Document 8
Asset Category - HV Switchgear and LV Plant
SPN

Asset Stewardship Report 2014

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Approved by Richard Wakelen / Barry Hatton

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Document History

Version	Date	Details	Originator	Revision Class	Section Update
1.0	19/02/2014	Original Submission	N/A	N/A	N/A
1.1	19/02/2014	Added preface	Zoe Cornish	Minor	Section 1.1
		Updated costs to reflect 19th February S&R NAMP figures.		Minor	Section 1.1, 1.3 & Appendix 5
		Updated references to align to latest NAMP		Minor	Throughout document
		Addition of Appendices 8, 9 & 10		Minor	Appendix 8, 9 & 10
		Updated HI profiles to reflect latest RIGs tables		Minor	Sec 7.7 & Appendix 2
		Removed HI/CI matrices		Minor	Section 7.7
1.2	27/02/2014	Minor changes to preface and Appendix 9	Zoe Cornish	Minor	Preface & Appendix 9
1.3	27/02/2014	Minor changes to Appendix 10	Zoe Cornish	Minor	Appendix 10
1.4	28/02/2014	Minor changes to Appendix 8	Zoe Cornish	Minor	Appendix 8
2.0	06/03/2014	Final Approved	Ian Butler		

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) 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 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 HV Switchgear and LV Plant

1.1 Scope

This document details UK Power Networks' non-load related expenditure (NLRE) intervention proposals for SPN High Voltage (HV) and Low Voltage (LV) switchgear for the ED1 period. Indicative proposals for the ED2 period are also included.

In total, there are approximately 27,668 HV switchgear (GM) assets and 3,000 HV switchgear (PM) assets (air break switch disconnectors and auto-reclosers) with a combined estimated Modern Equivalent Asset Valuation (MEAV) of £401m. The proposed investment is £6m per annum and this equates to an average annual 1.2% of the MEAV for these asset categories. Furthermore, the LV switchgear population comprises of 20,986 assets and 29,246 link boxes. The combined estimated MEAV of LV plant is £325m. The proposed investment is £3.7m per annum and this equates to an average annual 1.1% of the MEAV for these asset categories.

Intervention costs total £77.7m and are held in Ofgem's RIGs reporting plan and UK Power Networks' investment planning documents as shown in the Table 1:

Investment Type	NAMP Reference	RIGs Volumes		RIGs Costs	ED1 Investment
		Additions	Removals		
Install HV CB at Secondary Sites	1.49.30	CV3 34	CV3 162	CV3 34	**£38.2m Asset Replacement (CV3)** **£9.1m Operational IT (CV105)**
				CV6 27/28/29	
	2.50.33*	V4b 34	V4b 34	CV15a 27	
Install HV Switch at Secondary Sites	1.49.32	CV3 37	CV3 165	CV3 37	
				CV6 27/28/29	
	2.50.35*	V4b 37	V4b 37	CV15a 27	
Install HV RMU at Secondary Sites	1.49.51	CV3 38	CV3 166	CV3 38	
				CV6 27/28/29	
				CV105 6	
	2.50.21*	V4b 38	V4b 38	CV15a 27	
Switchgear Weather Cover Installation	1.22.10	CV6 11		CV6 11	
Replace Pole-Mounted Recloser	1.19.27	CV3 32	CV3 160	CV3 32	***£0.5m Asset Replacement***
Replace 11kV ABSD	1.20.34	CV3 36	CV3 164	CV3 36	
LV Pillar - TMFC (ID)	1.44.03	CV3 16	CV3 144	CV3 16	**£10.9m Asset Replacement (CV3)**
	2.50.25*	V4b 16	V4b 16	CV15a 20	
LV Feeder Pillar and TMFC (OD)	1.44.03	CV3 17	CV3 145	CV3 17	
	2.50.25*	V4b 17	V4b 17	CV15a 20	
Remove Service Turret	1.44.05	V4a 19	V4a 19	C26 8	
Replace LV Boards	1.44.08	CV3 18	CV3 146	CV3 18	
Replace LV Network Pillar	1.44.02	CV3 19	CV3 147	CV3 19	**£18.8m Asset Replacement (CV3)** **£0.2m I&M (CV13)**
Replace Link Boxes	1.44.04				
	2.50.17*	V4b 19	V4b 19	CV15a 20	
Replace Covers & Frames	1.44.07	CV13 11		CV13 11	

Note: **The 2.50 NAMP lines are fault restoration costs for HV and LV plant*

Table 1: Total Investment *(Source: 21_02_2014 ED1 Business Plan Data Tables)*

[Note: Expenditure on these asset types is also included on CV6 Civils. A full list of abbreviations is included in Section 6.0 of Document 20: Capex Opex Overview].

1.2 Investment Strategy

The long-term investment proposal for the replacement of HV switchgear and LV plant is based on analysis of modelling forecasts and historical fault rates (combined with observed trends in condition data for the ageing LV switchgear population). Investment levels have been set as such that we will maintain the level of risk on the network, i.e. the number of assets with a poor Health Index (HI4 and HI5) at the start and end of ED1.

1.3 ED1 Proposals

The proposed investment level for the replacement of HV switchgear and LV plant in SPN is £82m (including civils/automation etc.). The annual expenditure profile is broken down in Table 2.

		Sub-Category	NAMP line(s)	NAMP Description	2015/ 2016	2016/ 2017	2017/ 2018	2018/ 2019	2019/ 2020	2020/ 2021	2021/ 2022	2022/ 2023
SPN	*Switchgear*	*HV Switchgear (GM)*	*1.49.30/ 2.50.33*	*Install HV CB at Secondary Sites*	*380*	*380*	*380*	*380*	*380*	*380*	*380*	*380*
			1.49.32/ 2.50.35	*Install HV Switch at Secondary Sites*	*309*	*309*	*309*	*309*	*309*	*309*	*309*	*309*
			1.49.51/ 2.50.21	*Install HV RMU at Secondary Sites*	*5,405*	*5,405*	*5,405*	*5,405*	*5,405*	*5,405*	*5,405*	*5,405*
			1.22.10	*Switchgear weather cover installation*	*48*	*48*	*48*	*48*	*48*	*48*	*48*	*48*
		HV Switchgear (PM)	*1.19.27*	*Replace Pole Mounted Recloser*	*26*	*26*	*26*	*26*	*26*	*26*	*26*	*26*
			1.19.08/ 1.20.34	*Replace 11kV ABSD*	*38*	*38*	*38*	*38*	*38*	*38*	*38*	*38*
		LV Switchgear	*1.44.02*	*Replace LV Switchgear - Network Pillar*	*652*	*652*	*652*	*652*	*652*	*652*	*652*	*652*
			1.44.03/ 2.50.25	*LV Pillar - TMFC (ID)*	*204*	*204*	*204*	*204*	*204*	*204*	*204*	*204*
			1.44.03/ 2.50.25	*LV Feeder Pillar and TMFC (OD)*	*878*	*878*	*878*	*878*	*878*	*878*	*878*	*878*
			1.44.05	*Replace Service Turret*	*313*	*313*	*313*	*313*	*313*	*313*	*313*	*313*
			1.44.08	*Replace LV Boards*	*286*	*286*	*286*	*286*	*286*	*286*	*286*	*286*
		Link Boxes	*1.44.04/ 2.50.17*	*Replace Link Boxes*	*1,693*	*1,693*	*1,693*	*1,693*	*1,693*	*1,693*	*1,693*	*1,693*
			1.44.07	*Replace Covers & Frames*	*23*	*23*	*23*	*23*	*23*	*23*	*23*	*23*
		TOTAL (£k)			***10,225***	***10,225***	***10,225***	***10,225***	***10,225***	***10,225***	***10,225***	***10,225***

Table 2: Summary Table of ED1 Investment (£k)including civils *(Source: 19_02_2014 NAMP Table JLI)*

Figures 1-3 show the Health Index (HI) profiles for HV switchgear and LV plant at the start, mid-point and end of ED1, with and without investment. [Note: 'Without Investment' is with intervention to Y3 then without Y4 to Y11].

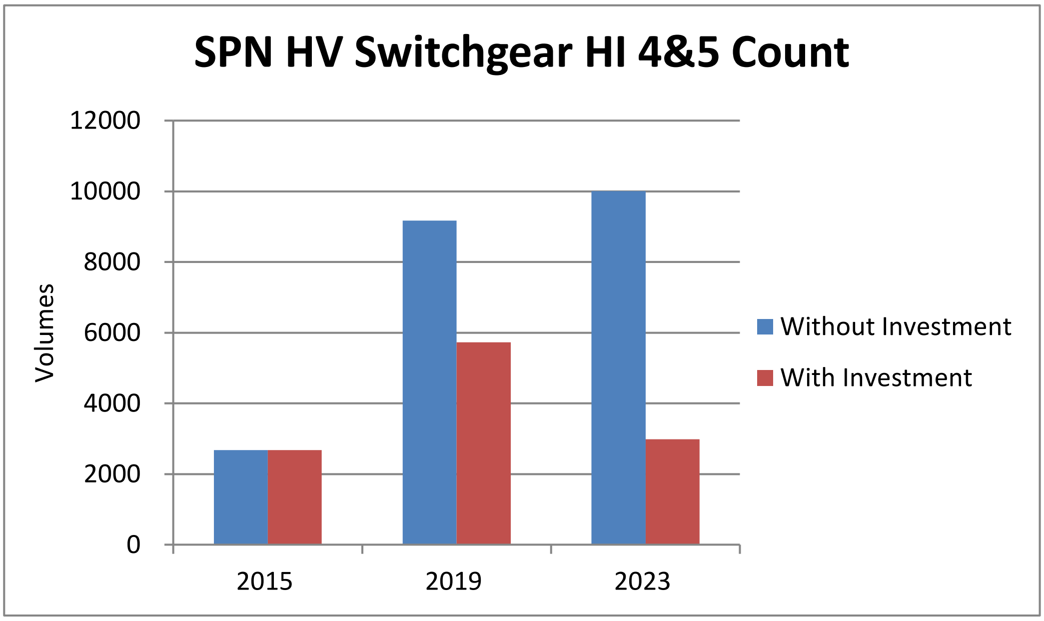


Figure 1: HV Switchgear HI4 and 5 Count (Source: 25_07_2012 ARP Model)

Figure 1 shows how the HV switchgear HI 4 and 5 count increases over the ED1 period without the proposed level of investment. The ARP 2023 prediction aligns to the age profile in Figure 5; the proportion of HI 4 and 5 assets at the end of ED1 are the vast number of older oil-filled defective assets that are in poorest condition on the network. These are the targeted interventions over ED1.

