Document 6
Asset Category – EHV Switchgear
SPN

Asset Stewardship Report 2014

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Document History

Version	Date	Details	Originator	Revision Class	Section Update
1.0	20/02/2014	July 2013 Submission	Richard Gould		
1.1	20/02/2014	Expenditure tables and charts updated with 19th February S&R NAMP figures	Richard Gould	Major	Header, 1.1, 1.3, 1.5, 7.4, Appendix 5
1.2	20/02/2014	Updated Appendix 7 with list of scheme papers and added Appendices 8-10	Richard Gould	Minor	1.1, Appendix 7, 8, 9, 10
1.3	24/02/2014	Updated HI Profiles and added Preface	Richard Gould	Minor	7.2, 7.8, Appendix 2
1.4	26/02/2014	Figure and table numbers added to Appendices. Network risk removed from section 7.8.	Richard Gould	Minor	7.8, Appendix 1-10
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Preface

UK Power Networks uses Asset Stewardship Reports ('ASR') to describe the optimum asset management strategy and proposals for different groups of assets. This optimised asset management strategy and plan details the levels of investment required and the targeted interventions and outputs needed. Separate ASRs define the most efficient maintenance and inspection regimes needed and all documents detail the new forms of innovation which are required to maximise value, service and safety for all customers and staff throughout the ED1 regulatory period. Outline proposals for the ED2 period are also included.

Each DNO has a suite of approximately 20 ASR's. Although asset policy and strategy is similar for the same assets in each DNO the detailed plans and investment proposals are different for each DNO. There are also local issues which must be taken into account. Accordingly each DNO has its own complete set of ASR documents.

A complete list of titles of the ASR's, a summary of capex and opex investment is included in '**Document 20: Asset Stewardship Report: Capex/Opex Overview'**. This document also defines how costs and outputs in the various ASR's build up UK Power Networks 'NAMP' (Network Asset Management Plan) and how the NAMP aligns with Ofgem's ED1 RIGs tables and row numbers.

Where 'HI' or asset 'Health Index' information is included please note predicted ED1 profiles are before any benefits from 'Load driven investment.'

This ASR has also been updated to reflect the feedback from Ofgem on our July 2013 ED1 business plan submission. Accordingly to aid the reader three additional appendices have been added. They are;

1. **Appendix 8 – Output NAMP/ED1 Business Plan Data Table Reconciliation:** This section explains the 'line of sight' between the UKPN Network Asset Management Plan (NAMP) and the replacement volumes contained in the Ofgem RIGS tables. The NAMP is the UKPN ten year rolling asset management investment plan. It is used as the overarching plan to drive both direct and indirect Capex and Opex interventions volumes and costs. The volume and cost data used in this ASR to explain our investment plan is taken from the UK Power Networks NAMP. Appendix 8 explains how the NAMP outputs are translated into the Ofgem RIGS tables. The translation of costs from the NAMP to the ED1 RIGS tables is more complex and it is not possible to explain this in a simple table. This is because the costs of a project in the 'NAMP' are allocated to a wide variety of tables and rows in the RIGS. For example the costs of a typical switchgear replacement project will be allocated to a range of different Ofgem ED1 RIGs tables and rows such as CV3 (Replacement), CV5 (Refurbishment) CV6 (Civil works) and CV105 (Operational IT Technology and Telecoms). However guidance notes of the destination RIGs tables for NAMP expenditure are included in the table in the Section 1.1 of the Executive Summary of each ASR.
2. **Appendix 9 – Efficiency benchmarking with other DNO's:** This helps to inform readers how UK Power Networks is positioned from a benchmarking position with other DNO's. It aims to show why we believe our investment plans in terms of both

volume and money is the right answer when compared to the industry, and why we believe our asset replacement and refurbishment investment proposals are efficient and effective and in the best interest for our customers.

3. **Appendix 10 – Material changes since the July 2013 ED1 submission:** This section shows the differences between the ASR submitted in July 2013 and the ASR submitted for the re-submission in March 2014. It aims to inform the reader about the changes made to volumes and costs as a result of reviewing the plans submitted in July 2013. Generally the number of changes made is very small, as we believe the original plan submitted in July 2013 meets the requirements of a well justified plan. However there are areas where we have identified further efficiencies and improvements or recent events have driven us to amend our plans to protect customer safety and service.

We have sought to avoid duplication in other ED1 documents, such as ‘Scheme Justification Papers’, by referring the reader to key issues of asset policy and asset engineering which are included in the appropriate ASR documents.

Contents

1.0 Executive Summary SPN EHV Switchgear

1.1 Scope

This document details UK Power Networks' non-load related expenditure (NLRE) investment proposals for EHV switchgear for the RIIO-ED1 period. Indicative proposals for the ED2 period are also included.

There are 789 items of EHV switchgear in SPN with an estimated MEAV of £114m. The proposed investment including civils is £0.3m per annum, which equates to an average annual 0.3% of the MEAV for this asset category.

Replacement and refurbishment costs for these assets during ED1 can be seen in Table 1. Appendix 8 contains a reconciliation between NAMP volumes and RIGs volumes.

Investment type	ED1 total expenditure	NAMP line	RIGs reference
Replacement	£1.2m	1.48	Additions CV3 Row 69 – 33kV CB (Air Insulated Busbar)(ID)(GM) CV3 Row 70 – 33kV CB (Air Insulated Busbar)(OD)(GM) CV3 Row 71 – 33kV CB (Gas Insulated Busbar)(ID)(GM) CV3 Row 72 – 33kV CB (Gas Insulated Busbar)(OD)(GM) CV3 Row 74 – Switchgear (other) Removals CV3 Row 197 – 33kV CB (Air Insulated Busbar)(ID)(GM) CV3 Row 198 – 33kV CB (Air Insulated Busbar)(OD)(GM) CV3 Row 199 – 33kV CB (Gas Insulated Busbar)(ID)(GM) CV3 Row 200 – 33kV CB (Gas Insulated Busbar)(OD)(GM)
Refurbishment	£0.4m	1.48	CV5 Row 33 – 33kV CB (GM)

Table 1 – Investment plan

Source: 21st February 2014 ED1 Business Plan Data Tables

*Expenditure on this asset type is also included in CV6 Civils and CV3 Underground Cables.

A full list of abbreviations is included in Section 6.0 of *Document 20: Capex Opex overview*.

1.2 Investment Strategy

The investment plan for ED1 for EHV Switchgear has been developed using the Asset Risk and Prioritisation (ARP) model. The plan focuses on items of switchgear that are in poor condition or are providing poor service and reliability; not items of switchgear that are old.

The strategy for selecting the level of investment required has been to maintain the same level of risk throughout the period. This has been done by keeping a similar number of HI4s and HI5s at the start and end of the period.

1.3 ED1 Proposal

The proposal for ED1 includes 17 replacements and eight refurbishments across the eight years at a total cost of £2.2m. DPCR5, which when adjusted for an eight-year period, had 72 replacements and no refurbishments at a total cost of £5m.

Appendix 9 benchmarks our ED1 proposals with reference to other DNOs July 2013 submissions. It shows that for EHV Switchgear we are proposing to replace 2% of our assets while other DNOs were seeking funding to replace 14% of these assets on average. This demonstrates the effectiveness of our asset risk management systems and the value for money of our proposals.

1.4 Innovation

As mentioned in section 1.2, the ARP model has been used to develop the investment plan. The model, which has been developed for EHV Switchgear as well as other asset categories, is industry-leading and uses environment, condition and manufacturer/model information to determine a Health Index for every asset currently and in the future. This has been developed with EA Technology.

The model is able to calculate a criticality index for every asset, as well as a risk value in monetary terms, though this part of the model is still in development. The risk for individual assets has not been looked at in this way before.

1.5 Risks and Opportunities

	Description of similarly likely opportunities or risks arising in ED1 period	**Uncertainties (£m)**
Opportunity	Refurbishment options become available 20% more often than planned	(0.3)
Risk	Cannot undertake refurbishment options	1.3
Risk	Cost of refurbishment rises by 20% for planned refurbishment interventions in ED1 period	0.1

Table 2 – Risks and opportunities

2.0 Description of EHV Switchgear Population

2.1 33kV and 25kV Switchgear

There are 798 circuit breakers, ring main units and ground-mounted switches currently operating at 33kV on the network. There is no 25kV switchgear operating on the network. The 33kV switchgear is distributed across 79 substation sites, with 781 units installed at indoor locations and 17 at outdoor locations. These are split into the three categories of switchgear as shown in Table 3.

Switchgear arc extinction method	Population
Oil	392
SF_6	155
Vacuum	251

Table 3 – EHV Switchgear type

Source: ARP Model 27th November 2012

It can be seen from the age profile in Figure 1 that there was significant investment in the 1960s resulting in an ageing switchgear fleet. The average age is 31 years. All of the pre-1980s switchgear is Reyrolle L42T or L45T switchgear. The oldest 10% of these assets have an average age of 54 years.

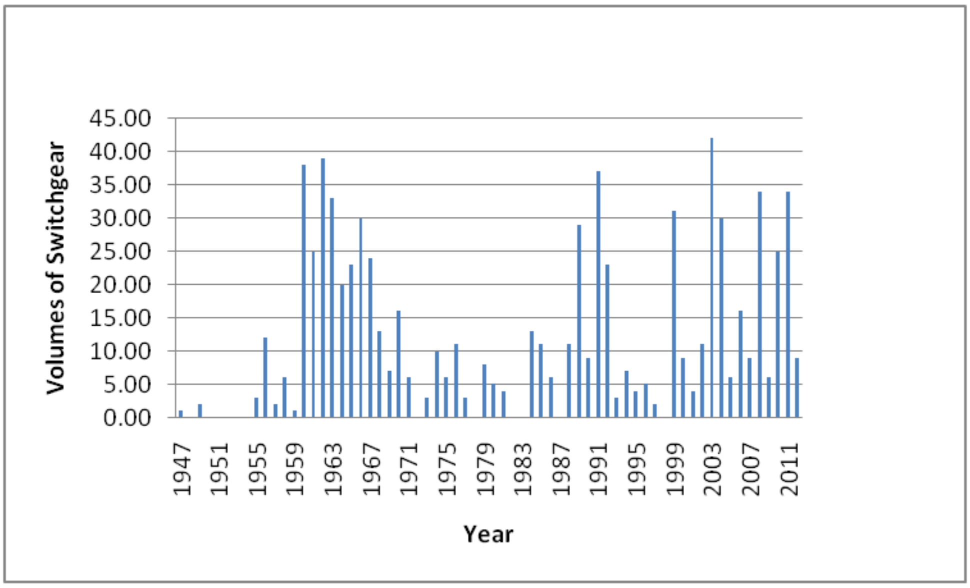


Figure 1 – EHV Switchgear age profile

Source: 2012 RIGs V5

The NAMP lines used for EHV switchgear can be seen in Table 4.

NAMP line	Description
1.48.02	Replace 33kV switchgear
1.48.11	Replace with 33kV indoor GIS
1.48.12	Replace with 33kV outdoor open terminal CB
1.48.13	Replace with 33kV outdoor GIS

Table 4 – EHV Switchgear NAMP lines

Refer to Table 5 and Table 6 for the mappings for additions and removals in the RIGs tables.

