HEALTH INDEX APPROACH TO SUBSTATION CIVILS

David NEILSON
SP Energy Networks – UK
David.Neilson@scottishpower.com

Lee SPEAKMAN
SP Energy Networks – UK
lee.speakman@scottishpower.com

Alberto ELENA DE LEONARDO
SP Energy Networks – UK
aelena@scottishpower.com

ABSTRACT

This paper is focused on extending asset health methodology from electrical to non-electrical assets, establishing a dynamic and systematic approach to managing substation civil assets. These assets include components such as buildings, foundations, supporting and boundary structures.

The condition of civil assets is essential to the safety, security, performance and ensuring the longevity of substation electrical components. To justify investment, manage risk and performance, and to prioritise sites, SPEN have developed a health index (HI) methodology to better understand the condition of their fleet of substation civil assets.

This HI approach is in line with the UK Regulator/Distribution Network Operator (DNO) classifications for the health of electrical plant which has proved essential to targeting and optimising investment. Further, SPEN plan to fully integrate this with the Health and Criticality approach to managing risk.

INTRODUCTION

Scottish Power Energy Networks (SPEN) operates within two distribution licence areas: SP Distribution Ltd (SPD), SP Manweb Plc (SPM). The distribution licences cover LV to 132kV voltage ranges.

SPEN maintain and operate 30,000 substations, 46,000 km of overhead line and 65,000 km of underground cable within the two Licence areas. The substations are a mixture of indoor and outdoor sites.

Included within the outdoor substation fleet are typically; Grid (Transmission/132kV to EHV), Primary (EHV to HV) and Secondary (HV to LV) substations. Primary and Grid substation can be sizeable containing substantial supporting structures for circuit breaker or disconnectors.

Within SPEN's indoor substation fleet there are 54 legacy substation sites which were previously AC/DC convertor stations, small local power stations or tram depots.

All physical assets are managed utilising an Integrated Management System which combines the requirements of the Asset Management System specification (ISO 55001), the Quality Management System international standard (ISO 9001), the Occupational Health & Safety Management System international standard (OHSAS 18001) and the Environmental Management System international standard (ISO 14001).

This paper summarises SPEN's methodology for assessing asset health, targeting interventions and recording regulatory outputs, bound within the Integrated Management System.

Asset Management is often defined as the method by which costs are optimised and risks balanced to effectively manage the lifetime of equipment, including the "Systematic and coordinated activities and practices through which an organization optimally and sustainably manages its assets and asset systems, their associated performance, risks and expenditures over their life cycles for the purpose of achieving its organizational strategic plan". "Good asset management considers and optimizes the conflicting priorities of asset utilization and asset care, of short-term performance opportunities and long-term sustainability, and between capital investments and subsequent operating costs, risks and performance".

Gauging the condition of assets by means of understanding the asset health, through the application of a Health Index (HI), is an important element to managing the whole life cost and condition of any asset base. It may significantly drive the replacement strategy and is part of an integrated and holistic approach to asset management, which creates a link between the asset condition and the investment plan.

Health indices are used to facilitate the targeting of investment on the poorest condition and highest risk assets. Experience has found that the more detailed and meticulous the condition assessment, the more accurately and efficiently investment can be targeted.

Asset health depends on engineering information, knowledge and experience collated from a variety of sources, including corporate systems and local expert knowledge. Individuals have the expertise to identify and assign appropriate weight to relevant information for particular assets, which can be used to determine health, degradation and failure. It is based on a structured and repeatable approach, and provides both quantitative and qualitative engineering analysis.

This paper sets out a step change for managing civil assets in line with a Health Index approach; outlining the methodology, its application and implementation.

ISSUE

In the past substation civil assets were managed in an ad-hoc manner, with inefficient risk management and undefined investment decisions. This resulted in the early ageing of plant and, consequentially, poor performance.

SPEN civil assets were previously managed using defect and hazard data logged in corporate systems. Due to high volumes and poor reporting, this data was unable to be used to create a prioritised civil plan. Therefore there was no holistic link between the asset data and the plant investment plan.

APPROACH

The asset Health Index assigns a relative health/condition value, of between 1 and 5, to each asset dependant on the factors affecting its health. The asset information that is used to generate the health index varies in nature, between each asset but is deemed the most relevant to represent the condition of the asset. The level of risk attributable to an asset determines the depth of detail, sophistication and rigour of asset information required to manage the asset risk, considering:-

1. The asset volumetric determines what information can practicably be obtained.
2. Asset health information can only be an indicator of useful remaining life, not a predictor of failure.
3. The asset information obtained has to be commensurate with the cost benefit attributable to the asset risk.

