SPEN SWITCHGEAR LIFE EXTENSION STRATEGY

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ABSTRACT

SP Energy Networks (SPEN) has an increasingly ageing asset population. Regulatory focus on reducing costs for customers has made SPEN review its switchgear strategy around wholesale replacement of equipment, and look for more cost-effective investment, implementing new interventions to extend the operational life of the asset base as an alternative to replacing assets in order to meet increasing performance and regulatory targets

SPEN intends to implement a Life Extension plan increasing the volume of retrofit switchgear as part of its Asset Management Strategy. Refurbishment and retrofitting of distribution switchgear will extend the asset life, improve the Health Index, reduce risk and increase reliability. The engineering balance, between refurbishment and replacement, allows efficient utilisation of resources, maximises economic returns while continuing to provide safe and reliable network solutions.

INTRODUCTION

SPEN operates two distribution licence areas: SP Distribution Ltd (SPD) and 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.

Within primary substations (EHV to HV), SPEN has a total population of around 10,000 HV (11kV) circuit breakers. Around 50% of this population was installed during the 1950's, 60's and 70's, as shown in Figure 1.

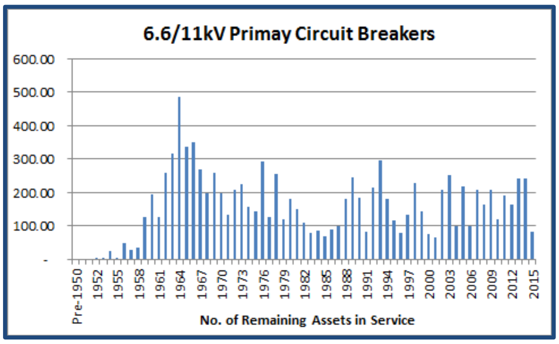

Figure 1: HV (11kV) Primary Circuit Breakers Age Profile

Whilst many of these legacy assets are still operating effectively, they are approaching or have already exceeded their original design life requiring a major intervention. The challenge is to achieve performance improvements without major capital investment or the disruption caused by replacing large quantities of assets.

SPEN and other UK Electricity Distribution Network Operators (DNOs) operate in a new RIIO model for network regulation. The current price review (RIIO-ED1) focuses on reducing costs for customers, delivering outputs and innovation strategies [1]. This changing operating environment has offered SPEN the opportunity to review its switchgear strategy; moving from the wholesale replacement of equipment to more cost-effective investment strategies, where the life of the current asset population can be reliably and safely extended by improving its asset health, while at the same time protecting employees and the public.

The new regulatory contracts offer UK DNOs the opportunity to implement different interventions for assets other than replacement. SPEN's portfolio of switchgear during the previous price control (DPCR5) was, in the main, very poor condition assets that had no viable intervention other that full replacement. However SPEN's switchgear strategy in RIIO-ED1 implements a mix of asset replacement and asset refurbishment interventions, which includes the retrofit of legacy switchgear [2].

During the current regulatory period, 2015-2023, SPEN plans to retrofit 12% of the existing HV circuit breaker population, compared to replacing 8%; i.e. the balance has shifted away from large scale replacement. Retrofitting involves the replacement of the moving portion oil filled circuit breakers with modern vacuum circuit breakers. This is a much more cost effective option when compared to replacing the whole circuit breaker (fixed and moving portion).

This paper sets out a step change for managing ageing switchgear assets in line with a Health Index approach; outlining the methodology, its application and implementation. In addition, this paper summarises SPEN's methodology for assessing asset health, targeting interventions and recording regulatory outputs, bound within the Integrated Management System.

APPROACH

All physical network assets in SPEN are managed utilising an Integrated Management System. This system 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).

The SPEN switchgear strategy is to add an additional stage, ‘Upgrade – Life Extension’, into the HV circuit breaker life cycle in order to improve the management of ageing assets (Figure 2). This additional stage helps identify the correct assets to be included in the retrofit plans. These assets would normally be considered for replacement, but with certain criteria and intervention, their life can be extended while maintaining acceptable standards of operation, within safe operating limits.