Description	Table	Row
33kV CB (Air Insulated Busbar)(ID)(GM)	CV3	69
33kV CB (Air Insulated Busbar)(OD)(GM)	CV3	70
33kV CB (Gas Insulated Busbar)(ID)(GM)	CV3	71
33kV CB (Gas Insulated Busbar)(OD)(GM)	CV3	72
33kV CB (GM)	CV5	33

Table 5 – Additions and refurbishments RIGs mappings

Description	Table	Row
33kV CB (Air Insulated Busbar)(ID)(GM)	CV3	197
33kV CB (Air Insulated Busbar)(OD)(GM)	CV3	198
33kV CB (Gas Insulated Busbar)(ID)(GM)	CV3	199
33kV CB (Gas Insulated Busbar)(OD)(GM)	CV3	200

Table 6 – Removals RIGs mappings

3.0 Investment Drivers

3.1 Investment Drivers

Investment drivers for switchgear can be split into two categories: internal condition and external condition. External condition factors include paint condition and corrosion of any part of the switchgear. On outdoor sites, the condition of air-insulated busbars and any concrete or steel support structures will also be considered. Internal considerations can include mechanism wear and circuit breaker trip times.

As mentioned in section 2, all pre-1980s switchgear on the network is Reyrolle L42T or L45T – indoor withdrawable oil circuit breakers. There are 388 remaining on the network. The circuit breaker has generally proved to be reliable; however, problems are being experienced at a few sites.

Figure 2 – Reyrolle L42T switchboard

Figure 3 shows the circuit breaker trip times of the switchgear since 2007. The circuit breaker trip time is the time a circuit breaker takes to open following a fault or an open command from control. In Figure 3, the x axis shows the time recorded of a number of circuit breaker trips, going from earliest on the left of the graph to the most recent. It shows that trip times have increased by 10% over the six years. A slower trip time increases the chance of the circuit breaker upstream operating, as described in section 4.3, and is therefore a driver for intervention.

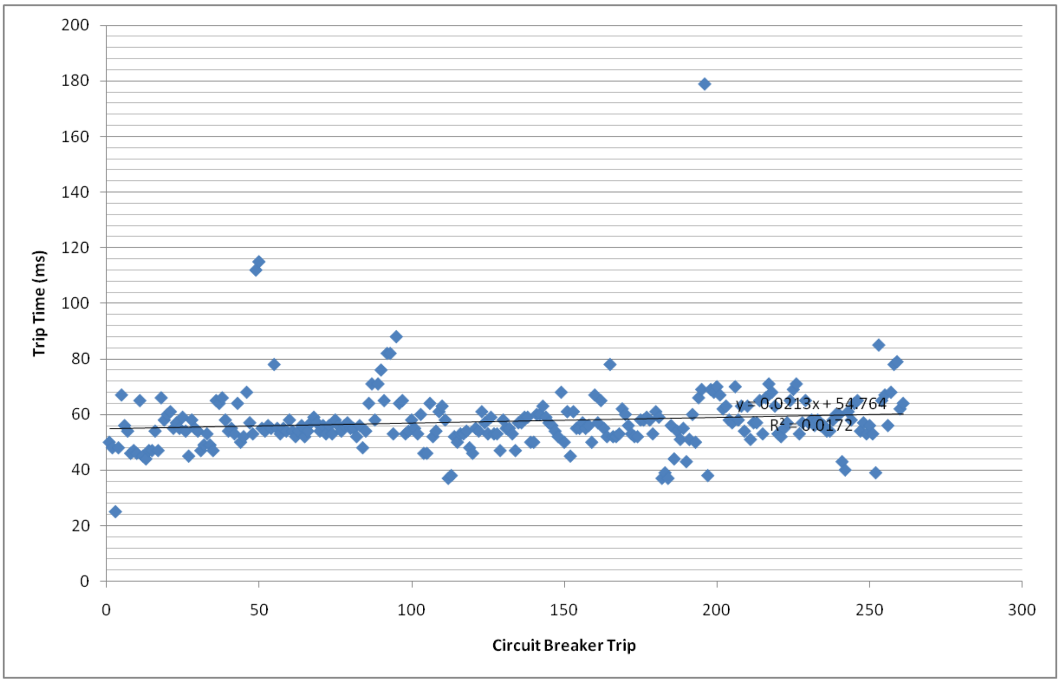


Figure 3 – Reyrolle L42T and L45T trip times

Source: Ellipse

There are a number of switchgear defects that are seen as critical in the ARP model, which is described in section 4. As defects are found or cleared, they are recorded in the Ellipse asset register using the handheld device (HHD). Defects can be captured either on an ad hoc basis or at each inspection and maintenance.

Measure	Inspection	Maintenance
Compound leak	Yes	Yes
Control cubicle	If present	If present
External connections	If present	If present
Gasket	If present	If present
Oil level	Yes	Yes
Oil sight glass	Yes	Yes
Partial discharge	Yes	Yes
SF_6 gas pressure	Yes	Yes
Shutter mechanism	No	Yes

Table 7 – Defects used in ARP model

In calculating the Health Index, the ARP model counts the total number of defects recorded against individual items of plant; not just those currently outstanding. These defects are described in more detail below.

- Compound leak – To provide an impulse voltage rating, bitumen compound was used as an insulation medium in busbars, CT (current transformer) chambers and cable termination boxes on older metal-clad switchgear. If any compound leaks out, the impulse rating is reduced, with the risk of a disruptive failure if the equipment is subject to an overvoltage.
- Control cubicle – This is a means of recording defects in the small wiring, auxiliary fuses and terminal blocks associated with the control of the circuit breaker. These defects can prevent the CB from operating correctly with a resultant impact on Customer Interruptions (CIs) and Customer Minutes Lost (CMLs).
- External connections – For 33kV circuit breakers, this records defects with the bushings of the switchgear and associated busbar connections. A problem here can result in overheating and eventual disruptive failure.
- Gasket – For oil-filled switchgear, this records defective gaskets. No action is needed immediately, but, if left unchecked, this can result in a low oil level.
- Oil level – For oil-filled switchgear, this shows that the oil level is low and needs to be topped up. If left unchecked, this can result in a disruptive failure.

Figure 4 – Reyrolle L42T Oil Leak

- Oil sight glass – For oil filled switchgear, this shows that the oil sight glass is unreadable, broken or missing. If left unchecked, it can result in a disruptive failure.
- Partial discharge – This shows that partial discharge has been recorded, which, if left, unchecked can result in disruptive failure.
- SF_6 gas pressure – SF_6 gas is used as an insulating medium. If the pressure falls below the rated value, the equipment could fail disruptively if left in service.
- Shutter mechanism – For withdrawable switchgear only, this records defects with the mechanism used to cover the busbar and circuit spouts when the breaker is withdrawn from its housing. Broken mechanisms represent a serious risk to operator safety.

Figure 5 shows the number of defects that have been recorded against the Reyrolle L42T and L45T since 2007. There is an increasing number of defects during the period.

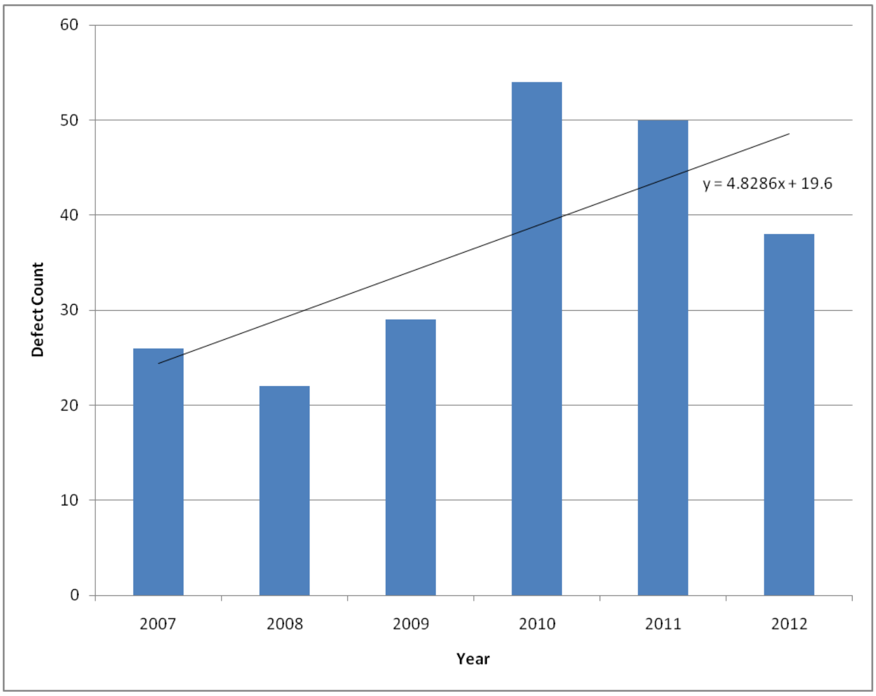


Figure 5 – Reyrolle L42T and L45T defects

Source: ARP Model 25th July 2012

The age of an asset when a new defect was reported on it is shown in Figure 6, plotted against the ages of assets currently on the network. There are defects at ages where there are currently no assets, as those assets have either aged or been removed from the network since the defect was reported. This shows that the Reyrolle L42T and L45T still provide reliable service, but at some sites, defects are posing a risk to the network and personnel. This risk increases the chance of a catastrophic failure at one of these sites.

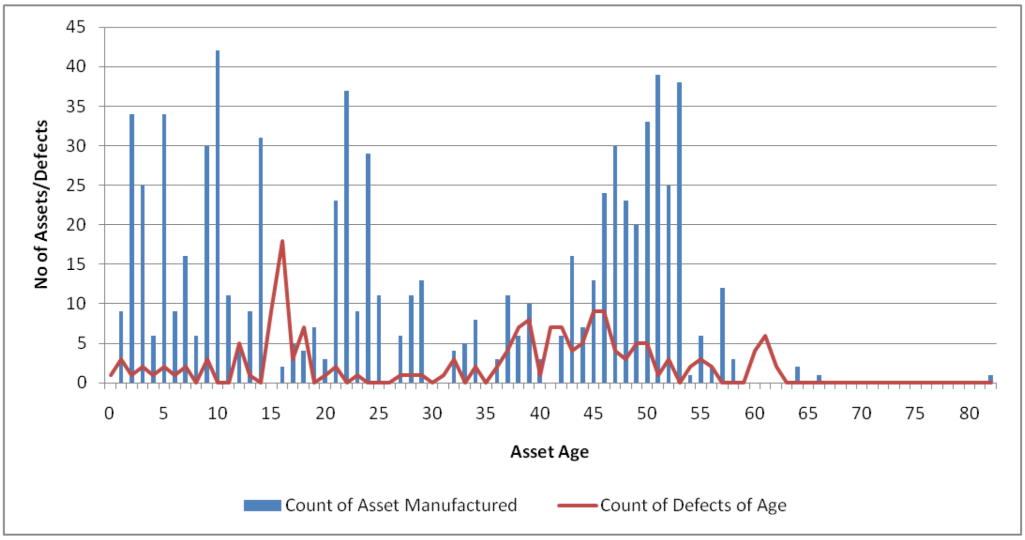


Figure 6 – EHV Switchgear defects by asset age

Source: Ellipse Extract 19/02/2013 and 2012 RIGs V5

Figure 7 shows the fault rate for all faults relating to switchgear, and split by i) faults caused by the condition of the switchgear and ii) non-condition-related faults. Non-condition-related faults would include damage to the switchgear caused by a third party, and would not necessarily be reduced by intervention. This shows that there is an increasing amount of faults being caused by switchgear and therefore an increase in CIs and CMLs for customers.

