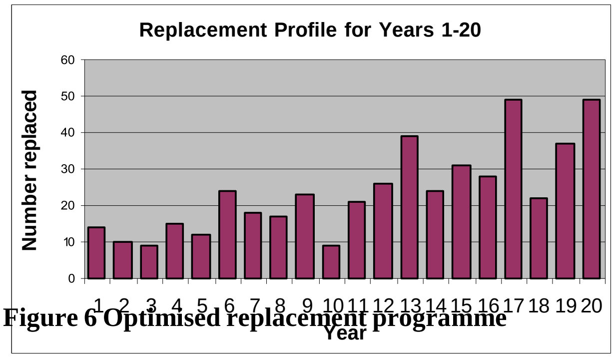


Figure 6 Optimised replacement programme

This information can be used directly as the basis of a regulatory submission or future budgetary plan.

By applying the process to all major asset groups the current overall risk and the optimum future overall risk can be quantified. This has recently been completed with two distribution companies and the optimum future risk (in 10 years time) was shown to be very similar or slightly higher than the current risk. This could be most economically achieved by investment programmes that reduced risk in some groups while allowing increased risk in others.

PRACTICAL APPLICATION OF RISK INFORMATION

The above calculations have been incorporated into a financial model that enables the optimum replacement programme to be quickly identified. This enables:

- The representation of engineering knowledge and experience in clear financial terms: the benefits of improved asset management techniques and policies can be demonstrated.
- The generation of well-researched, defensible capital investment programmes for asset replacement: this can help to ensure that asset risk is managed appropriately even when investment or resources are constrained.
- Visibility of the asset risk profile over 5, 10 or even 20 years: such information is essential to help long-term investors determine their strategy.
- Direct linkage of the investment programme to the condition and performance of the asset base: if a method is found to improve condition or extend asset lives, investment plans can be quickly revised.

- Immediate visibility of the likely effect of over- or under- investing in the network: for example, in the face of proposed budget or resource restrictions, the additional (and, often, unplanned) costs can be clearly identified.

CONCLUSIONS

A risk-based approach to asset management has been recommended for a number of years. However, the tools with which to deploy such an approach have long been hampered by the data and resource requirements needed to produce usable results, making the value of such techniques rather subjective. Through CBRM, EA Technology have demonstrated that effective risk-based asset management decisions can not only be made using existing data sources, but that the benefits are quantifiable and considerable; the difference between the "initial" and "optimised" capital programmes described here equate to several million pounds over the duration of the programme.
Furthermore, such an approach enables senior management and decision makers not only to engage fully with the asset management process, but also to derive clear and tangible financial benefits from its adoption.

ACKNOWLEDGEMENTS

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