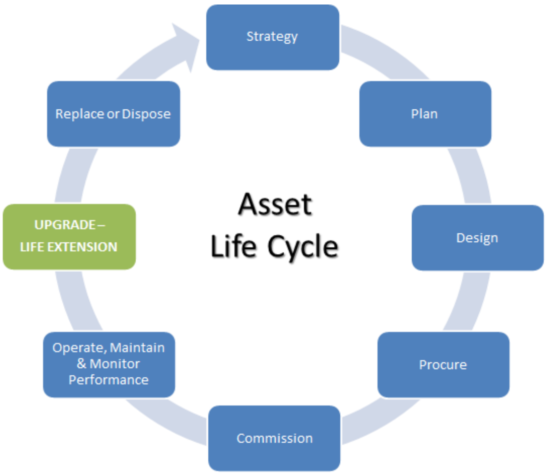

Figure 2: Asset Life Cycle with Life Extension Management

Management of ageing assets requires a good understanding of their condition, how that condition changes over time, and how carrying out maintenance in a timely manner minimises the risk of major accidents. There is evidence that asset age is not necessarily a reliable indicator of condition. Management of life extension requires the advanced and continuing assessment of assets to ensure they are fit for purpose, and safe to use when required to operate longer than their original design life. This is achieved in SPEN with the application of an Asset Management Assessment Methodology together with a robust inspection and maintenance policy.

Asset Management Assessment Methodology

SPEN’s Asset Management Assessment Methodology is based on a Condition Based Risk Management process (known as CBRM) that uses current asset information, engineering knowledge and practical experience to determine the current (and forecast) asset condition, performance and risk for key network assets [3].

CBRM expresses the condition of individual assets as a numeric Health Index (HI). The purpose of Health Indices is to provide a consistent indicator across all key network assets. The HI depends on collated engineering information, knowledge and experience from a variety of sources including corporate systems and local experts. 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.

Gauging the condition of assets by means of understanding their health, through the application of a Health Index, is an important element to managing the whole life cycle 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 utilised to facilitate the targeting of the optimum investment intervention; the more detailed and meticulous the condition assessment, the more accurately and efficiently investment can be targeted.

The Health Index assigns a relative health/condition value of between HI 1 and HI 5 (Figure 3) to each asset dependent on the factors affecting its health. The information that is used to generate the Health Index is based on [4]:

i) the age of the asset;
ii) the normal expected life for an asset, i.e. original design life;
iii) factors relating to aspects of the environment in which the asset is installed that may impact on its expected life (e.g. location factors);
iv) factors relating to the usage of the asset at its specific location that may impact on its expected life (e.g. duty factors);
v) factors relating to the observed condition of the asset;
vi) factors relating to the condition/health of the asset determined by measurements, tests or functional checks; and
vii) a factor relating to generic reliability issues associated with the individual make and type of an asset (e.g. known problems attributable to a manufacturer type).

Future asset health is derived using similar age based deterioration assumptions to those used in the calculation of the Heath Index. The rate of deterioration used for forecasting the future asset health is informed by the amount of deterioration that has already been observed for its current state (i.e. Health Index), age and future failure rates.

Figure 3: Health Index scores

Inspection and Maintenance policy

An important element in Life Extension is the assessment of the changing condition of an asset. This is achieved by the implementation of a robust inspection and maintenance policy. Without these, assets will deteriorate leading to reduction of performance, accelerated aging and compromising public and employee safety.

SPEN's HV circuit breaker (CB) inspections consist of:

- Annual visual inspection to gather observed condition information (Figure 4).

Asset	Component	Indicator	1	2	3	4	5
Oil Circuit Breaker	Moving Portion	Corrosion	<12yrs old, as new condition.	> 12yrs old, painting required, condition good.	Light Corrosion & Localised bubbling of paint	Significant Corrosion & Widespread flaking of paint	Delamination present
Oil Circuit Breaker	Moving Portion	Oil leaks	No leaks Visible	Infrequent staining apparent	Widespread staining	Oil visible	Components covered in oil
Oil Circuit Breaker	Fixed Portion	Compound/ Oil leaks	No leaks Visible		Leaking Joints		
Oil Circuit Breaker	Cable End Box	Compound/ Oil leaks	No leaks Visible		Cable End Box Leaking		Severe Leak Possibility of Insulation Failure

Figure 4: Observed Condition points for oil HV CBs

- Annual diagnostic tests to ascertain the health of the circuit breaker. Measured condition information includes trip/timing test, partial discharge and temperature measurements (Figure 5).

Asset	Measured Condition Input
11kV Primary CB	1. Partial Discharge 2. Ductor Test 3. IR Test 4. Oil Tests 5. Temperature Readings 6. Trip Test

Figure 5: Measured Condition points for oil HV CBs

Observed and Measured condition is then stored in SPEN corporate systems feeding into the circuit breaker Health Index calculation.

Additionally, SPEN's HV circuit breaker maintenance consists of:

- Major Maintenance every 12 years for oil circuit breakers or every 20 years for SF6 and vacuum circuit breakers. This includes a detailed intrusive examination. This may also include major dismantling and/or replacement of parts.
- Minor Maintenance as required following slow operation during operational checks and Major Maintenance after a fault clearance.