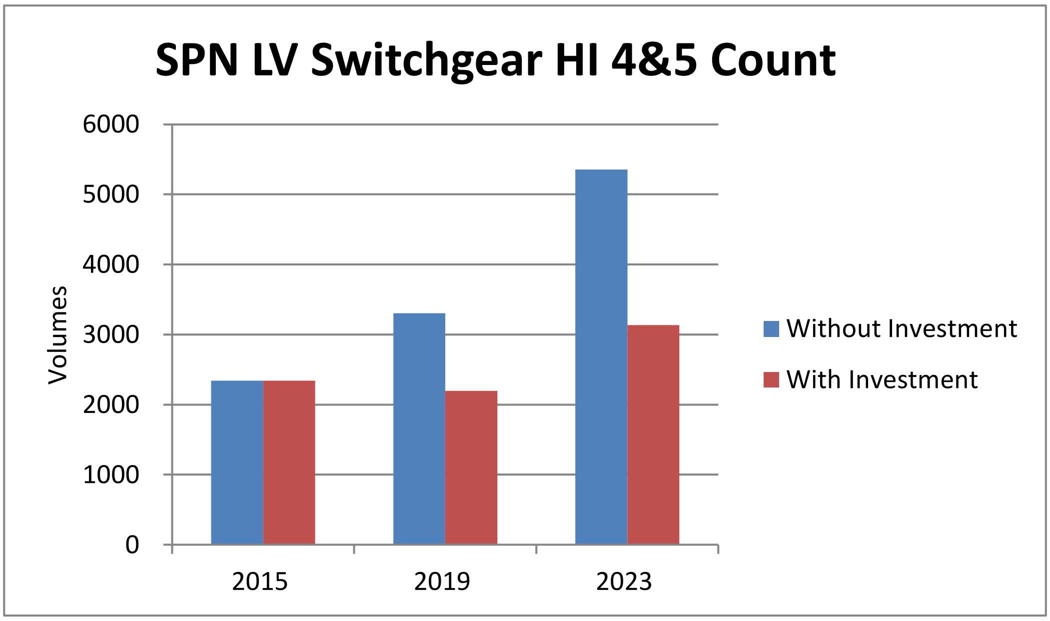


Figure 2: LV Switchgear HI4 and 5 Count (Source: SARM v0.3 Statistical Model)

Figure 2 shows a rapid increase in HI 4 and 5 assets over the ED1 period for LV switchgear without investment. This is due to the LV switchgear HI profile being based on the SARM statistical model, as there is not a representative sample of condition data for this asset class. It highlights the number of assets that were commissioned during the 1960s (as shown in Figure 8) that will be above their average asset life by the end of ED1.

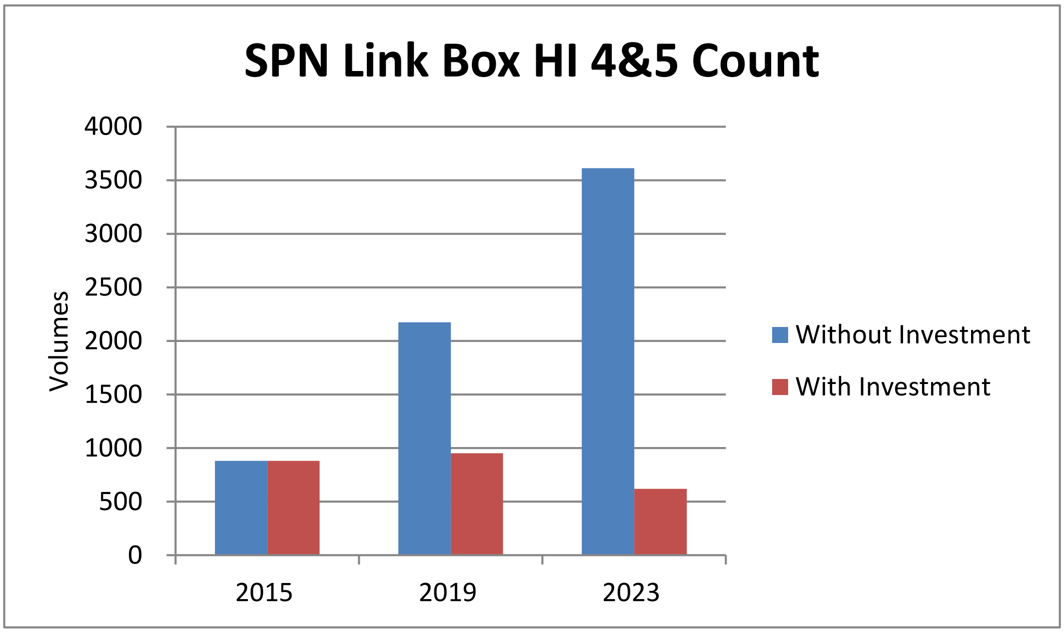


Figure 3: Link Box HI4 and 5 Count (Source: Stocks & Flows Model V1.1)

As shown in the link box HI profile (Figure 3), it is expected that high numbers of HI 4 and 5 assets will be removed from the network by the start of ED1 (2015), and similarly by end of ED1 (2023), reducing the likelihood of asset failure whilst minimising the health and safety risk to the public.

1.4 Innovation

A range of innovative techniques are currently being explored, including an integrated LV remote control and automation system, which is presently being trialled on the LPN LV network. This will enable UK Power Networks to improve network performance and gain higher granular visibility to improve our understanding and management of the LV network. As a Company, we have experienced sserious events relating to gas and electrical link box explosions, some with severe consequences. In order to minimize these health and safety risks, we are exploring a range of innovative mitigation options including hinged, vented and sprung covers.

Furthermore, a new innovative technique associated with the ARP modelling tool has the ability to show what effect the annual replacement rate has on the overall network risk. This technique allows the effect of any proposed variation from the optimum level of replacement to be quickly assessed.

1.5 Risks and Opportunities

	Description of similarly likely opportunities or risks arising in ED1 period	Uncertainties
Risk/ Opportunity	Exploring the provision of link box covers.	± 7% of ED1 investment
Risk/ Opportunity	As part of UKPNs comprehensive end-to-end review of its link box processes, we will complete all inspections for link boxes that have no condition data by the end of 2014. For those with missing condition data we have assumed the same proportion of CR4s as those with data. The number of link boxes that require replacements may increase/decrease following completion of the inspections exercise.	± 8% of ED1 investment
Risk/ Opportunity	UK Power Networks has limited inspection results for LV network pillars recorded in our asset management system – aligning data systems is a core part of the company's improvement programme. This may lead to additional assets being recorded in the asset register and may differ from ED1 assumptions.	± 10% of ED1 investment

Table 3: Risks and Opportunities

2.0 Description of HV Switchgear and LV Plant

2.1 HV Switchgear

HV switchgear on the SPN distribution network includes 2kV, 3kV, 6.6kV and 11kV units. Its function is to control, protect and isolate electrical equipment. There are approximately 27,668 HV switchgear assets operating within the SPN region of UK Power Networks, consisting of Ring Main Units (RMUs), circuit breakers and switches. Due to the vast rural area within this region, many of these installations are outdoors. As shown in Figure 4, over half of these are oil-filled switchgear (59%), with 40% of the population being SF_6 switchgear and 1% vacuum, distributed over more than 19,000 substation sites.

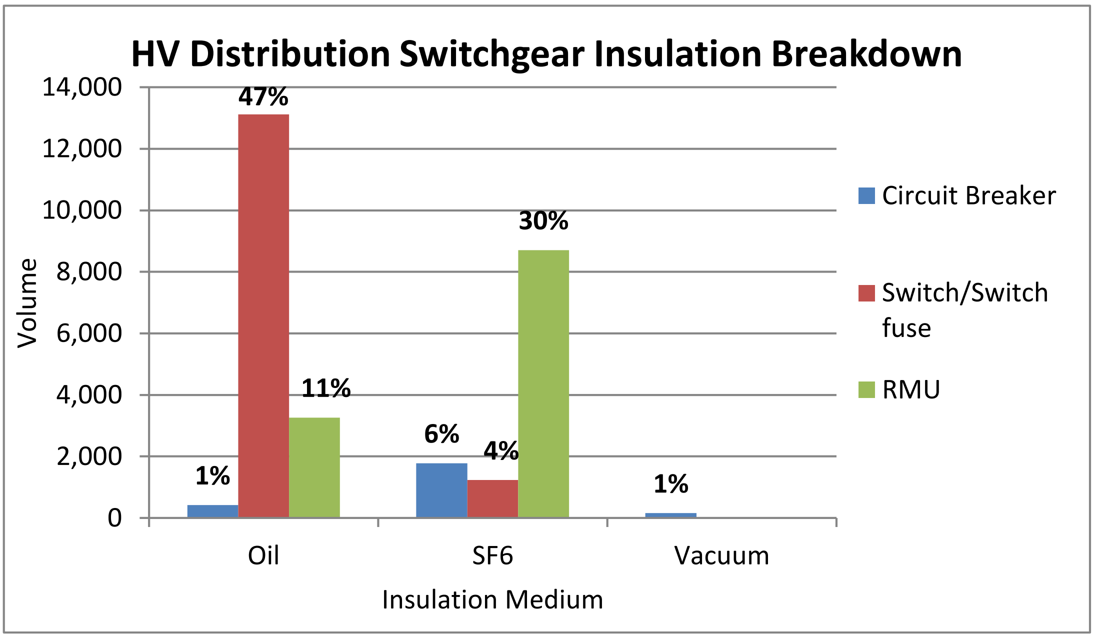


Figure 4: HV Switchgear (GM) Insulation Breakdown (Source: 25_07_2012 ARP Model)

Figure 5 demonstrates the large amount of electrical infrastructure that was commissioned during the 1960s, which has resulted in a high number of assets approaching their end of life. Although age itself does not necessarily drive the failure of all types of assets, it can increase asset stress and makes assets more vulnerable to deterioration. The oldest 10% of secondary switchgear assets in this region has an average age of approximately 50 years. Furthermore, without intervention 7% of the SPN HV switchgear population will be beyond the average asset life by the end of ED1.