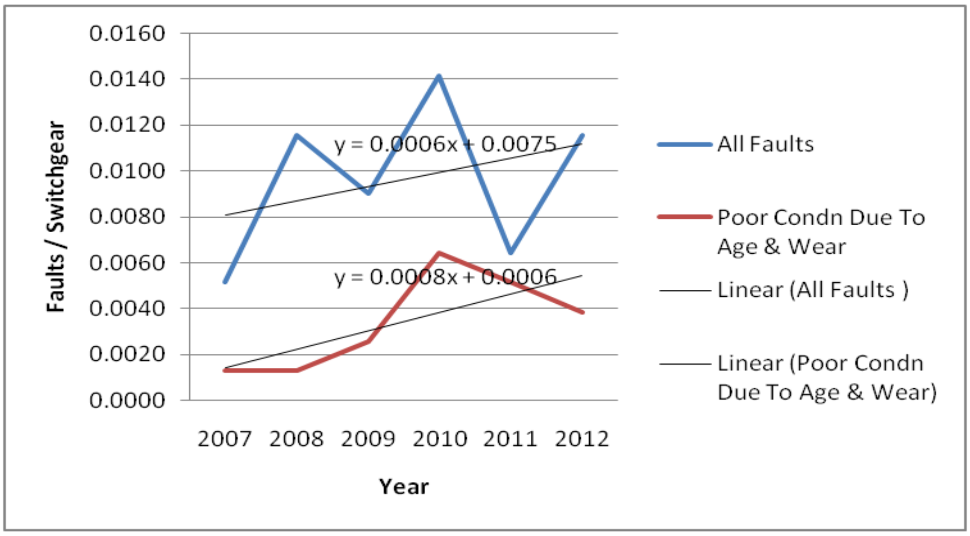


Figure 7 – EHV Switchgear fault rate

Source: UK Power Networks Fault Analysis Cube

3.2 Condition Measurements

3.2.1 Substation inspection

The main source of asset external condition data is from substation inspectors. As such, during the first half of DPCR5 a review of the *Substation Inspectors' Handbook* was carried out and a new handbook was issued. Each inspector was required to undertake a two-day training course and pass the theory and practical examinations before being certified as a competent inspector.

Figure 8 – Substation inspector with HHD

In order to ensure good quality data is captured and recorded in the asset register in a timely manner, handheld devices (HHD) are used on site at the point of inspection to record it in the correct format within the asset register (Ellipse). When an inspection HHD script is run, the user answers set questions, specific to each asset type, about the condition. This allows defects to be recorded, reviewed and cleared. The inspection scripts have been designed to be as objective as possible so that there is consistency across the whole network.

Inspections are carried out at a set frequency, which is recorded in EMS 10-0002 *Inspection and Maintenance Frequency Schedule*. For grid and primary substations with wet cell batteries, two minor inspections and one major inspection are carried out annually; for substations with dry cell batteries, one minor inspection and one major inspection are carried out annually. Switchgear is inspected at both minor and major inspections.

3.2.2 Maintenance

There are two routine maintenance tasks carried out on EHV switchgear: mechanism maintenance and a full maintenance. The two maintenance tasks are carried out alternatively at six-year periods, as recorded in EMS 10-0002 *Inspection and Maintenance Frequency Schedule*. A circuit breaker operation is also carried out yearly for bus section and transformer breakers, and every two years for feeder breakers.

Maintenance fitters also use the same HHD technology to record their assessments of the internal and external condition of the assets being maintained. This assessment is made twice, to provide condition data ‘as found’ and ‘as left’.

The key condition points recorded during maintenance are the circuit breaker trip time, overall internal condition, condition of operating mechanism and condition of isolating contacts. For oil circuit breakers, an onsite oil test is also carried out.

4.0 Asset Assessment

4.1 Asset Health

An innovative asset health modelling tool, Asset Risk and Prioritisation (ARP) model, has been developed for several asset categories, including EHV Switchgear. The methodology behind the modelling is the same for all asset categories, but the switchgear model has been tailored specifically to use the data collected to assess against the identified investment drivers for switchgear.

The general methodology for the ARP model can be found in *Commentary Document 15: Model Overview*. The EHV switchgear ARP model uses the age, location information and condition data of an asset to calculate its Health Index. An initial HI is calculated based on the year of manufacture, expected average initial life, the environment the asset is installed in, and the duty of the switchgear during its life. The environmental factors considered are the distance from coast, whether it's indoors or outdoors, and the level of pollution. The function of the switchgear, whether it is a feeder, bus section, or transformer breaker, is used to account for the duty. An average initial life is assigned per make and model of switchgear to show the expected time from when the asset was manufactured until it shows signs of increased deterioration. It is not the time from when the asset is commissioned until it is decommissioned. This initial HI is capped at HI3 to ensure assets will never achieve a HI greater than 3 and therefore be considered for intervention on the basis of age alone.

A factor value is then calculated using condition, defects and switchgear reliability data. The condition and defect data is obtained from the asset register, Ellipse, and input into the model. The reliability is assigned based on the make and model of the switchgear. There are a number of condition points that force the HI to a minimum of HI5, including external condition of housing and the number of SF_6 top-ups. Assets showing poor condition in these measures regardless of asset age must be flagged, as they will have a higher probability of failure.

This factor value is then combined with the initial HI to produce the current HI of the asset.

4.2 Asset Criticality

The ARP model can also be used to calculate the criticality of a particular switchgear asset. This is then output in the form of a Criticality Index 1 to 4, with 1 being the least critical and 4 being the most critical. A detailed methodology for calculating the criticality index can be found in *Commentary Document 15: Model Overview*. The criticality section of the ARP model is under development.

In the switchgear model, five main areas are considered when calculating the criticality of an asset: network performance, safety, operational expenditure, capital expenditure and environment. A number of key factors are considered in each of these areas.

For network performance, the key factors for the switchgear model are the number of customers that the substation feeds and the function of the asset. The function of the switchgear can be either a feeder breaker, bus section or transformer breaker, with a bus section breaker being the most critical and a feeder breaker being the least critical.

The factors considered for the safety criticality specific to switchgear are the arc extinction method, and whether the switchgear is internally arc rated. The arc extinction method plays a large part in the safety of a particular type of switchgear, with oil switchgear considered the most dangerous method and therefore the most critical in the model. Items of switchgear that aren't internal arc rated are considered more critical that switchgear that is.

The operational and capital expenditure sections both consider the difference in criticality between assets in terms of maintenance costs between makes and models of switchgear and capital expenditure for different voltage levels.

Finally, the environment section considers the effect that different types of insulation have on the environment. The volume of gas and oil is also considered.

4.3 Network Risk

The network risk in monetary terms can also be calculated in the ARP model. This is done using the probability of failure, the criticality, and the consequence of failure, although it is still under development. The probability of failure is calculated using the current Health Index of the item of switchgear, and the criticality is calculated as described in the previous section. The consequence of failure is the average cost to either repair or replace the item of switchgear following one of four failure modes. The failure modes used are detailed in Table 8. The effect of risk can be seen in section 7 of this document.

Failure mode	Description
Minor	Can be repaired in-house
Significant	Can be repaired using external resource
Major	Beyond repair –disruptive failure ***or*** sent away for repair
Failure to trip	No repair needed

Table 8 – Network risk failure modes

Although no repair is needed for the failure to trip mode, post-fault maintenance will be carried out to investigate the cause of the stuck circuit breaker. Stuck or slow operating breakers have a big impact on customers, as they result in increased CIs and CMLs. This is because the circuit breaker upstream will operate if a feeder circuit breaker fails to trip or is slow to trip during a fault. The circuit breaker upstream will usually be the transformer breaker that feeds the bus section, meaning the bus section will be lost. The loss of the bus section will result in an increased number of customers affected than if just the original feeder was lost.

4.4 Data Validation

All data used in the ARP model is subject to validation against a set of data requirements. The requirements ensure data is within specified limits, up to date and in the correct format for use in the model. On completion of the validation process, an exception report is issued that provides details of every non-compliance, enabling continual improvement of data quality.

An example of this is the circuit breaker trip times that are used in the model. These values have to be between 10 and 1,000ms, otherwise they are discarded and not used in the model. There is also an age limit on the condition data that is used in the model; no data recorded more than five years ago is used. This is to ensure that the outputs of the model are describing the current asset rather than its past condition.

4.5 Data Quality

The completeness, accuracy and timeliness of the data used in the ARP model are routinely checked and a CAT score is produced. The latest results for the data used in the EHV Switchgear model are given in Table 9.

The score is colour coded as follows.

- Green – Score of 85% or greater
- Amber – Score of 65-84%
- Red – Score of less than 65%

Area	Score
Completeness	69%
Accuracy	89%
Timeliness	98%

Table 9 – EHV Switchgear CAT score

Source: Ellipse Extract 27/11/2012

The completeness score is a combination of switchgear nameplate data and condition data. Information used on the nameplate includes the year of manufacture, the operating voltage, circuit breaker function and any other information that will remain constant during an asset's life. Condition data is recorded by substation inspectors, as described in section 3.2, and will change with time. The completeness of any data used in the network risk section of the model, such as customer numbers, is also included.

There has been investment to improve and consolidate the nameplate completeness during DPCR5. As with the nameplate information, there has been a project during DPCR5 to improve the completeness of the condition data, and this has led to some new condition points being created. Due to this, in some cases the condition point may not be populated until the next maintenance.

The accuracy score is a measure of the reliability and correctness of the condition data stored in Ellipse. This is done by comparing the condition measure recorded by UK Power Networks with the same measure recorded by an independent third party, SKM.

The timeliness score shows the percentage of assets that have condition data recorded within the expected time period, as stated in EMS 10-0002 *Inspection and Maintenance Frequency Schedule*.

5.0 Intervention Policies

5.1 Interventions: Description of Intervention Options

Two categories of intervention were initially considered for EHV Switchgear: replacement and refurbishment. Examples of refurbishment that could take place include replacement of the operating mechanism or replacement of seals and pipework to solve any problems with SF_6 leaks.

There are a number of options available for the replacement of switchgear, depending on the plant that is currently on the site. These are shown in Table 10.