DECISION PROCESS

SPEN Switchgear Life Extension strategy uses decision process flowcharts to allow the correct switchgear to be targeted within the retrofitting plans as shown in Figure 6. The decision process uses the current HI and the forecasted HI after intervention, for both the fixed and moving portions.

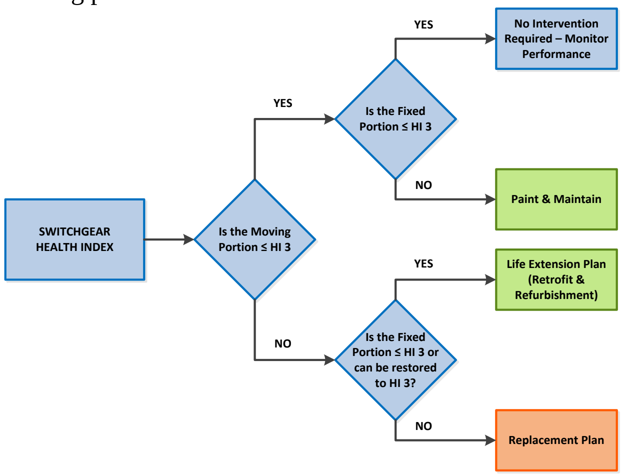

Figure 6: Switchgear Decision Process Flowchart

Retrofitting involves the replacement of the moving portion oil filled circuit breakers with modern vacuum circuit breakers and the refurbishment of the fixed portion.

Retrofitting of circuit breaker moving portions is only carried out where the fixed portion can be restored to a minimum of Health Index 3 (i.e. a mid-life asset). Prior to works an on-site survey is carried out to prove that there is no known partial discharge (PD) or associated corrosion issues.

A full cost benefit analysis, for the retrofit work to be carried out, is conducted before progressing with any solution. Factors such as heating, environment, civils and other associated switchgear and substation works are also considered as part of that analysis.

IMPLEMENTATION

SPEN's HV circuit breaker retrofit plan targets assets suitable for life extension; improving their asset health, extending the asset life and the reducing risk associated with this high volume key asset. Examples of the results that are able to be achieved utilising the above strategy is highlighted in the following case studies.

Case Study 1

A 50 year old AEI type BVP17 11kV oil circuit breaker was identified for Life Extension. Its moving portion was categorised as HI4 and its fixed portion as HI3.

The retrofitting works were split into two phases:

- Phase 1 – Enhanced Maintenance / Inspection of the 11kV fixed portions and protection relays.
- Phase 2 – Retrofitting of the 11kV moving portions with new 11kV vacuum circuit breaker.

Figure 7 shows the circuit breaker before and after retrofitting.

Figure 7: AEI BVP17 CB before and after retrofitting

Case Study 2

A 46 year old Reyrolle type LMT 11kV oil circuit breaker was identified for Life Extension. Its moving portion was categorised as HI5 and its fixed portion as HI4.

The retrofitting works were split into two phases:

- Phase 1 – Enhanced Maintenance / Inspection of the 11kV fixed portions. Arc doors, end blast sheets and new top boxes fitted with new control & protection.
- Phase 2 – Retrofitting of the 11kV moving portions with new 11kV vacuum circuit breaker.

Figure 8 shows the circuit breaker before and after retrofitting.

Figure 8: AEI BVP17 CB before and after retrofitting

After the retrofitting work was completed the condition of the switchgear was substantially improved, extending its life expectancy up to 20 years. The new scores Heath Index, resulting from the intervention, were suitably recorded in the asset register.

CONCLUSIONS AND NEXT STEPS

Deployment and installation of retrofit HV circuit breakers is an economic and deliverable solution. It is designed to be safely fitted in the existing fixed portion with minimum network disruption.

Retrofitting provides the additional benefits of:

- Extending the life expectancy of existing legacy switchgear by up to 20 years
- Improved performance and reliability
- Reduced maintenance and removal of circuit breaker manual spring charging
- Improvement of Health & Safety and environmental impact by removal of oil
- Addition of automation for better network management and reduction of interruption times
- No civil works required as existing fixed portion and cabling remains undisturbed

Nonetheless, it should be noted that retrofitting might throw up new potential failure modes and issues which would not be evident or considered during the original switchgear life. In order to mitigate against this the following actions have been taken to identify any potential asset life extension issues:

- New and old asset plant and equipment registered in the asset register
- Understanding of current condition, and where applicable historical review
- A systematic assessment of asset performance and data gathering to support life extension goals and requirements

REFERENCES

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