However, it is recognised that asset specific information can never be all encompassing such that future failures can be totally avoided.

The information parameters: health index and asset volume are charted, and provide an effective visual tool for assisting with the decision making process for replacement priorities. It has historically been applied across each of the main asset types; switchgear, transformers, cables and overhead lines. This is then used to optimise investment decisions across the full range of assets. The number of assets in each specified category is depicted graphically to demonstrate the overall health of the asset as shown Figure 1.

SPEN has been developing an HI methodology to:-

- Effectively risk-manage ageing assets
- Achieve policy compliance
- Satisfy statutory obligations

This paper outlines the HI methodology which SPEN is applying to managing its substation portfolio.

SPEN have

Health Index Definitions

The definitions for assessing the health index of substation buildings are:

- **Health Index 1** - As new: New installation in excellent condition with no visual signs of deterioration.
- **Health Index 2** - Good condition: Installation in all round good condition with insignificant repairable deterioration including superficial damage.
- **Health Index 3** - Minor deterioration: Installation showing some signs of deterioration but still reasonable condition with repairable defects to roofs, gutters, heaters, doors, brickwork, lighting and welfare facilities.
- **Health Index 4** - Material deterioration: Significant deterioration to roofs which are showing internal water ingress; heating & lightings installations which require panel heater replacements and lighting upgrades; internal decoration which is showing severe deterioration and require upgrading; door and security defects; and, welfare facilities which have deteriorated in condition. These will render the assets to become 'End of Life' within 5 to 10 years.
- **Health Index 5** - End of Life: Serious signs of deterioration due to age, wear and suitability that cannot be rectified. Serious building defects including roofing, doors, brickwork, electrical, welfare, subsidence or defects which render the assets ''End of Life'. It should generally be replaced within 5 years.

This HI methodology is in line with SPEN's Asset Health Methodology for circuit breakers and transformers. An example of how HI can be represented pictorially in histograms is shown Figure 1.

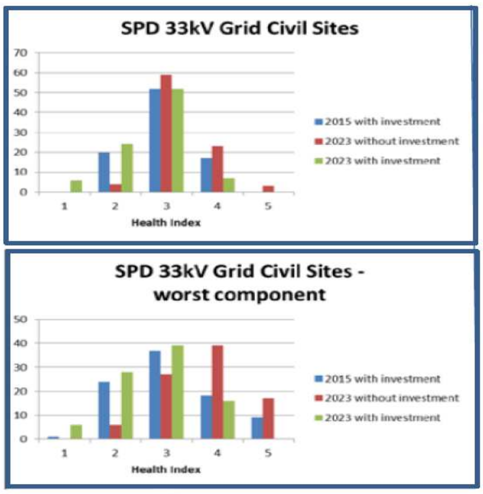

Figure 1 – Investment impact on Health Index movement

APPLICATION

Key substation components

Deriving an HI with a variety of components could drive different HI scores. To achieve consistency civil components have been grouped as:-

- **Foundations** - Condition of foundations is a key area of focus, due to the dependency main plant has on its performance and state.
- **Major supports** - Substations contain concrete and metal structures which support switchgear, such as VT / CT's, busbars and bushings.
- **Buildings** - Substation buildings contain critical plant such as circuit breakers and light current equipment, which ensure the reliable operation of the network. The performance of this plant and equipment relies on a water tight and adequately heated substation environment.
- **Trenches and manholes** - Trenches allow cable and pilot wires to be ducted through substation sites. These often have trench covers which, if not replaced, can deteriorate beyond repair.
- **Fences and retaining walls** - drivers include deteriorating asset condition and compliance with the Electricity Safety, Quality and Continuity Regulations (2002).
- **Non supporting structures** - Other structures include lighting, telecommunication towers and access gantries.

Each of these components is allocated a health index score during an onsite condition inspection and assessment.

Deriving HI and overall HI for a site

In order to attribute an HI to an asset a scripted question set is used, which asks a series of questions related to condition. The questions result in an HI score for each component inspected.

Asset	Component	HI-1	HI-2	HI-3	HI-4	HI-5
Gantries	Pre cast concrete	Surface condition OK		Minor surface deterioration, cracking.	Major surface deterioration, concrete breaking, spalling, <50% exposed reinforcing	>50% exposed Reinforcing
Gantries	Metalwork	No visible corrosion or damage		Minor corrosion, pitting, painting required	bent or missing bracing	Heavy corrosion, pitting, loss of cross section
Fencing	Stanchion Foundations	Complete and secure		Minor surface deterioration, cracking	Major surface deterioration, concrete breaking, spalling, <50% exposed reinforcing	Major subsidence

Figure 2 – Example Question Sets

Grouping components allows the user to derive a single overall HI. However to identify problematic individual components, the substation's worst components are highlighted on a summary report.