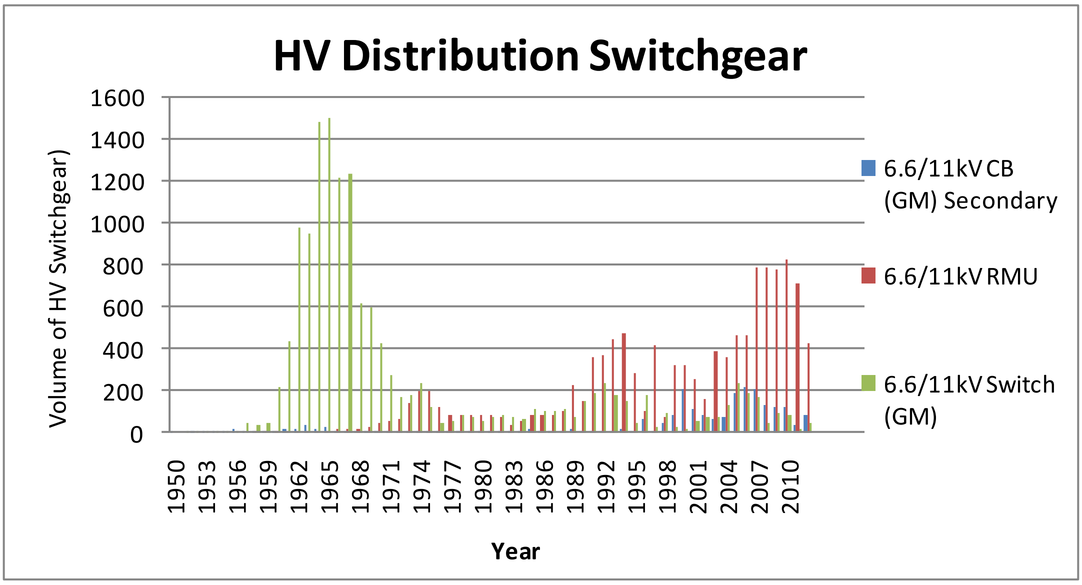


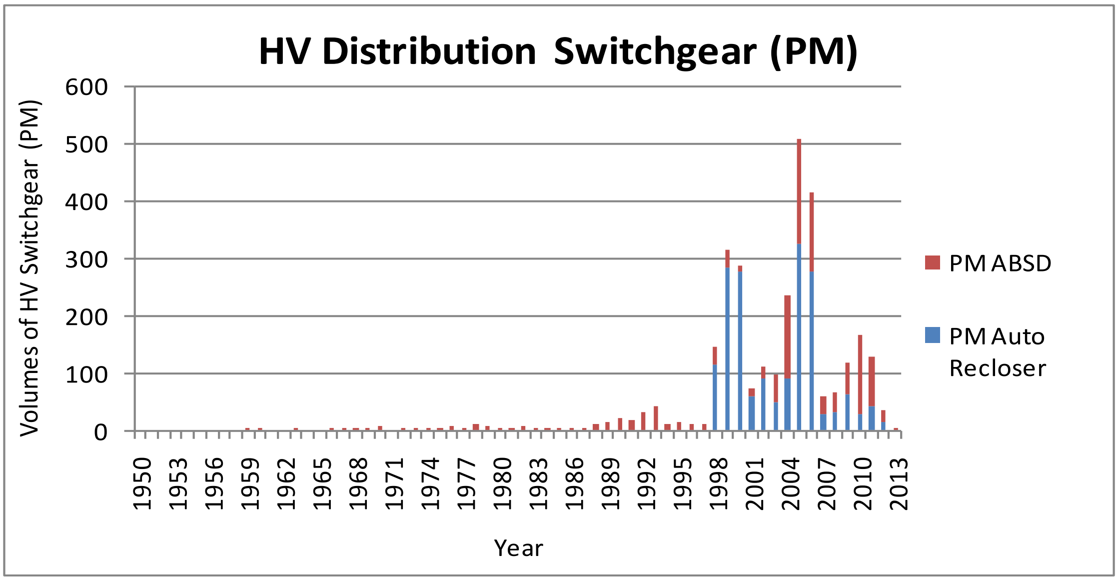
Figure 5: HV Distribution Switchgear Age Profile (Source: 2012 RIGs Table V5)

Oil-filled switchgear is still dominant on the SPN network, the largest population being the Reyrolle JS/JK/JSS switch/switch fuse (currently 4,366 with an average age of 47 years), followed by the Long and Crawford J/J2/ETV2 switch/switch fuse combination (3,782 with an average age of 46 years). SF_6 filled switchgear is steadily growing due to the fact that, in comparison to oil, it reduces the risk of hazards (such as fire and explosions) to personnel and the environment, and reduces maintenance costs, and there is currently no real cost-effective, safe alternative to gas at this voltage.

The effect on the age profile of removing the targeted HV distribution switchgear interventions from the network (taken from the ARP model) during ED1 is shown in Appendix 1.

2.1.1 HV Switchgear (Pole-Mounted)

The pole-mounted switchgear population comprises of Air Break Switch Disconnectors (ABSDs) and auto-reclosers and totals 3,000 within the SPN region. Historically, data has not been consistently recorded for these types of assets and hence condition data relating to these is sparse. However, the implementation of the hook stick conversion programme has allowed any poor condition and defective switches to be removed from the network.



`*Figure 6: HV Switchgear (PM) Age Profile* (Source: Ellipse Extract 14_03_2013)

2.2 LV Switchgear

There are approximately 20,986 LV switchgear assets commissioned on the SPN network, comprising of feeder pillars, network pillars, Transformer Mounted Fuse Cabinets (TMFCs) and distribution boards. The breakdown of these assets is shown in Figure 7.

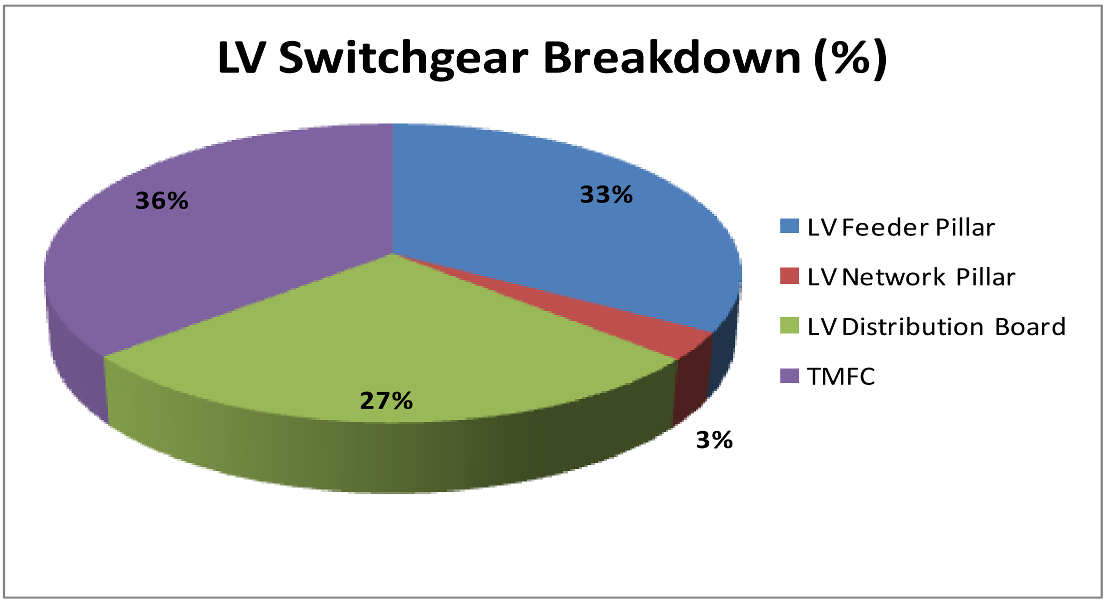


Figure 7: LV Switchgear Breakdown (Source: 27_02_2013 Ellipse Extract)

Similarly to the commissioning of HV switchgear, there was significant investment in the 1960s, as can be seen from the age profile in Figure 8. This resulted in an ageing LV switchgear asset-base, with the average age of the oldest 10% of assets being 64 years. Furthermore, without intervention 20% of the LV switchgear population will be beyond the average asset life by the end of ED1.