Option	Description	Advantages	Disadvantages
Outdoor AIS solution	This option uses outdoor circuit breakers, for example the Hawker Siddeley Switchgear Horizon (refer to Figure 9). Existing outdoor busbars can be reused, depending on condition.	Cheaper than indoor solution. Can reuse existing busbar. Replacement of individual circuit breakers possible.	Requires a lot of space. Can't always reuse busbar due to poor-condition support structures. Prone to deterioration as outdoors. Trespass risk resulting in security/safety issues.
Indoor GIS solution	Replacement of switchgear with panel type gear, such as the ABB ZX1.2 switchboard (refer to Figure 10). Will be located indoors.	Requires small foot compared to outdoor switchgear. Longer life as indoors, so less deterioration due to weather.	Civil costs can be expensive. May have to replace whole board for extensions of board.

Table 10 – Replacement options

Figure 9 – Hawker Siddeley Switchgear Horizon

Figure 10 – ABB ZX1.2 switchboard

5.2 Policies: Selecting Preferred Interventions

The process used for selecting interventions can be seen in Figure 11. The process is different, depending on whether the switchgear is part of a switchboard or a standalone unit.

If the switchgear is part of a switchboard, the whole board would need to be replaced, whereas refurbishment could be carried out on individual unit. However, in most cases, the switchboard will contain circuit breakers of the same model, same year of manufacture, same environmental conditions and same maintenance engineers, so should be in similar health.

If the switchgear is a standalone unit, it can be either refurbished or replaced as an individual item of switchgear. If there are multiple items of switchgear on the site, the condition and health of the other assets have been considered in case it is efficient to replace them at the same time. If modern switchgear is replaced as part of one of these projects, this can be reused at a different site or as a strategic spare.

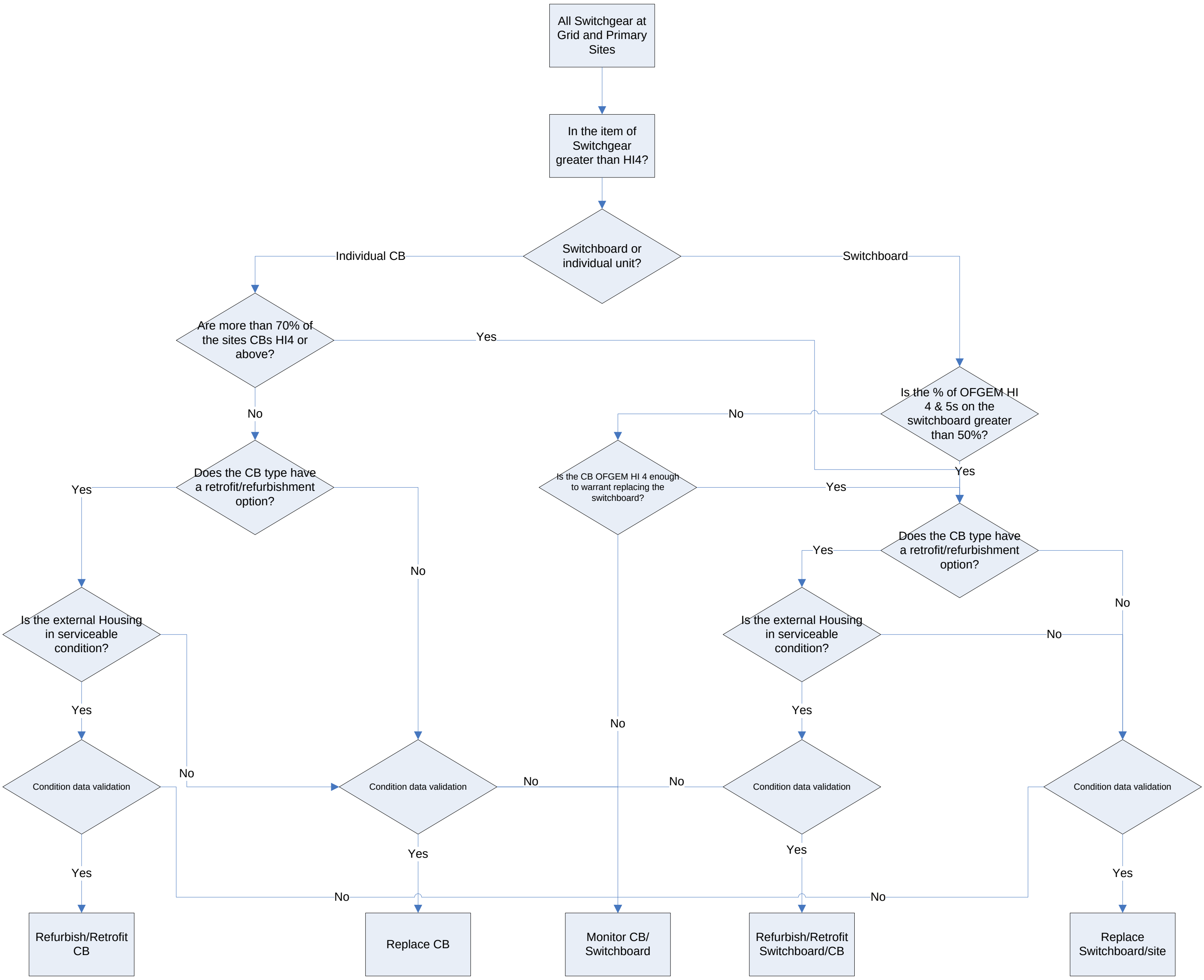


Figure 11 – Intervention strategy process

The capital expenditure plan for EHV Switchgear can lead to cost savings in operational expenditure. The maintenance costs of oil switchgear are higher than modern equivalents and tend to suffer more defects, so replacement of oil switchgear will reduce maintenance costs.

Figure 12 shows the cost of maintenance over a 58-year period, which is the average initial life of an asset. This value is calculated as an average across all 3 of UK Power Networks licence areas (refer to *Commentary Document 15: Model Overview*, section 8, for an explanation of average life). The maintenance costs of oil circuit breakers are 138% more than an SF_6/vacuum outdoor circuit breaker.

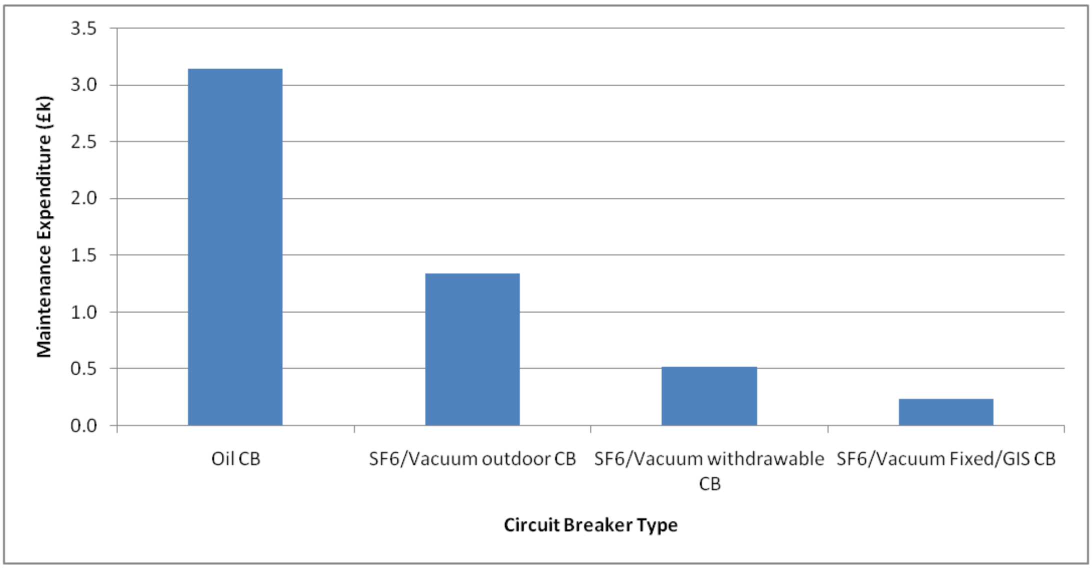


Figure 12 – EHV Switchgear maintenance costs

Source: EMS 10-0002 Inspection and Maintenance Frequency Schedule

6.0 Innovation

As mentioned in section 4, an innovative new model has been used to develop the plan, the Asset Risk and Prioritisation (ARP) model. The model, which has been developed for EHV Switchgear, as well as other asset categories, is industry-leading and uses environment, condition and manufacturer/model information to determine a Health Index for every asset currently and in the future. This has been developed with EA Technology.

The model is able to calculate a criticality index for every asset, as well as a risk value in monetary terms, though this part of the model is still in development. The risk for individual assets has not been looked at in this way before.

7.0 ED1 Expenditure Requirements for EHV Switchgear

7.1 Method

Figure 13 shows an overview of the method used to construct the ED1 NLRE investment plans.

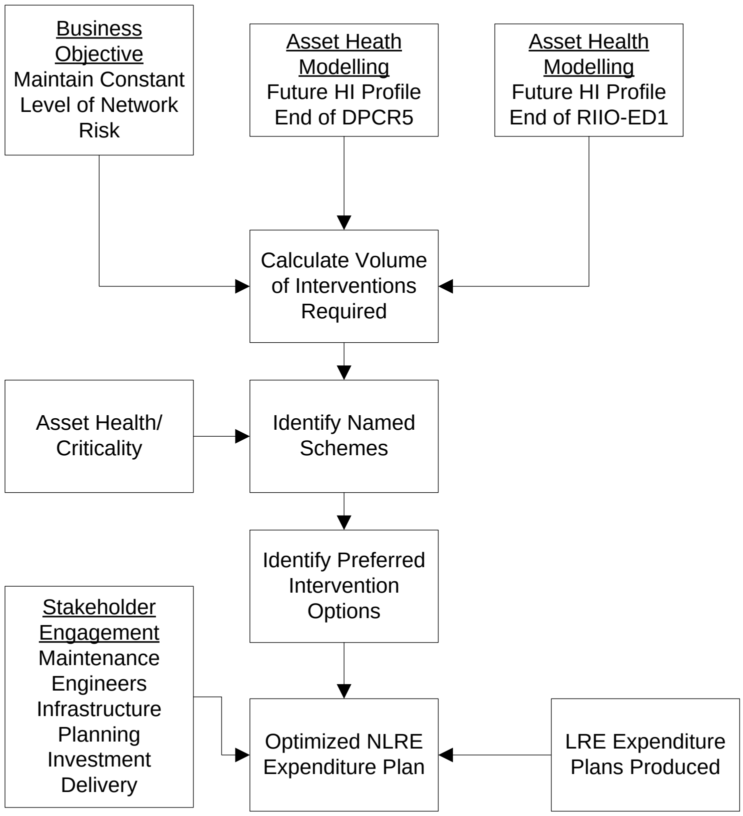


Figure 13 – Programme development methodology

7.2 Constructing the Plan

The overall strategy for non-load related expenditure on EHV switchgear during ED1 has been to maintain the level of risk, so that it is the same at the end of the period as it was at the beginning – keeping the same number of HI4s and HI5s at the beginning and end of the period. The HI profiles are outputs from the ARP model. The HI profiles for the start and end of ED1 can be seen in Figure 14.