The overall HI is composed of:

- **Overall substation HI** - Summary of the condition of that site based on a weighted approach, outlined in Figure 2
- **Worst component HI** –identifying specific defects with the worst components

Scoring methodology

To evaluate the overall substation HI, the components outlined as key substation components are categorised. An average health index is then calculated for each of these categories.

To arrive at an overall HI, these scores are then weighted based on the relative importance of each category. The weightings are attributed based on SPEN's view of risk to substation components [1].

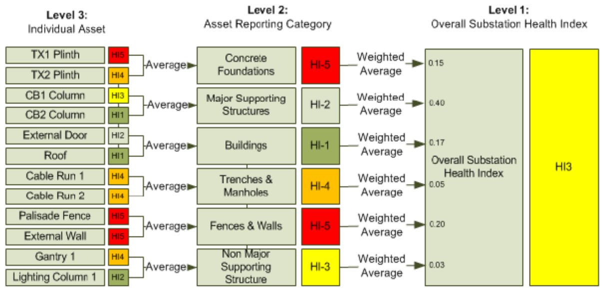

Figure 3 – Civil survey weighted approach

ASSET HEALTH IMPROVEMENT

Investment in substation civil infrastructure is prioritised to ensure substation equipment is adequately protected from damage due to leaking or poor condition buildings and structures. The refurbishment plans target components in poor health.

Civil refurbishment is undertaken aligned to detailed surveys of the a substations' infrastructure conditions.

Image 1 – Major supports and buildings scored as HI5 in condition based assessment

of the substations's

After the refurbishment work is completed the condition of buildings and structures is substantially improved, resulting in an HI improvement. The new scores, resulting from the intervention, are suitably recorded in the asset register.

Image 2 – Major supports and buildings scored as HI2 after civil refurbishment works

CONCLUSIONS AND NEXT STEPS

Developing a substation civil index allows SPEN to accurately forecast the long term investment required to ensure civil assets are maintained in an acceptable condition; maximising the performance and expected life of critical assets.

The surveys identified a number of poor condition assets which if left without intervention could reduce public/staff safety and compromise system security with a major inservice failure. This information is incorporated in the Risk Register which allows the level of risk to be managed.

The Civil Health Index has also enabled SPEN to prioritise constrained civil investment and create robust intervention plans.

Next steps

Integrating the question sets into corporate system is under way, and SPEN plan to rollout this approach as business as usual over the next 18 months. This will bring the capture and reporting of civil asset health in line with other electrical assets such as circuit breakers and transformers.

SPEN intends to further develop the Civil Health Index to include a measure of criticality. The concept of criticality allows the relative importance of each asset and the consequence of its failure to be better understood. This is typically expressed as a monetary value and can include costs for:-

- Partial/full replacement
- Loss or reduced Security of Supply
- Safety impact
- Environmental compensation and reinstatement

Civil assets found within a substation can have substantially different criticality impacts, for example:-

SPEN intend

- A leaking roof can cause significant performance issues and reduced life of assets which are rated for indoor use only. Following discovery of a leaking roof additional asset maintenance and inspections are typically required.
- Poor condition doors and perimeter fences could cause a public safety issue due to reduced security and increased likelihood of vandalism or theft.
- Degraded busbar support structures could cause a catastrophic failure during adverse weather conditions which, in turn, could cause significant outages with long restoration times
- End of life transformer bunds may not perform their intended function causing large volumes of oil to leak resulting in damage to both equipment and environment; requiring significant remedial costs.

Once the critically of each asset class is identified it can be further modified by local parameters to enable comparisons of criticality of the same asset class across different sites. For example, a bund protecting a grid transformer adjacent to a watercourse is more critical than one protecting a primary transformer.

Image 3 – Bund containing oil spillage from primary transformer and grid transformer bund

SPEN believe developing and understanding the criticality of civil assets will further enhance the capability to optimise the risk based investment in these assets.

REFERENCES

[1] *SP Energy Networks 2015-2023 Business Plan*, Annex Volume C6 "Civil Strategy and Plans". L.Speakman, 2014.

[2] *Asset management – Management Systems – Requirements*, ISO 55001, 2014.

[3] *Quality management systems*, ISO 9001, 2015.

[4] *Occupational Health and Safety Management Systems – Requirements*, OHSAS 18001, 2007.

[5] *Environmental Management Systems*, ISO 14001, 2015.