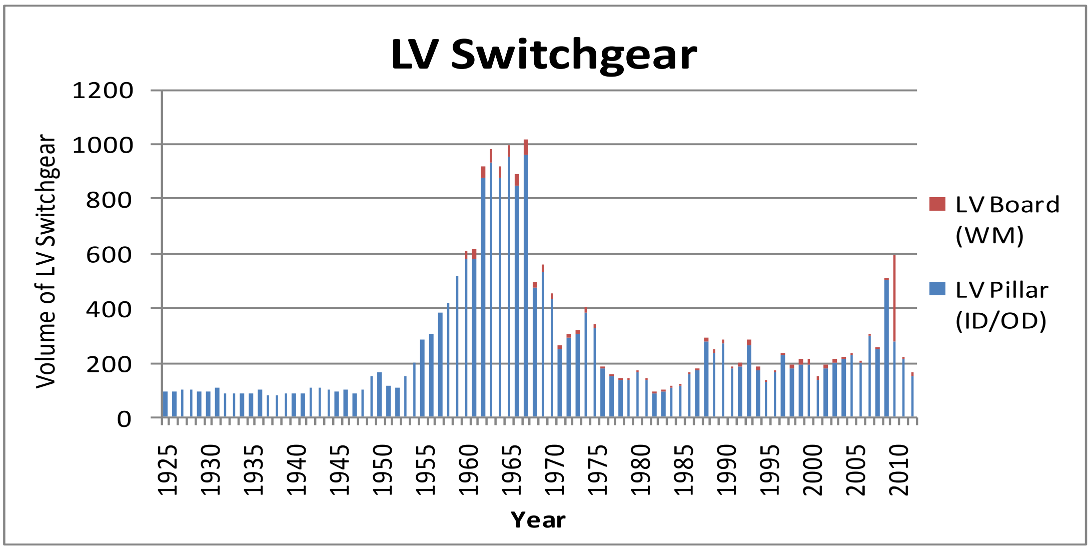


Figure 8: LV Switchgear Age Profile (Source: 2012 RIGs Table V5)

The effect on the age profile of removing the proposed volume of LV switchgear assets from the network during ED1 is shown in Appendix 1.

2.3 Link Boxes

There are approximately 29,246 link boxes currently operating within the SPN region of UK Power Networks, consisting of a mix of cast-iron bitumen-filled and plastic resin-filled construction. Underground link boxes are used within the distribution network to increase its flexibility, as different parts of the network can be energised or de-energised using both fuses and solid metal links. At present, there is no British Standard for link boxes, although an Energy Networks Association Technical Specification (ENATS) is proposed for introduction in 2013.

As link boxes have been traditionally viewed as low-risk and low-value assets, minimal information is recorded on link box age in our asset management systems. The age and, in most cases, the material type (metal/resin) are missing. However, their proximity to members of the public means that, as the assets age, they can expose the public to risk of injury.

In recent years, there has been a rise in link box disruptive failures due to gas leaks, water ingress, electrical distress and high fault levels. This led to an increase in capital expenditure allowance for the replacement of link boxes. A disruptive failure of a link box in 2012 resulted in an injury to a member of the public and consequently an Improvement Notice was issued to UK Power Networks by the Health and Safety Executive. Following this, UK Power Networks carried out a comprehensive end-to-end review of their link box processes and improved the management of these assets in the following ways:

- Ensuring the operational information on the condition of LV link boxes are passed to network control and the asset management systems for both planned and reactive work;

- Setting up a process in the SPN region to allow the operational diagram to be pinned ensuring a standardised approach in all three licence areas;
- Relevant information reported to the Accident Incident Report Line is sent to network control to ensure the appropriate operational pin can be raised;
- Daily and weekly reports are run to ensure constant visibility of faults or link boxes requiring replacement;
- Issuing an Engineering Operating Procedure EOP 10-0008 to the business detailing the end-to-end process for link boxes; and
- Releasing an Engineering Maintenance Procedure EMP 10-0006 to provide a guide to link box inspections. Only staff who have undergone and passed this training course will be able to inspect link boxes.

Following the implementation and management of these procedures and processes, the improvement notice was lifted by the Health and Safety Executive in December 2012 and UK Power Networks continues to manage its link box processes in accordance with the improvements listed above.

3.0 Investment Drivers

3.1 Asset Condition

Condition and asset performance information is a good indicator of end-of-life for assets. The following section describes how such information is collected.

3.1.1 Substation Inspection

The main source of asset external condition data is from substation inspectors. During the first half of DPCR5, a review of the substation inspectors' handbook was carried out and a new handbook was issued. All inspectors were required to undertake a two day training course and pass the theory and practical examinations before being certified as a competent inspector. Plant and equipment are inspected to confirm that they are operating correctly and safely and to collect key data about their condition in the following way:

Condition Value	Description
1	No measurable or detectable degradation.
2	Measurable or detectable degradation, which is considered normal ageing and has no significant effect on the probability of failure.
3	Significant degradation, considered to increase probability of failure in the medium term (the next maintenance cycle).
4	Serious degradation, considered to significantly increase the current probability of failure.

Table 4: Condition Descriptions (EMS 10-0001, Maintenance and Inspection Overview)

At the same time, minor preventive maintenance work will be carried out. Major work that is remedial in nature will be done on an 'as needed' basis – identified and prioritised from the inspections and from modelling, using data within Ellipse. In order to ensure good quality data is captured and recorded in the asset register in a timely manner, hand-held devices (HHD) are used on site at the point of inspection. When an inspection HHD script is run, the user answers a set of questions specific to each asset type about the condition of the asset. In addition, defects can be recorded, reviewed and cleared.

3.1.2 Maintenance

Maintenance fitters also use the same HHD technology to record their assessment 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'.

Our asset register and work scheduling system is used to schedule maintenance on assets and enables the efficient co-ordination of replacement, refurbishment and maintenance standards. Each asset recorded in Ellipse has a Maintenance Scheduled Task (MST), which drives maintenance activities. Maintenance tasks will be designed to ensure that the condition of mechanical components and systems is preserved and that the integrity of insulation and the condition of external surfaces are acceptable.

The scheduling of maintenance has a critical impact on the utilisation and effectiveness of an asset. The inspection and maintenance of distribution substation assets will be carried out at regular intervals, in accordance with UK Power Networks' inspection and maintenance standards. This is to ensure that each asset will reliably perform its function throughout its time in service and to ensure the safety of UK Power Networks' staff and the public. In line with Engineering Maintenance Standard EMS 10-0002 Inspection and Maintenance Frequency Schedule, the frequency of work for the SPN licensed network relating to the inspection and maintenance of distribution switchgear is shown in Table 5:

Plant	Inspection Frequency	Maintenance Frequency
HV Switchgear	1* or 2 years	18 years
LV ACB	1* or 2 years	18 years
LV Board (inc TMFC, feeder pillars and open boards)	1* or 2 years	18 years
Network Pillars/Link Boxes	4* or 8 years	-
Service Turrets	4* years	-

*Table 5: Frequency of I&M (*High risk area)*

3.1.3 Asset Condition Measures

The high-level investment drivers for distribution substations are detailed in Engineering Design Procedure EDP 00-0013 Asset Lifecycle Strategy – Distribution Substations. Key condition information collected during inspections which contribute to the overall assessment of the condition of HV switchgear and LV plant are described in Table 6.

<table>
<tr><th>HV Switchgear</th><th>LV Pillar (TMFC)/ LV Distribution Boards (WM)</th><th>Link Boxes</th></tr>
<tr><td>External condition of housing</td><td rowspan="5">Condition of fuse carriers</td><td rowspan="11">Overall condition</td></tr>
<tr><td>Condition of external bushing</td></tr>
<tr><td>Condition of isolating contacts</td></tr>
<tr><td>Condition of external kiosk</td></tr>
<tr><td>Operation of switchgear</td></tr>
<tr><td>Condition of bushings</td><td rowspan="6">External Condition of Housing</td></tr>
<tr><td>Overall internal condition</td></tr>
<tr><td>Condition of fusechamber/carriage</td></tr>
<tr><td>Oil acidity measure</td></tr>
<tr><td>Oil moisture measure</td></tr>
<tr><td>Oil breakdown score</td></tr>
</table>

Table 6: Distribution Switchgear Condition Measures

The main condition investment drivers that influence the actions and decisions involved in the management of distribution switchgear are primarily the external condition of the asset, recorded when inspected. External condition factors include paint condition and corrosion. Existing designs of oil-filled switchgear are susceptible to water ingress and corrosion problems. Moisture may enter oil-filled compartments via indicator windows, shaft seals, defective welds or test access/fuse access ports. Debris may also accumulate on main covers and lead to severe corrosion requiring the premature replacement of the switchgear, as shown in Figure 9.

Figure 9: Severe Corrosion and Debris Accumulation

The SPN region has already been proactive with the fitting of weather covers to outdoor oil-filled units (sought to maximise the useful life of existing switchgear, in line with Engineering Operating Standard EOS 03-0016 Distribution Switchgear Weather Covers), as shown in Figure 10. Existing designs of oil-filled switchgear are susceptible to water ingress and corrosion problems, which can lead to the premature replacement of the switchgear.

Figure 10: Weather covers fitted to a LCR T4GF3 RMU and a LUC FRMU2A RMU

Free-standing LV substation feeder pillars and LV street pillars need to be monitored, specifically for corrosion (as shown in Figures 11-13) of the enclosure that would allow third-party access to live equipment.

Figure 11: Badly Deteriorated LV Pillar at Cotswold Way, East Preston

Figure 12: Badly Deteriorated LV Substation Pillar at Wilmot Road, Shoreham-By-Sea

Figure 13: Corroded LV Network Pillar

Due to the obsolescence of pillars in the modern management and infrastructure of the LV network, there are no replacement pillars available for locations where a new pillar would be required. In this event, a link box would be installed in line with the Engineering Design Standard EDS 02-0047 Refurbishment and Replacement Policy for LV Link Boxes, Freestanding Substation Feeder and Street Pillars.

3.2 Defects

3.2.1 Defects used as Replacement Drivers for HV Switchgear

The defects used in the ARP model to help calculate the overall health index of HV distribution switchgear assets are shown in Table 7. Defects are recorded in the Ellipse asset register when found or cleared (recorded as a 4 or 1 respectively) and are documented either on an ad-hoc basis or at each scheduled inspection and maintenance.