At the start of the period, the number of HI4s and HI5s is 0.4% of the total population, and at the end of the period is 2.3%. The increase is due to a small proportion of circuit breakers on a switchboard being HI4s and HI5s, with the rest of the board being HI3. In these cases, it was not deemed economic for the whole switchboard to be replaced, so the circuit breakers will remain on the network and be monitored, as shown in the intervention strategy process in Figure 11.

The HI profiles indicated are derived from condition related investment only and exclude the contribution from load related expenditure.

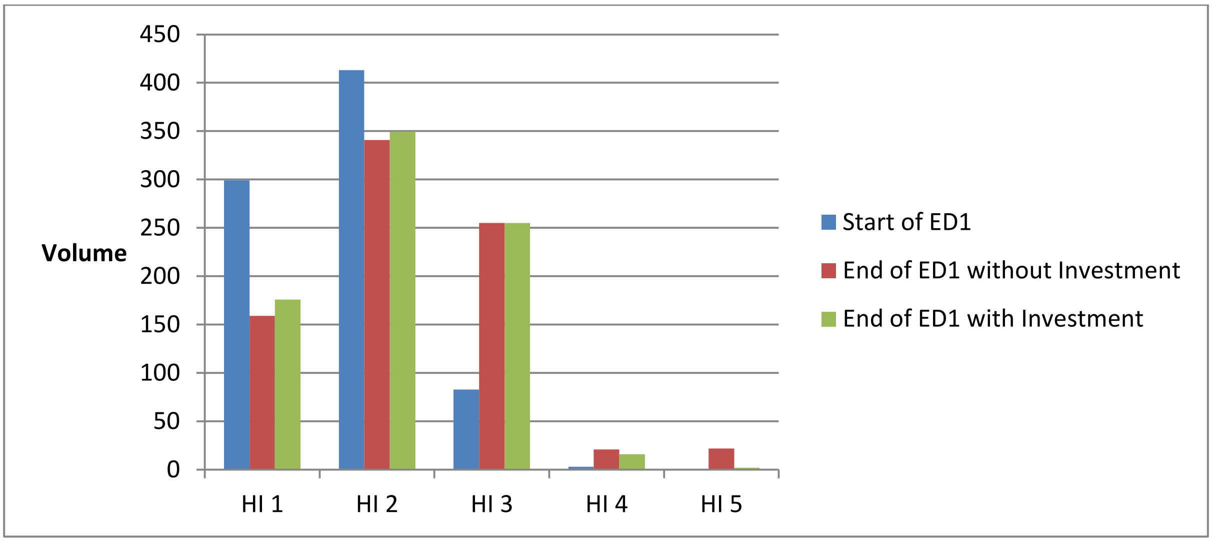


Figure 14 – ED1 HI profiles

Source: ARP Model 25th July 2012

Figure 15 shows the number of HI4s and HI5s with and without investment currently, and at the beginning, middle and end of ED1.

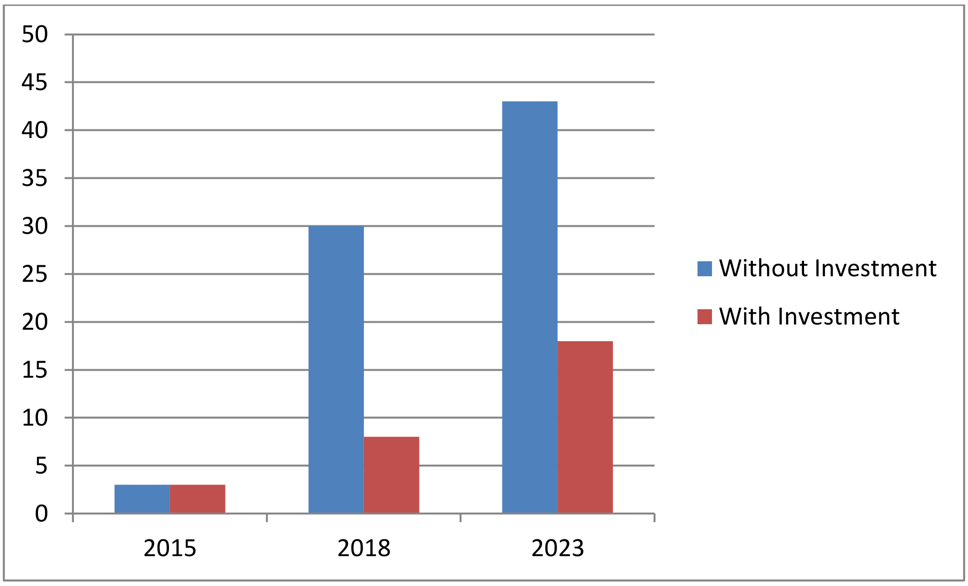


Figure 15 – Total number of HI4s and HI5s

Source: ARP Model 25th July 2012

7.3 Additional Considerations

There are a number of additional requirements that need to be considered when constructing the plan, with the two major factors being other NLRE investments, and LRE investments required at the site during ED1.

The main NLRE schemes that will affect EHV Switchgear projects are switchgear of other voltages interventions and transformer interventions at sites. If these schemes are within five years of the EHV Switchgear scheme, consideration has been given as to whether cost efficiencies are possible by combining the schemes. Combining the schemes can mean that site establishment (CDM) costs are reduced and project administration can be combined, and there is the possibility of combining network outages.

Any LRE requirements at the site may mean that the project needs to be rephrased. Where a project has both NLRE and LRE drivers, the NLRE is used as the primary driver.

7.4 Asset Volumes and Expenditure

Figure 16 shows the year-on-year volumes of EHV switchgear interventions from the start of DPCR4 to the end of ED1. Refer to Appendix 7 for a full list of projects to be completed in ED1.

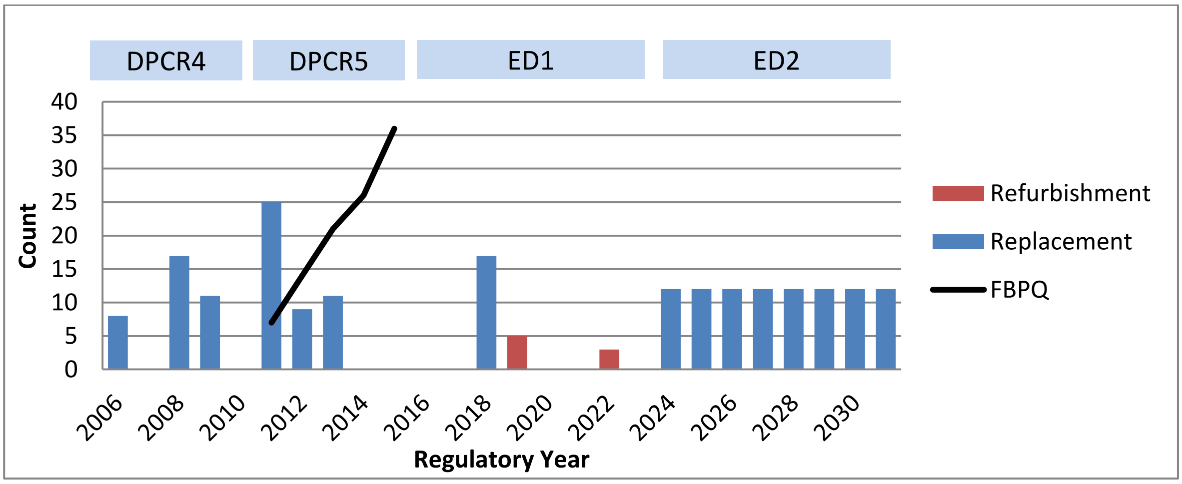


Figure 16 – EHV Switchgear yearly interventions

Source: DPCR5 FBPQ, 2013 RIGs, 19th February 2014 S&R NAMP, and Age Based Model

Refer to Figure 17 for EHV Switchgear expenditure during DPCR5 and ED1.

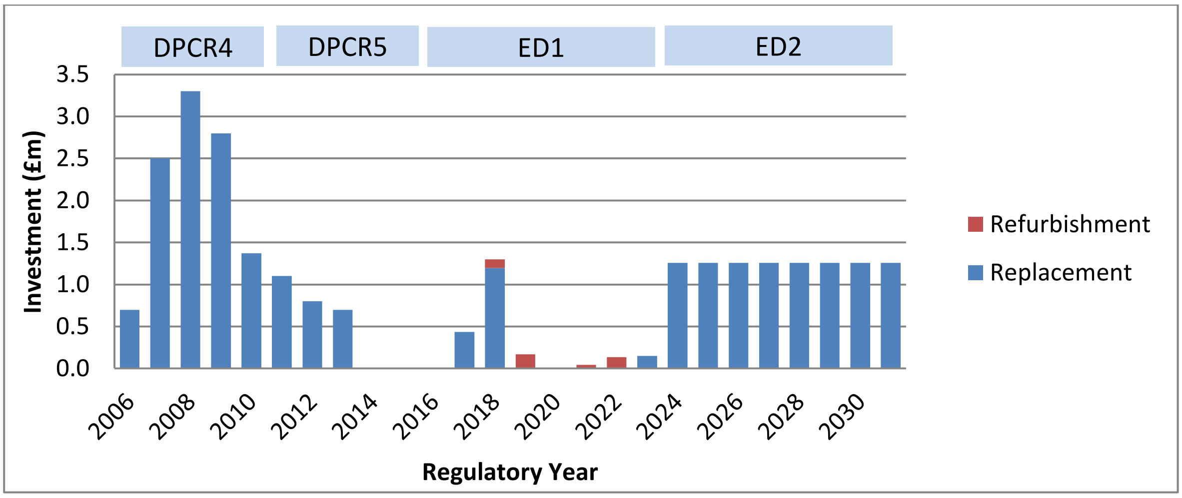


Figure 17 - EHV Switchgear yearly expenditure

Source: DPCR5 FBPQ, 2013 RIGs, 19th February 2014 S&R NAMP, and Age Based Model

Expenditure appears in years without volumes due to project set-up costs and design work being required before work can start on site. Full page versions of Figure 16 and Figure 17 can be found at the end of Appendix 5.

7.5 Commentary

Careful end-of-life asset management and the use of effective ARP models informed with real-time inspection data is allowing SPN to safely manage increasing volumes of equipment.

There are fewer interventions planned in DPCR5 than originally forecast in the FBPQ. This is due to better end-of-life management, and a large proportion of replacements in the FBPQ were sites with Reyrolle L42T that, as stated in section 3.1, has proven generally reliable.

The yearly average volume of interventions during DPCR4 is seven items of switchgear, and the projected yearly average for DPCR5 is 9 items. This compares with a yearly average for ED1 of three items of switchgear, meaning that the number of interventions during ED1 is significantly less than in DPCR5. During the whole eight-year ED1 period, there are 17 replacements and eight refurbishments. All the replacements are in one year because they are all on one site.

The reason for this reduction in replacement volumes is the continued reliability seen by the Reyrolle L42T and L45T, which account for a large population of assets on the network. However, due to defects at one site, there is one switchboard of Reyrolle L42T in for replacement during ED1. There are defects recorded against oil levels and oil test results on the switchboard. There is a large proportion of the population of Reyrolle L42T and L45T not requiring intervention during ED1.