Defect	Description
Compound leak	To provide an impulse voltage rating, bitumen compound has been used as an insulation medium in busbars and cable termination boxes on older 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.
Oil level	For oil-filled switchgear, this defect point is used to show that the oil level is low and needs to be topped up. If left unchecked, the asset

	can fail disruptively.
Partial discharge	Partial discharge can occur within voids in the insulation. Increasing levels of PD often indicate deteriorating switchgear insulation which, if left uncorrected, can lead to a disruptive failure and serious safety implications.
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.
Defective 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.
Defective gaskets	For oil-filled switchgear, this is used to record a defective gasket, i.e. one that is allowing fluid to leak. No action is needed immediately, but if left unchecked, the defect can result in a low oil level.
Blackened temperature strip	A blackened temperature strip shows signs of overheating, representing serious risk that plant may be in distress.

Table 7: Defects used in ARP Model

The ARP model not only looks at the outstanding defects, but also combines the total number of defects recorded against an item of plant, allowing an asset to have a higher weighting if a problem reoccurs.

3.2.2 Analysis of Defects

Analysis of all switchgear defects used in the ARP model is shown in Figure 14. It can be seen that the number of defects increases as the plant ages, with the highest numbers occurring between 35 and 50 years of age. This corresponds to the range of average asset life settings in the ARP model.

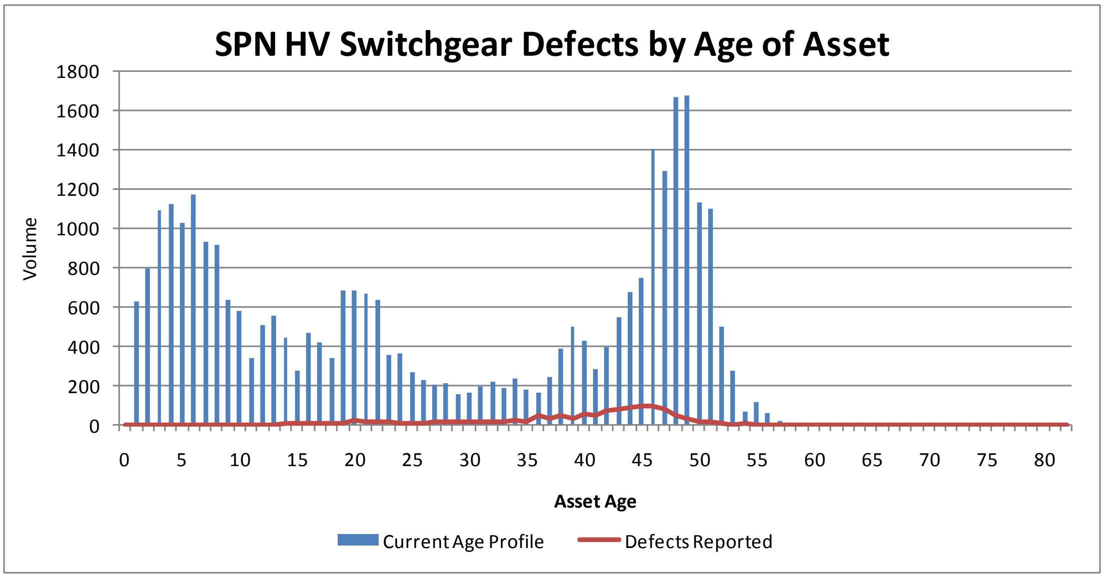


Figure 14: Defects by Age (Source: Ellipse Extract 19_02_2013 & RIGs V5)

Figure 15 shows the number of switchgear defects reported since 2007, when the Ellipse asset register was introduced. There is a rising trend of reported defects, with the increase likely to be improvements in reporting due to the substation inspector training programme. Most of the defects found are familiar due to a high proportion of oil-filled switchgear still commissioned on the SPN network.

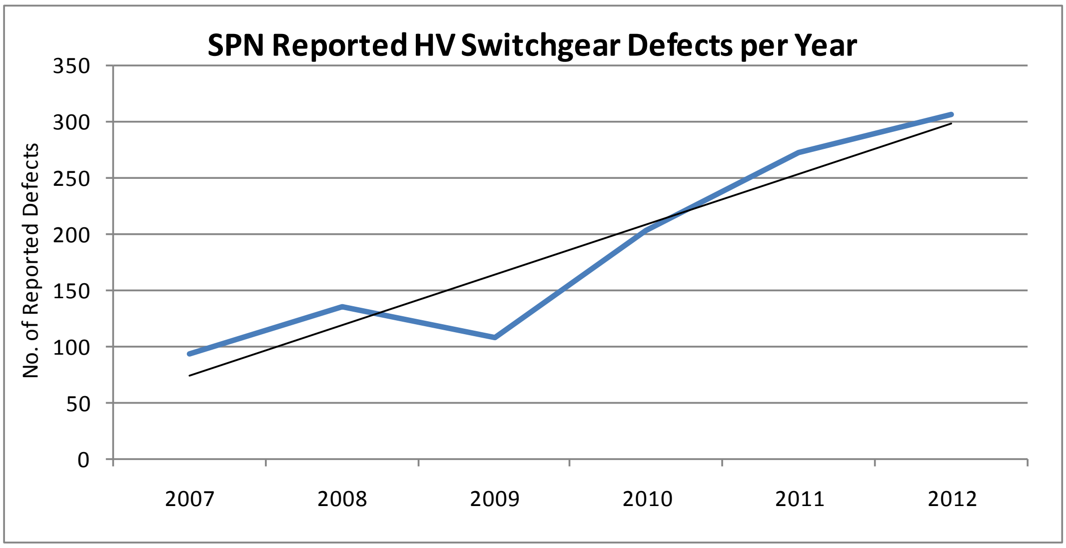


Figure 15: Defects per Year (Source: Ellipse Extract 19_02_2013)

3.2.3 Examples of HV Switchgear Defects

This section shows some examples of common defects affecting certain items of plant on our network.

Figure 16 shows a severe oil leak from a Long and Crawford ETV2 switch fuse at Lyndhurst Avenue and a defective cable box on a RMU at Rowena Road substation, inevitably increasing the likelihood of asset failure.

Figure 16: Severe Oil-leak of a LCR ETV2 Switch Fuse at Lyndhurst Av, Rainham and a Defective Cable Box at Rowena Road, Westgate-on-Sea

Similarly, Figure 17 highlights a serious compound leak where the only option is to replace the item of switchgear.

Figure 17: Serious Compound Leak

Increasing levels of partial discharge often indicate deteriorating switchgear insulation, which, if left uncorrected, could lead to disruptive failure with serious public and operator safety implications. The following photograph shows partial discharge activity on the transformer switch bushing of the Brush Falcon Beta RMU. This indicates a problem such as the misalignment or displacement of the switch mechanism.

Figure 18: White Deposits on Yellow Phase Bushing Bolts

Figure 19 shows the results of a GEC VMX circuit breaker that failed disruptively at Southwark Street 65 substation due to partial discharge. In this case, tracking had been taking place in the moulding that transmits drive to the vacuum bottles. Discharge had been recorded beforehand but repairs were delayed. (For further details, see section 3.6 of Document Commentary 7: 11kV Switchgear).

Figure 19: Failure of GEC VMX CB due to Partial Discharge

3.2.4 Types of HV Switchgear Highlighted for Intervention

The HI4 and HI5 oil-filled units predominant in the SPN area that are the targeted intervention over ED1 are shown in Figure 20. Asset replacement will continue to reduce this oil-filled population in favour of gas-insulated switchgear.

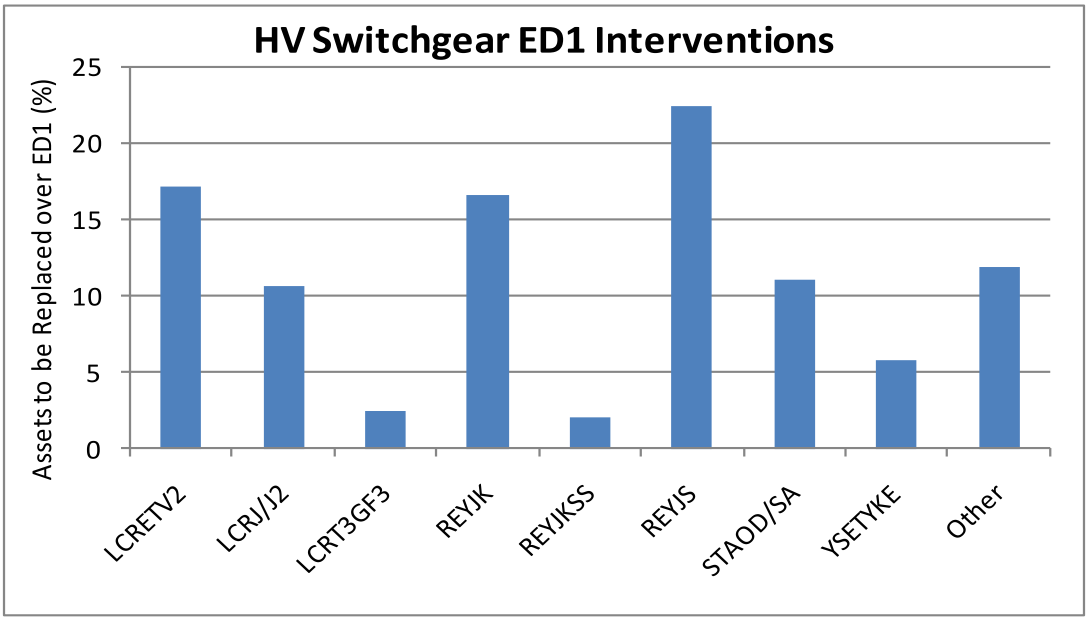


Figure 20: HV Switchgear Intervention Breakdown (Source: 25_07_2012 ARP Model)

Grouping the results by equipment type highlights the fact that certain switchgear types are suffering more mechanism issues than others.

Long and Crawford J/J2 switches use an external operating mechanism that can seize up; they also suffer from compound insulated end cap, band joint or busbar chamber failures when situated outdoors. As a result of these replacements, high numbers of ETV2 switch fuses must be replaced when Long and Crawford equipment is replaced.

Statter OD/SA oil switches have a variety of know operating problems. There have been several instances where water has been found in the main tank, which can have severe health and safety and performance consequences. In addition seizure of the main operating shaft has been reported.

Furthermore, extensive corrosion of the fuse access cover affects the Reyrolle JK/JS switches where cadmium plating on in-tank components leads to accelerated oil ageing and sludging. Most of the defects found are familiar, and the environmental conditions at distribution sites are usually worse; this results in faster deterioration of the plant which is likely to escalate over the ED1 period.

3.2.5 Defects used as Replacement Drivers for LV Plant

LV switchgear and link box defects are recorded in the Ellipse asset register on an ad-hoc basis or at their scheduled inspections, as shown in Table 8.

Asset Type	Defect	Description
LV Switchgear	Defect compound Level	To provide an impulse voltage rating, bitumen compound has been used as an insulation medium in busbars and cable termination boxes on older 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.
	Defect phase barriers	Existing phase barriers broken/missing – water transfer between phases causing electrical breakdown.
	Defective cable box	Oil/compound leaks can occur around cable boxes where there is a flange or gasket. Defective cable boxes may also show large amounts of rust increasing the likelihood of failure.
Link Box	Defect cover and frame	Cracked/broken – allows water, sand, soil and wildlife to enter the pit in which the link box is installed. It could also create a tripping hazard to members of the public and operational inspectors.
	Bell cover (cracked/water ingress)	Allows water, sand, soil or vermin to enter the link box – can potentially lead to failure.
	Defect stalks misaligned	Misaligned or damaged conductor stalks can cause high contact resistance – overheating and in severe cases can lead to insulation breakdown.
	High/low compound level	High compound level will prevent links or fuses from being installed/removed and low compound level will expose live busbars allowing water to reach phase connections.

Table 8: Defects Recorded against LV Plant

In line with Engineering Design Standard EDS 02-0047 Refurbishment and Replacement Policy for LV Link Boxes, Freestanding Substation Feeder and Street Pillars, the main investment driver that influences the actions and decisions involved in the management of link boxes is primarily if they are found to be faulty or in an inoperable state, posing a high risk to the network. Furthermore, a link box that requires the use of non-standard links or fuses for day-to-day operation can also influence link box management.

Analysis of defects versus age is not applicable due to the lack of data for LV plant.

3.2.6 Examples of LV Plant Defects

As shown in Figure 21, the pillar poses a risk to the public as it is leaning onto a footpath and there is danger that someone could insert an object into the damaged door. The LV network pillar's internal contacts are quite corroded and cannot be dressed without making the entire pillar dead. Of the four fuseways that are closed, three have asbestos-backed fuse carriers and carry fuse wire instead of HRC fuses.

Figure 21: Defective Door and Damaged Fused Barriers

As can be seen in Figure 22 the fuse carriers on a separate LV network pillar were found to be damaged with cracks in the porcelain, exposing live parts that should be insulated. Pillar stalks are prone to burning out if heavily loaded and not adequately tightened. However, the biggest concern remains the rust corrosion that is appearing on external surfaces of pillars.

Figure 22: Damaged Fused Barriers

Figure 23 shows a broken bell cover found on inspection, allowing the ingress of water into the link box that could lead to failure.

Figure 23: Broken Bell Cover

The high compound level in the left-hand photograph (Figure 24) at Collier Row would render this link box inoperable and should be recorded as a defect 4 in order to be replaced. The compound level should not be so high that fuses cannot be inserted, or so low that the metal is exposed.

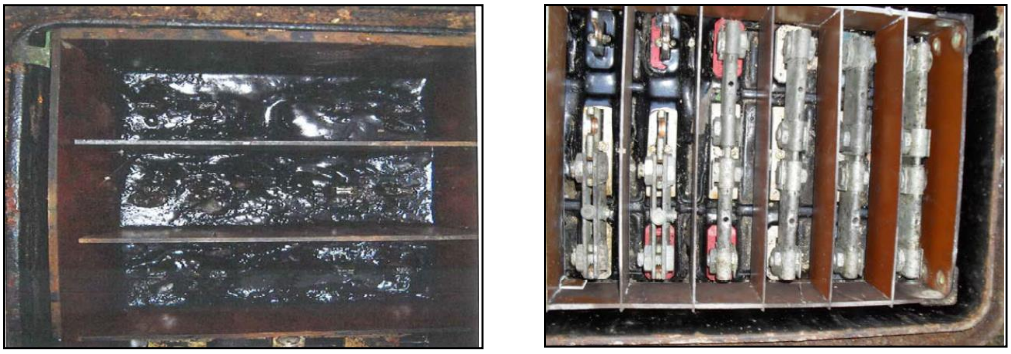


Figure 24: Example of High and Low Compound Level

3.3 Obsolescence

For many older types of switchgear, obsolescence is an issue as there is no manufacturer support to obtain the necessary parts. A spares/obsolescence factor is used in the ARP model when calculating asset criticality and is defined in Table 9.

Obsolescence Value	Definition
1	Still in production, supported by the manufacturer, all parts available.
2	No longer in production, supported by the manufacturer, most parts still available.
3	No longer in production, not supported by the manufacturer, limited parts available.
4	No longer in production, not supported by the manufacturer, no parts available.

Table 9: Spares/Obsolescence Definition

3.4 SF_6 Switchgear

Generally, SF_6 switchgear designs are proving to be gas-tight and there is no evidence that ageing of seals is occurring. Many of the earlier non-oil circuit breakers have ‘sealed for life’ operating mechanisms that are not readily accessible for normal maintenance. The majority of SF_6 filled switchgear is either from the Schneider Ringmaster or the Lucy range, which have proved to be reliable. However, modern switchgear designs offer little resistance to contamination from internal failures, which, if present, can spread throughout the unit requiring imminent replacement. Furthermore, long-term performance and operational reliability of these units will not be known for several years, although manufacturers quote an estimated nominal life of 25 to 30 years.

3.5 Faults

The five-year fault rate trends for HV and LV switchgear (including link boxes) are shown in Figures 25 and 26.

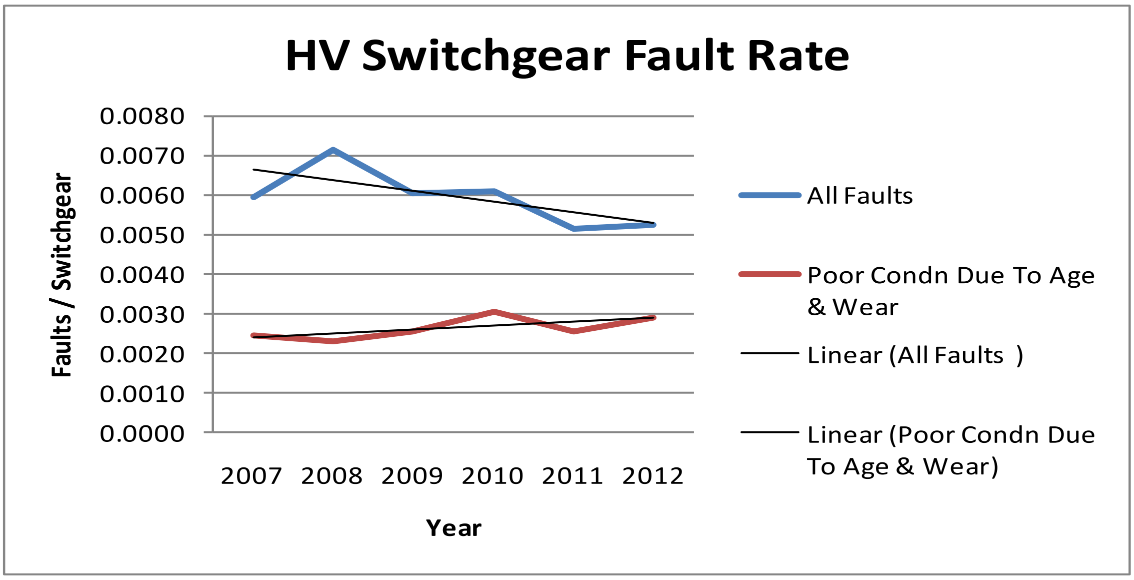


Figure 25: HV Switchgear (GM) Fault Rate (Source: UKPNs Fault Analysis Cube 15/03/2013)

The fault rate has been falling over the past five years for HV switchgear, aligning with improving techniques to identify life-expired plant before it fails in service. A further breakdown of fault causes shows that high proportions (approximately 50%) of these faults are due to poor condition (age or wear). Furthermore, although there is an increase in faults related to this condition measure, the total number has only increased by a small amount.

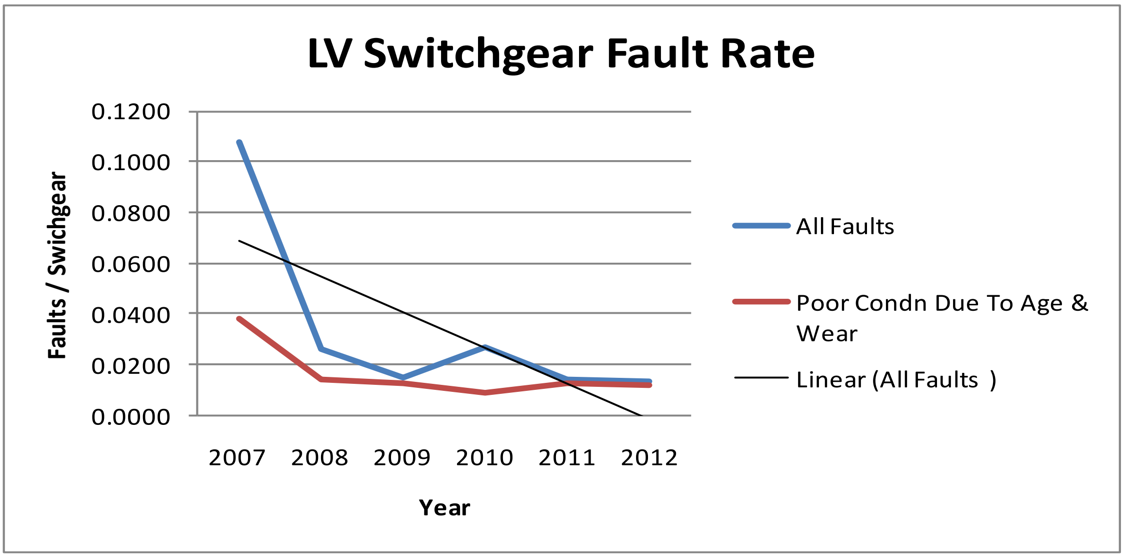


Figure 26: LV Plant Fault Rate (Incl. Link Boxes) (Source: UKPNs Fault Analysis Cube 15/03/2013)

As shown in Figure 26, if the abnormally high volumes in 2007/08 are ignored there has been a broadly similar volume of faults in recent years, suggesting current replacement levels are keeping up with degradation levels. From a further breakdown of fault causes (again ignoring the abnormally high volumes in 2007/08) it is evident that the proportion of faults caused by age or wear is steady-state.