The expenditure in ED1 shows a reduction in the yearly average when compared with DPCR4 and DPCR5. The ED1 average yearly expenditure is £0.3m; it is £2.1m for DPCR4, and £0.5m for DPCR5.

The ED2 figures shown in Figure 16 and figure 17 have been derived from age-based modelling. Asset condition and health will be used nearer to ED2 to reassess the volume of interventions required and if refurbishment options are available. The increase in volumes is due to the large amount of older assets on the network that are expected to start to show increased levels of defects during ED2. A review will take place closer to the time to assess if there are any refurbishment options available.

7.6 Sensitivity Analysis and Plan Validation

Sensitivity analysis has been carried out on the ARP models to see how changes in the average initial life affect the HI profile.

Average life change	2015 percentage HI profile				
	HI1	HI2	HI3	HI4	HI5
-4	34.3	42.4	22.3	0.6	0.4
-2	35.4	47.2	16.7	0.4	0.3
-1	35.4	52.3	11.9	0.4	0.0
0	36.5	53.0	10.1	0.4	0.0
1	36.5	56.9	6.3	0.4	0.0
2	36.5	58.0	5.6	0.0	0.0
4	37.1	58.6	4.5	0.0	0.0

Table 11 – 2015 sensitivity analysis

Average life change	2023 percentage HI profile				
	HI1	HI2	HI3	HI4	HI5
-4	20.5	34.7	35.8	7.3	1.6
-2	21.8	39.6	35.4	2.2	0.9
-1	22.3	43.3	32.2	1.3	0.9
0	22.3	45.9	30.0	1.3	0.5
1	24.1	47.8	27.2	0.6	0.4
2	24.5	50.2	24.7	0.3	0.4
4	29.2	48.8	21.6	0.3	0.1

Table 12 – 2023 sensitivity analysis

Source: Decision Lab Analysis February 2013

In Table 11 and Table 12, each average initial life change of years +/- 1, 2 and 4 are represented as a percentage of the current population. With each change in average initial life, there is a subsequent movement in the percentage of population in each Health Index. An average initial life at 0 represents the current population split within each Health Index with intervention strategies applied. The two tables range from the start of ED1 (2015) and the end of ED1 (2023).

These tables show the percentage population movements over the eight-year period and the impact any change in average initial life will have on the HI profile.

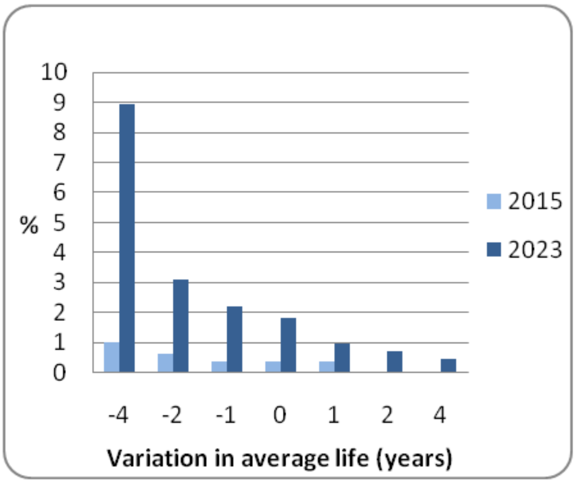


Figure 18 – Total HI4s and HI5s sensitivity analysis

Source: Decision Lab Analysis February 2013

Figure 18 represents the number of HI4s and HI5s as a percentage of the population, showing the change at each average initial life iteration, comparing 2015 and 2023.

The analysis shows that the model is sensitive with a difference of 1% in the number of HI4s and HI5s in 2015 for a change of eight years in the average initial life. There is a larger difference of 8.5% in 2023, although the majority of this difference is due to a reduction of four years in the average initial life. Increasing the average life by four years only reduces the total number of HI4s and HI5s by a small amount.

If the average initial lives turn out to be less than assumed in the ARP models the number of interventions required in ED1 will rise by 7.1%. Conversely, if average initial lives in ED1 transpire to be slightly longer than assumed, then the required number of interventions to maintain the same number of HI4 and HI5s in ED1 will drop by 1.4%. Accordingly, the company is carrying more of the risk than customers for uncertainty in the average initial life of these assets in the ED1 regulatory period.

7.7 Model Testing

The ARP model had undergone rigorous testing to ensure it meets the defined requirements prior to acceptance. There were four distinct subsets to the testing process: algorithm testing, software testing, data flow testing and user and methodology testing. Each test is designed to capture potential errors in specific parts of the system and the completion of all tests provides assurance that a thorough evaluation has been carried out to ensure correctness and validity of the outputs.

7.7.1 Algorithm testing

The ARP model comprises a set of algorithms implemented within the database code. The tester in a spreadsheet mimics each algorithm, with the results compared to those of the ARP algorithm for a given set of test data inputs. The test data comprised data within normal expected ranges, low-value numbers, high-value numbers, floating point numbers, integers and negative numbers, and included unpopulated values. In order to pass the test, all results from the ARP algorithm are required to match the spreadsheet calculation.

7.7.2 Software testing

A number of new software functions are used in the model, which required testing to ensure correct performance. A test script was created to identify the functional requirement, method to carry out the function and the expected outcome. In order to pass the test, the achieved outcome had to match the expected outcome.

7.7.3 Data flow testing

In order to ensure data presented in the ARP upload files passes into the model correctly, data flow testing has been carried out. The test carries out data counts to check that the number of records input to the model is the same as the number shown in the final model.

7.7.4 User and methodology testing

The aim of the user and methodology testing is to ensure that the models are fit for purpose. A test script has been created to check displays operate correctly and the outputs respond correctly to changes in calibration settings.

7.8 Network Risk Sensitivity

As mentioned in section 4, the ARP model is able to produce a criticality index (C1 to C4) for each individual asset, although this is a very new concept and is still being developed. The Criticality Index can be used with the Health Index to give an indication of the level of risk that can be seen on the network. Table 13 and Table 14 show the HI and criticality matrix for 2015 and 2023 with investment during ED1.

Asset categories	Criticality	Units	Estimated asset health and criticality profile 2015					Asset register
			Asset Health Index					2015
			HI1	HI2	HI3	HI4	HI5	
EHV Switchgear	Low	No. CB	136	76	5	0	0	**217**
	Average	No. CB	153	280	69	3	0	**505**
	High	No. CB	8	54	8	0	0	**70**
	Very High	No. CB	2	3	1	0	0	**6**

Table 13 – 2015 HI and criticality matrix

Source: ARP Model (HI: 25th July 2012, Criticality: 27th November 2012)

Asset categories	Criticality	Units	Estimated asset health and criticality profile 2023					Asset register
			Asset Health Index					2023
			HI1	HI2	HI3	HI4	HI5	
EHV Switchgear	Low	No. CB	80	117	18	2	0	**217**
	Average	No. CB	86	198	207	12	2	**505**
	High	No. CB	10	32	26	2	0	**70**
	Very High	No. CB	0	2	4	0	0	**6**

Table 14 – 2023 HI and criticality matrix

Source: ARP Model (HI: 25th July 2012, Criticality: 27th November 2012)

8.0 Deliverability

The number of interventions taking place during ED1 is less than what is predicted to be delivered during DPCR5, so resources are available and consideration of network outage issues has taken place during project phasing.

All projects will be created in the Network Asset Management Plan (NAMP) and this will be used to manage the project portfolio internally.

Appendices

Appendix 1 – Age Profiles

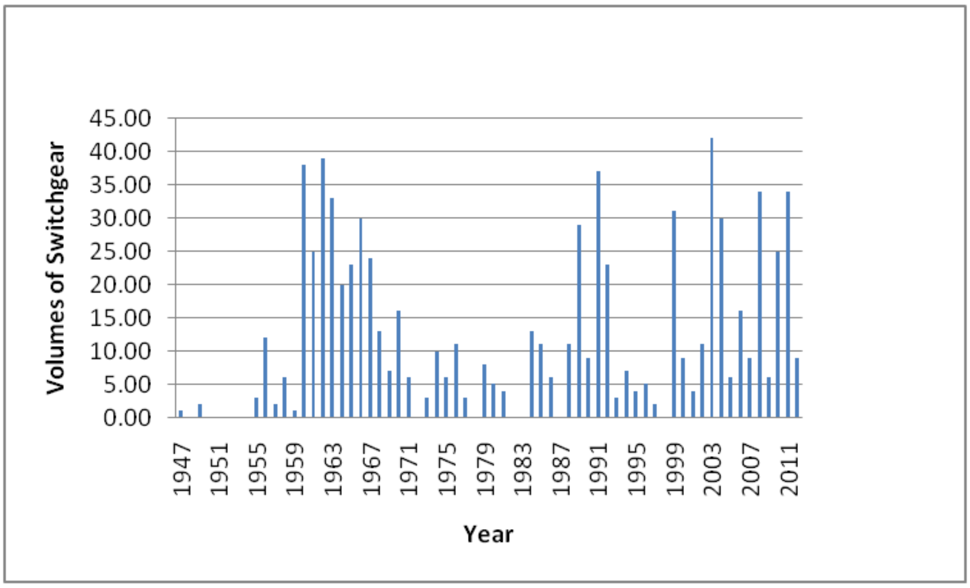


Figure 19 – EHV Switchgear age profile

Source: 2012 RIGs V5

Appendix 2 – HI and Criticality Profiles

Asset categories	Criticality	Units	Estimated asset health and criticality profile 2015					Asset register
			Asset health index					2015
			HI1	HI2	HI3	HI4	HI5	
EHV Switchgear	Low	No. CB	136	76	5	0	0	**217**
	Average	No. CB	153	280	69	3	0	**505**
	High	No. CB	8	54	8	0	0	**70**
	Very high	No. CB	2	3	1	0	0	**6**

Table 15 – 2015 HI and criticality matrix

Source: ARP Model (HI: 25th July 2012, Criticality: 27th November 2012)

Asset categories	Criticality	Units	Estimated asset health and criticality profile 2023					Asset register
			Asset health index					2023
			HI1	HI2	HI3	HI4	HI5	
EHV Switchgear	Low	No. CB	80	117	18	2	0	**217**
	Average	No. CB	86	198	207	12	2	**505**
	High	No. CB	10	32	26	2	0	**70**
	Very High	No. CB	0	2	4	0	0	**6**

Table 16 – 2023 HI and criticality matrix

Source: ARP Model (HI: 25th July 2012, Criticality: 27th November 2012)

Appendix 3 – Fault Data

	2007	2008	2009	2010	2011	2012
All faults	4	9	7	11	5	9
Corrosion	0	0	0	0	0	0
Deterioration due to ageing or wear (excluding corrosion)	1	1	2	5	4	3
Deterioration due to ageing or wear (including corrosion)	1	1	2	5	4	3

Fault Rates

	2007	2008	2009	2010	2011	2012
All faults	0.0051	0.0116	0.0090	0.0141	0.0064	0.0116
Poor condition due to age and wear	0.0013	0.0013	0.0026	0.0064	0.0051	0.0039