4.0 Asset Assessment

4.1 Asset Health

4.1.1 ARP Model

An innovative asset-health modelling tool has been developed for several asset categories, including HV switchgear. The methodology behind the modelling is the same for all asset categories, but the HV switchgear model has been tailored specifically to utilise the data collected to assess against the identified investment drivers for this asset class.

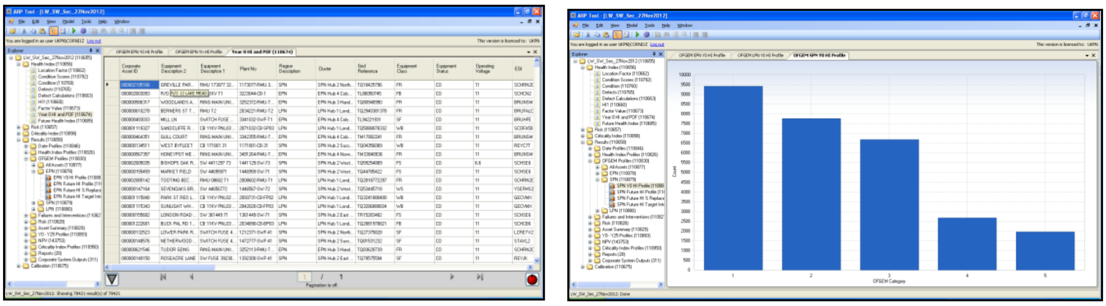


Figure 27: ARP Model

The general methodology for the ARP model can be found in Document Commentary 15: Model Overview. The model assesses each piece of switchgear based on its age, location and duty to calculate an initial HI. An average asset life is assigned to each type of switchgear to show the expected time from when the asset was manufactured until it will show signs of increased deterioration. The 'average asset life' is defined as the age at which an item of plant is expected to show increased levels of deterioration and not the point at which it is replaced. For HV distribution switchgear, the average asset life varies between 30 and 55 years depending on the equipment type and design. Note that the initial HI is capped so that switchgear with no adverse condition or defect data cannot rise above the equivalent of Ofgem HI3, irrespective of age. This is due to the fact that age alone is not sufficient to indicate the end-of-life of an asset, or to form a well-justified business plan. Older assets may not present the highest risk; young assets exposed to extreme conditions and operating under demanding duty cycles can have a higher failure rate than older assets that are well maintained with lower utilisation.

Asset condition assessments are used to detect and quantify the measure of asset degradation and to provide a means of estimating the remaining asset life based on condition. Asset condition scores recorded during inspection and maintenance activities are used (combined with an asset reliability rating) to calculate a degradation factor that is applied to the initial HI. These are combined to give an overall HI score for each asset on a scale of 1 to 5.

Where the condition measure known as 'external condition of housing' is identified as being a condition 4 for this particular asset group, the model will override the calculated HI and give the asset a HI of no less that 4 (described as having serious degradation, considered to significantly increase the probability of failure). If left, this could lead to significant network and business consequences.

4.1.2 Statistical Asset Replacement Model

Statistical models have been used for various asset categories (including LV switchgear) to determine the long-term investment requirements in ED1. They primarily cater for assets where there is not a representative sample of condition data to develop a full condition- and risk-based deterioration model. This model only operates at a group level and does not model deterioration on an asset-by-asset basis. The model computes future replacement requirements for an asset-base based on the purchase year and volumes of LV switchgear and produces an age-at-replacement profile based on a user-defined mean and standard deviation.

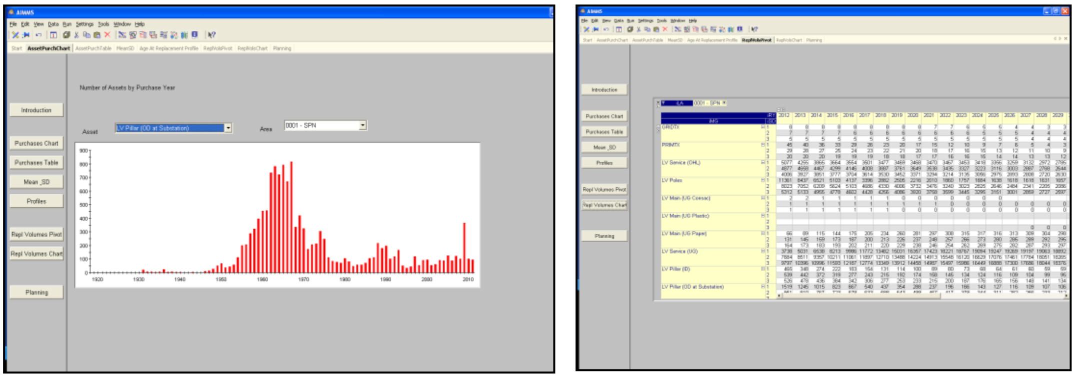


Figure 28: Statistical Model

To determine the correct inputs for the model, analysis of age versus condition data was performed and the outputs were compared to expected design lives for LV switchgear. This gave an average asset life for a piece of equipment on the SPN network of 65 years (with a standard deviation of five years). An average asset life of 65 years implies that most LV switchgear will be replaced between 50 and 80 years. The oldest 10% of LV switchgear is 64 years (rising to 74 years by 2023).

4.1.3 Stocks and Flows Model

The Stocks and Flows modelling tool has been developed for assets, including link boxes, where reliable age information is unavailable. It models movements between the condition points the asset goes through during its life.

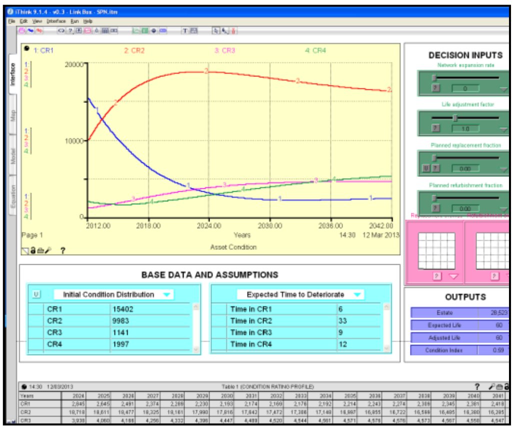


Figure 29: Stocks and Flows Model

The starting point for this approach is to determine the estimated number of assets in each of the condition ratings CR1, CR2, CR3 and CR4. By considering the transitional probabilities (the chance of moving between conditions in any one year) the model calculates the likely number of CR4 assets in each future year. The stocks and flows model was run for a range of inputs and the outputs were compared to DPCR5 replacement rates.

4.2 Asset Criticality & Network Risk

[Note: Asset criticality and network risk is a new concept that is still under development]. Network risk can also be calculated in the ARP model. The outputs are shown in section 7 of this document however, this is a new concept that is still being developed for all asset categories. The risk of an asset failing is a combination of the *probability of failure* (such as age and duty) and the *consequence of failure* (such as network performance). Asset criticality provides a measure of the consequence of failure and is evaluated in terms of the following four primary criticality categories:

- Network Performance (PD monitoring, function, spares/obsolescence, licence area and customer number)
- Safety (internal arc rated, arc extinction and ESQC risk level)
- Financial; opex (licence area, spares/obsolescence) and capex (voltage and licence area)
- Environmental (site sensitivity, arc extinction, gas capacity and volume of oil).

In order to compare and combine category consequences, each consequence value is equated to a monetary assessment. Once the average consequence of failure for a group has been valued, it is necessary to define the criticality of an individual asset (for each consequence category). The score for each consequence category is then added together and converted to an Ofgem criticality index (C1-4) A detailed methodology for calculating the criticality index can be found in ‘Commentary Document 15: Model Overview’.

4.3 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, providing details of every non-compliance and allowing continual improvement of data quality to be achieved.

An example of this is the age limit on the condition data used within the ARP model. No data recorded more than five years ago is used, ensuring the outputs of the model are accurate.

4.4 Data Verification

The ARP model has 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. The completion of all tests provides assurance that a thorough evaluation has been carried out to ensure correctness and validity of the outputs.

4.4.1 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, negative numbers and unpopulated values. In order to pass the test, all results from the ARP algorithm are required to match the spreadsheet calculation.

4.4.2 Software Testing

A number of new software functions used in the model required testing to ensure they performed correctly. A test script was created to identify the functional requirement, the 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.

4.4.3 Data Flow Testing

Data flow testing was carried out to ensure that data presented in the ARP upload files passes into the model correctly. Data counts from the ARP model upload files were compared to data successfully uploaded to the model. To pass the test, counts of the data had to match within specified tolerances.

4.4.4 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 that displays operate correctly and that outputs respond appropriately to changes in calibration settings.