Table 17 – EHV Switchgear Faults data

Source: UKPN Faults cube

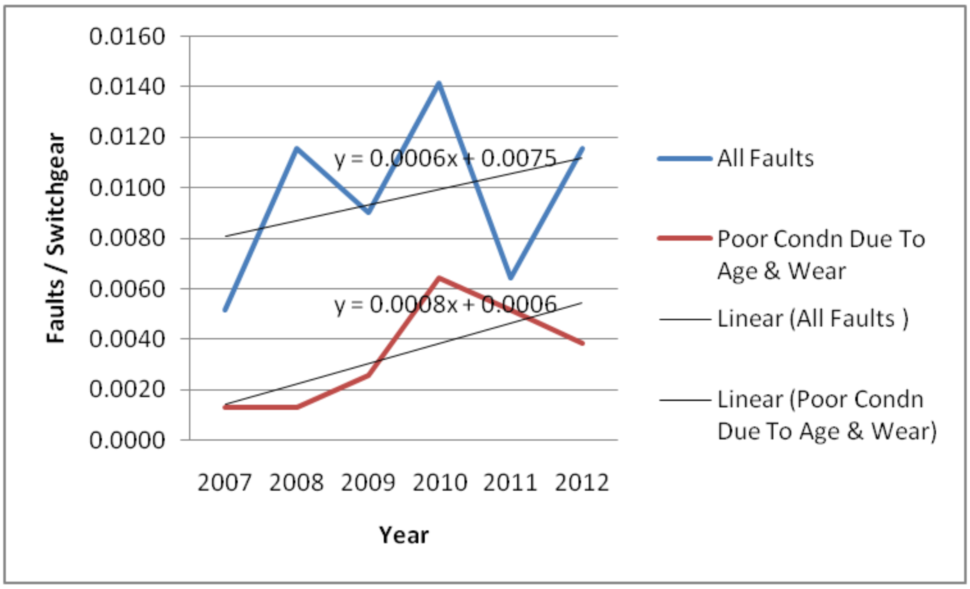


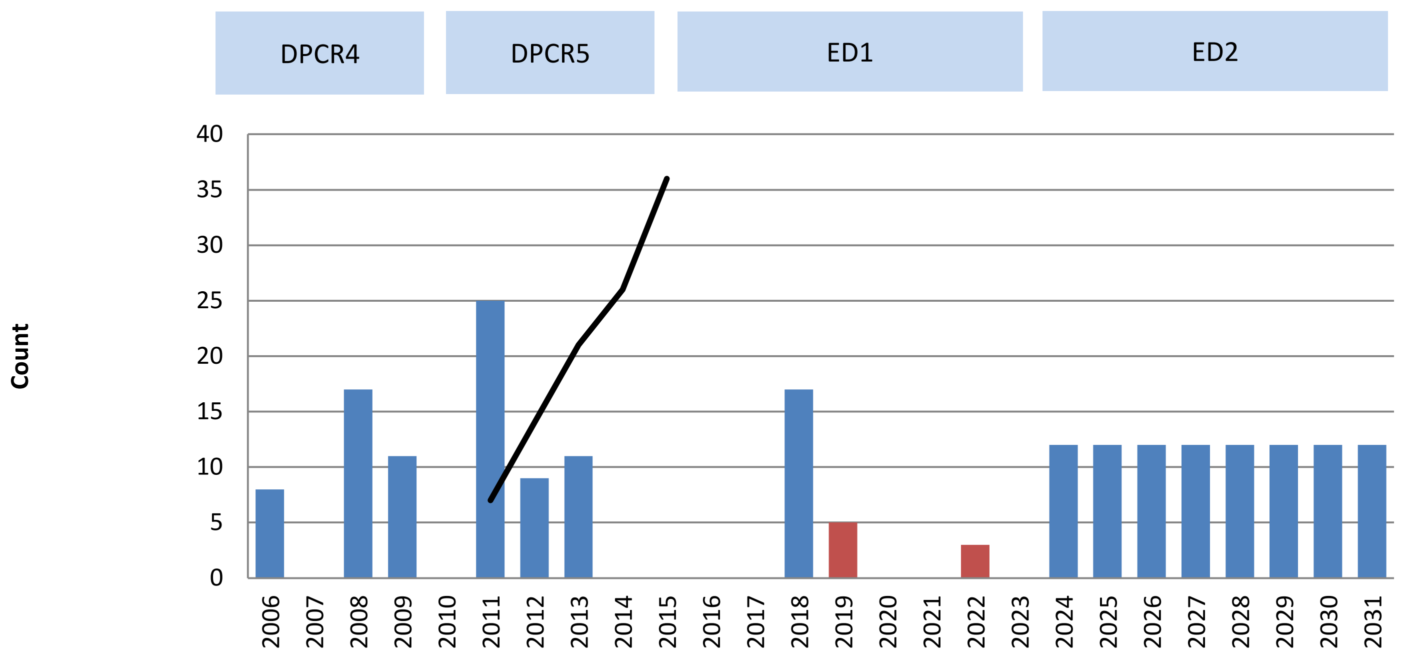
Figure 20 –Fault Rate EHV Switchgear in SPN

Source: UKPN Faults Cube

Appendix 4 – WLC Case Studies

Section not applicable.

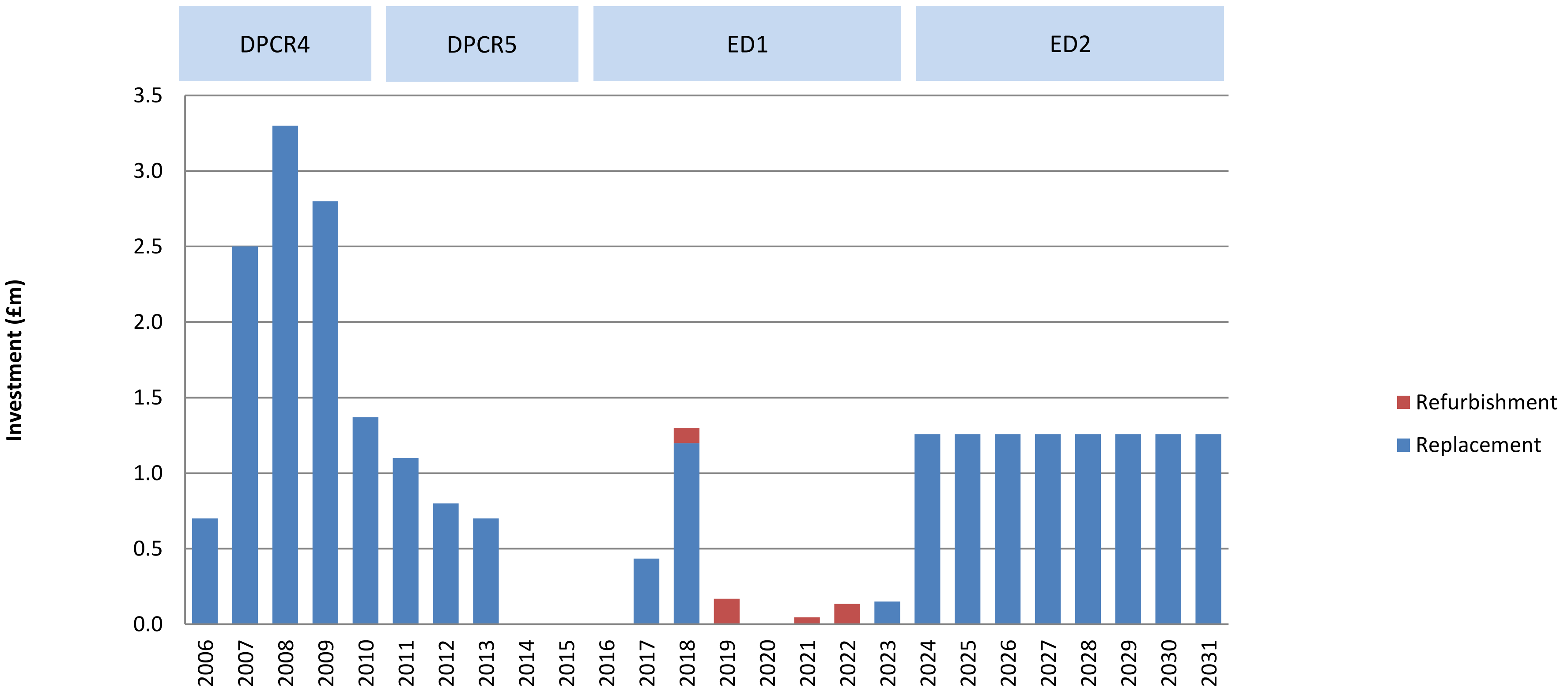
Appendix 5 – NLRE Expenditure Plan



	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
Refurbishment	0	0	0	0	0	0	0	0	0	0	0	0	0	5	0	0	3	0	0	0	0	0	0	0	0	0
Replacement	8	0	17	11	0	25	9	11	0	0	0	0	17	0	0	0	0	0	12	12	12	12	12	12	12	12
FBPQ						7	14	21	26	36																

Figure 21 – EHV Switchgear yearly interventions

Source: DPCR5 FBPQ, 2013 RIGs, 19th February 2014 S&R NAMP, and Age Based Model



	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
Refurbishment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Replacement	0.7	2.5	3.3	2.8	1.4	1.1	0.8	0.7	0.0	0.0	0.0	0.4	1.2	0.0	0.0	0.0	0.0	0.1	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3

Regulatory Year

Figure 22 - EHV Switchgear yearly expenditure

Source: DPCR5 FBPQ, 2013 RIGs, 19th February 2014 S&R NAMP, and Age Based Model

Appendix 6 – Sensitivity Analysis

Sensitivity Analysis:

EA Technology's Asset Risk and Prioritisation Model for SPN EHV Switchgear

Introduction

This is a report on the sensitivity analysis conducted on the Asset Risk and Prioritisation (ARP) model, developed by EA Technology and used to support the asset replacement and investment strategy for SPN EHV switchgear, which is included in the ED1 plan.

The objective is to understand how the Health Index profile of assets may change if the average life of assets does not turn out as predicted.

An input to the ARP model is the starting asset population in each Health Index, which is different in each region. Therefore, sensitivity analysis has been done on a region-by-region basis.

The Asset Risk and Prioritisation Model

The ARP model uses database information about each individual asset, and models many parameters to predict the Health Index of each asset in the future. Significant parameters are age, location, loading and current average life.

Sensitivity Analysis

Variation in average asset life can occur, but this is significantly less than the variation in individual asset lives.

Standard average asset lives are used in the ARP model. These are from 40 to 55 years. In 2012, the current average life values of the population had a mean of 50.6 years. This study covered the full population of SPN EHV switchgear.

Using 2012 asset data and the replacement plans up to 2023, the ARP model was used to predict the Health Index of each asset at the beginning and end of ED1. This was then repeated, varying each current average asset life by +/- 1, 2 and 4 years.

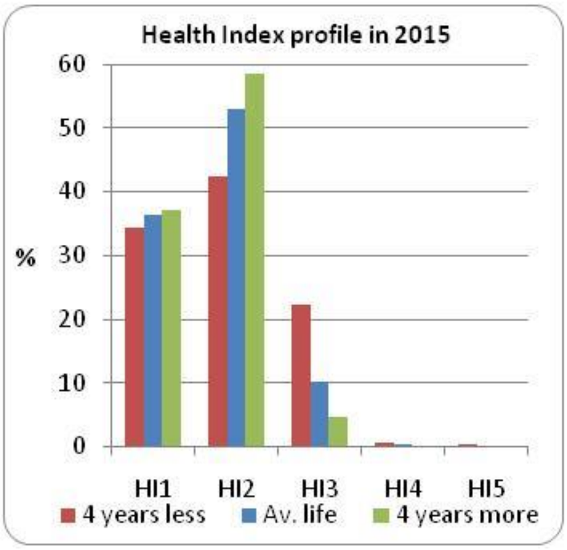
All results are shown below as the percentages of the population.

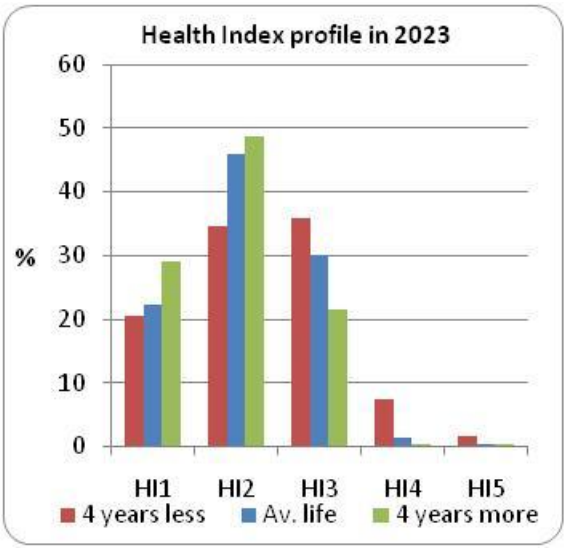
Average life change	**2015** percentage HI profile				
	HI1	HI2	HI3	HI4	HI5
-4	34.3	42.4	22.3	0.6	0.4
-2	35.4	47.2	16.7	0.4	0.3
-1	35.4	52.3	11.9	0.4	0.0
0	36.5	53.0	10.1	0.4	0.0
1	36.5	56.9	6.3	0.4	0.0
2	36.5	58.0	5.6	0.0	0.0
4	37.1	58.6	4.5	0.0	0.0

Average life change	**2023** percentage HI profile				
	HI1	HI2	HI3	HI4	HI5
-4	20.5	34.7	35.8	7.3	1.6
-2	21.8	39.6	35.4	2.2	0.9
-1	22.3	43.3	32.2	1.3	0.9
0	22.3	45.9	30.0	1.3	0.5
1	24.1	47.8	27.2	0.6	0.4
2	24.5	50.2	24.7	0.3	0.4
4	29.2	48.8	21.6	0.3	0.1

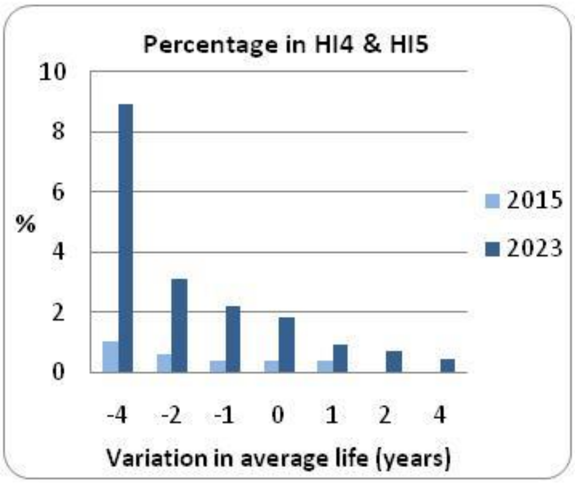
As the percentages above are rounded, the sum of a row may be 0.2% above or below 100%.

The upper and lower and current average life cases are charted below.





For all cases modelled, the sum of assets in Health Indices HI4 and HI5 is plotted below.



The results show:

- A variation in asset life will affect the proportions of HI4 and HI5 assets in 2015 and 2023.
- In 2015, if average life is four years longer, the proportion of HI4 and HI5 assets will reduce from 0.4% to 0.0%; if four years shorter, it will increase to 1.0%.
- In 2023, if average life is four years longer, the proportion of HI4 and HI5 assets will reduce from 1.8% to 0.4%; if four years shorter, it will increase to 8.9%.

Conclusion

The ED1 replacement plan for SPN EHV switchgear is moderately sensitive to a variation in average asset life of up to four years.

Appendix 7 – Named Schemes

GWP	Ref	Project ID	DNO	Description	Switchgear manufacturer and model	Volume	Scheme Paper
1.48	1.48.02.7809	7809	SPN	Betteshanger Grid 33kV – Refurb 33kV Switchgear	Reyrolle L42T	5	No
1.48	1.48.02.7808	7808	SPN	Pembury Grid – Refurb 33kV Switchgear	Reyrolle L42T	3	No
1.48	1.48.11.7811	7811	SPN	Sittingbourne Grid – Replace 33kV Switchgear	Reyrolle L42T	17	Yes

Table 18 – EHV Switchgear Named Schemes

Source: 19th February NAMP 2014 Table J Less Indirect

Appendix 8 – Output NAMP/ED1 Business Plan Data Table Reconciliation

Outputs	Asset Stewardship Report										Business Plan Data Table										
Investment description	NAMP Line	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	Total	RIGs Table	RIGs Row	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	Total
EHV Switchgear Removals	1.48.02 1.48.11 1.48.12 1.48.13	0	0	17	0	0	0	0	0	17	CV3	197	0	0	17	0	0	0	0	0	**17**
											CV3	198	0	0	0	0	0	0	0	0	**0**
											CV3	199	0	0	0	0	0	0	0	0	**0**
											CV3	200	0	0	0	0	0	0	0	0	**0**
											CV3	205	0	0	0	0	0	0	0	0	**0**
											CV3	206	0	0	0	0	0	0	0	0	**0**
											CV3	207	0	0	0	0	0	0	0	0	**0**
											CV3	208	0	0	0	0	0	0	0	0	**0**
EHV Switchgear Refurbishment	1.55.02	0	0	0	5	0	0	3	0	8	CV5	33	0	0	0	5	0	0	3	0	**8**
											CV5	43	0	0	0	0	0	0	0	0	**0**
Total		**0**	**0**	**17**	**5**	**0**	**0**	**3**	**0**	**25**			**0**	**0**	**17**	**5**	**0**	**0**	**3**	**0**	**25**

Table 19 NAMP to ED1 Business Plan Data Table Reconciliation

Source: 19th February 2014 NAMP Table J less indirects and 21st February 2014 ED1 Business Plan Data Tables

Appendix 9 – Efficiency Benchmarking with other DNOs

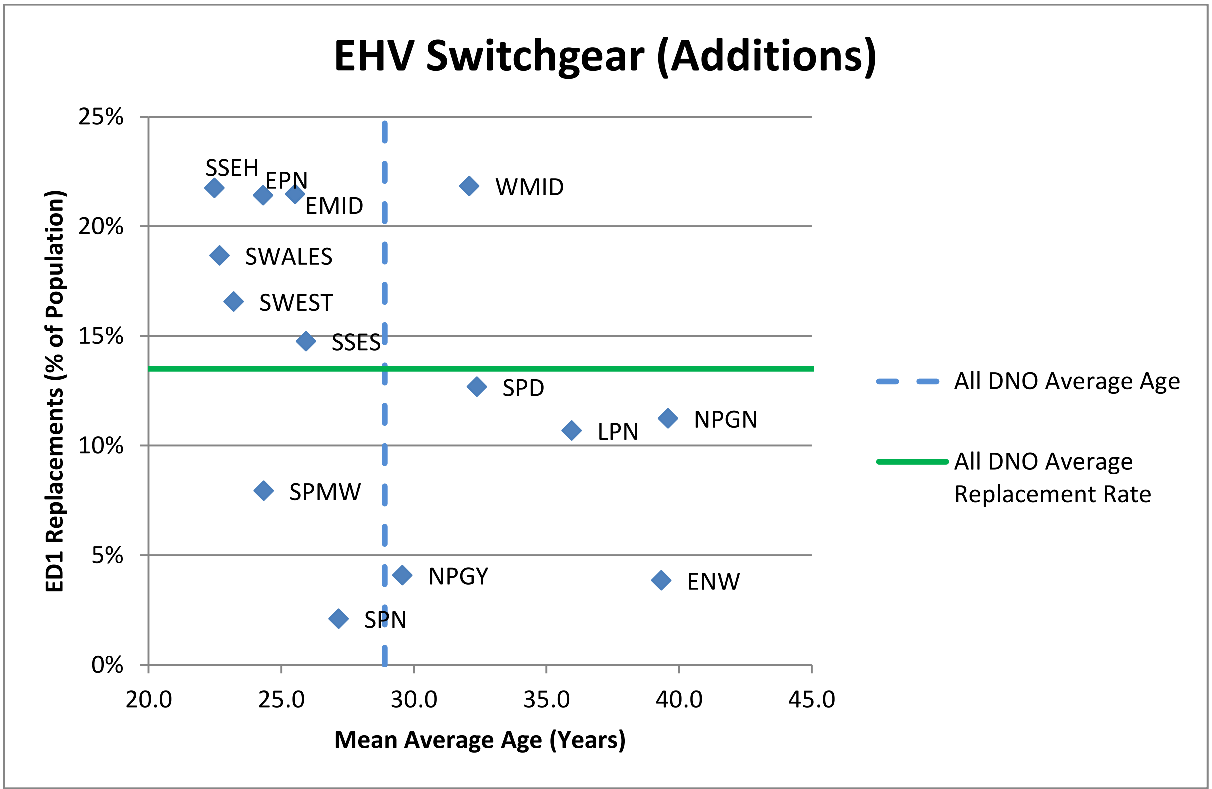


Figure 23 - Efficiency Benchmarking

Source: DNO Datashare_2013

The graph above shows that SPN has the fewest replacements as a percentage of its population during ED1 compared to other DNOs. It also has a younger population than the DNO average.

Appendix 10 – Material changes since the July 2013 ED1 submission

Changes between the July 2013 submission and the March 2014 re-submission are summarised and discussed below.

Asset type	Action	Change type	2013 Submission	2014 Submission	Difference (Reduction)	Comment
33kV Switchgear (Other)	Replace	Volumes (Additions)	81	81	0	Removal of cost savings from line
		Volumes (Removals)	81	81	0	
		Investment (£m)	-2.4	0.3	2.7	
		UCI (£k)	-29.5	35.4	64.9	

Table 20 - Material Changes to July 2013 ED1 Submission (CV3)

Source: ED1 Business Plan Data Tables following OFGEM Question and Answer Process and 21st February 2014 ED1 Business Plan Data Tables

33kV Switchgear (other)

The negative expenditure in the July 13 submission represented the savings expected as part of partial discharge monitoring. As part of Ofgem question Ph1-84 this was moved to the 6.6/11kV Transformer (GM) line.

The following Ofgem questions were answered relating to EHV Switchgear:

- Ph1-14
- Ph1-82
- Ph1-84
- Ph1-147