4.5 Data Completeness

CAT scoring (Completeness, Accuracy and Timeliness) of data is routinely carried out on our asset data. For HV switchgear and LV plant, the results are shown in Table 10. Further information on CAT scores can be found in section 4.2 of Document Commentary 15: Model Overview).

Asset Category	Completeness	Accuracy	Timeliness
HV switchgear	62%	89%	97%
LV switchgear	94%	*	*
Link boxes	65%	*	100%

Table 10: CAT Scores as of 8th February 2013

**Not available: quality standards are under review*

(Source : Decision Lab report "CAT Scoring" 08_02_2013)

The completeness score is a combination of switchgear nameplate and condition data. Although the overall completeness of data is 62% for HV switchgear, the external condition is one of the main drivers for this asset category (which has the highest individual impact on moving a HI from a 3 to a 4) and this is populated for 97% of assets. Data completeness is 94% for LV switchgear assets and during DPCR5 and ED1 data accuracy is being improved through inspector training courses and cyclic inspection schedules. Improved link box management combined with the review of the end-to-end process is set to improve completeness of link box data during the remainder of DPCR5 and ED1. During DPCR5, there has been a drive to improve the completeness score of condition data for all asset categories and this has led to some new condition points being created. It was found that a large proportion of the missing data is from newer (low-risk) assets and the blank condition points will be updated during the next scheduled maintenance cycle.

The accuracy score (89%) is a measure of our data reliability stored in Ellipse. An external company (SKM) assessed the visual inspection methodology used within UK Power Networks and the results showed that fairly similar ratings were given for each condition point, with 92% varying by 0 or 1 condition points.

The timeliness score shows the percentage of assets that have condition data recorded and aligned to the Inspection and Maintenance frequency schedule. DPCR5 has seen a rise in comprehensive condition and defect data, and our strategy is to gain even better data so that we can efficiently and effectively manage the growing risks from ageing assets and greater defects. As a consequence UK Power Networks is prepared to carry the risk associated with missing asset and condition data.

5.0 Intervention Policies

5.1 Interventions: Description of Intervention Options

The two categories of intervention that have been considered for HV switchgear and LV plant are:

- Replacement; and
- Maintenance.

Maintenance can be further broken down into a range of options that will be driven specifically by the individual switchgear requirements (maintenance standard). Asset replacement will be carried out when condition and defect measurements from routine inspections (combined with factors described in the modelling techniques detailed in section 4) show the overall health of the switchgear is poor (HI4 or HI5). For less critical defects, repairs will be carried out as part of routine maintenance activities, such as the defect rectification work programme.

The refurbishment of an item of switchgear is a one-off activity that extends the life of the asset or restores its functionality. Unlike the higher voltage items of plant, refurbishment has not been considered for distribution assets as it is more cost effective to replace an asset that is deemed close to its end of life or otherwise not fit for purpose.

5.1.1 Selecting Preferred Interventions

The process used for selecting interventions for HV switchgear and LV plant is shown in Figure 30.

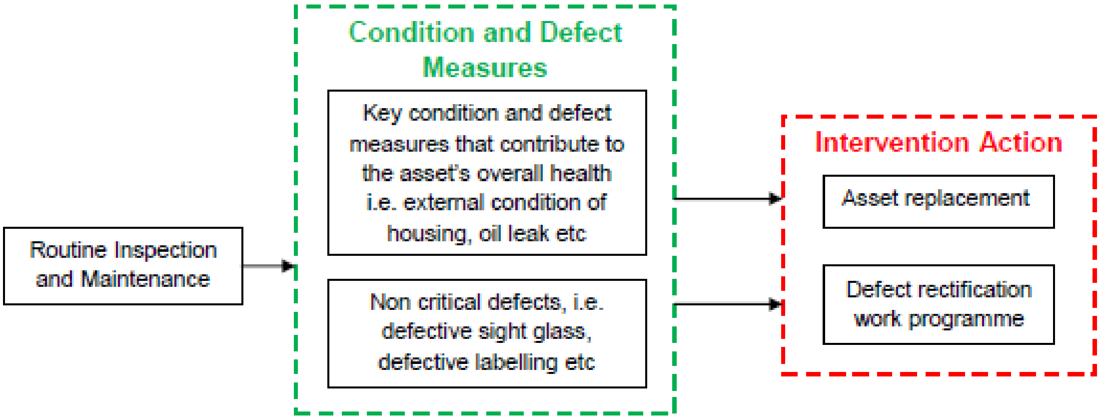


Figure 30: Intervention Decision Flow Chart

5.1.2 How Intervention Strategies Optimize Expenditure Plans

The derivation of health indices and network risk allows replacement priorities to be identified. This serves as an indication that asset failure may be approaching and allows assets to be removed from the network prior to failure. With the increasing age of LV and HV switchgear, a condition- and risk-based intervention approach will help towards optimising asset life at minimum costs and, through the criticality approach, will maintain safety and performance of the network. The replacement of distribution substation assets in poor condition results in a reduction in operating costs (due to the reduced routine maintenance requirements of new assets), the reduction in corrective maintenance work associated with the replaced switchgear, and the reduction or elimination of post-fault maintenance.

6.0 Innovation

6.1 Network Risk Sensitivity

A new innovative technique associated with the ARP model has the ability to show what effect the annual replacement rate has on the overall network risk. This is currently untested for all asset groups and will be one of the key focuses during 2013-14. However, as shown in Figure 31, with a proposed annual replacement rate of 2.03% over ED1 for HV switchgear, risk is maintained at a fairly constant level. Increasing the volume of replacements to 3.00% reduces the risk over the eight-year period, highlighting the possibility of over-optimisation. This technique allows the effect of any proposed variation from the optimum level of replacement to be quickly assessed.

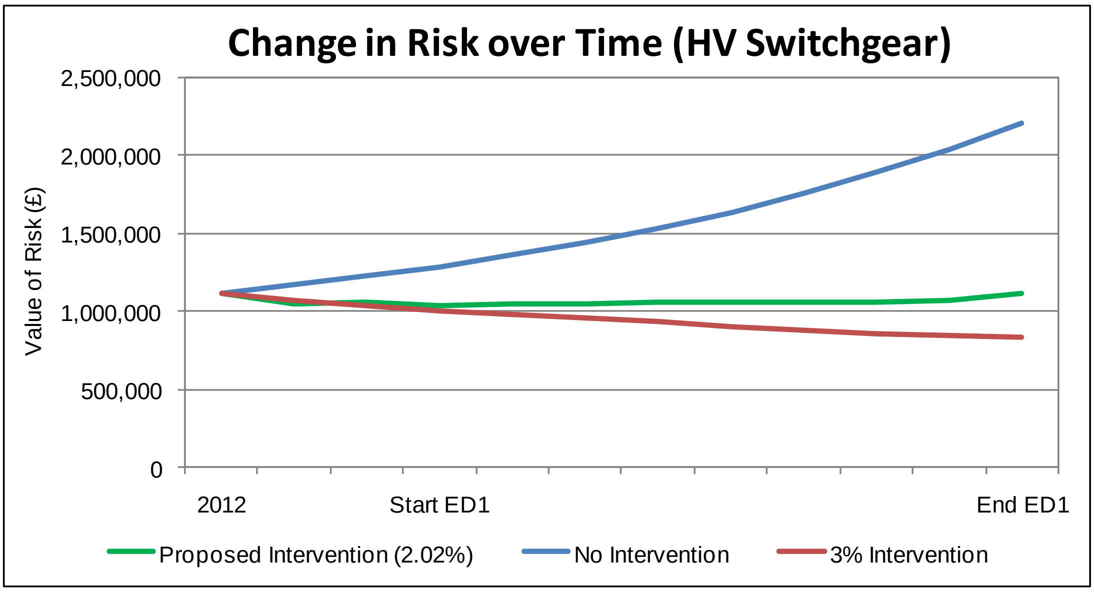


Figure 31: Change in Risk over Time (Source: 25_07_2012 ARP Model)

6.2 LV Remote Control and Automation

The IFI team within UK Power Networks is currently exploring the benefits provided by an integrated LV remote control and automation system, which is being trialled on the LPN LV network. New technologies at distribution substations include single phase fault-break/fault-make circuit breakers retrofitted in place of existing LV fuses (as shown in Figure 32) and RTUs (Remote Terminal Units) that provide remote control of the LV devices.

Figure 32: LV CBs installed on an LV board

Similarly, an ESQC-driven project for link boxes, which primarily sought to improve public safety, includes the trialling of load break/fault-make switches to replace solid links in LV link boxes. This is shown in Figure 33 and allows paralleled networks to be sectionalised during a fault. Furthermore, a control panel will provide local control of switches (which are fitted under the link box lid).

Figure 33: Before and after: Switches Installed to a LB in place of Standard Links

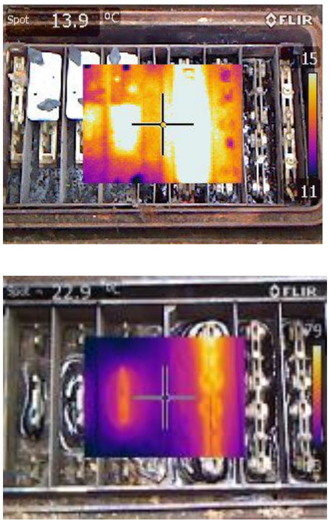
This will enable UK Power Networks to improve network performance and gain higher granular visibility to improve our understanding and management of the LV network.

6.3 Link Boxes

UK Power Networks has experienced serious events relating to gas and electrical link box explosions, some with serious consequences. In order to minimize these health and safety risks, we are exploring a range of innovative mitigation options including hinged, vented and sprung covers, as shown in Figure 34.

Figure 34: Exploring different types of Link Box covers

Furthermore, thermal imaging of link boxes is being investigated.



The top picture (left) pinpoints exactly where within the link box the thermal imaging is picking up the hot spot. This is used to assess the condition of the link box connections and compound, and can assess which connections may be loose.

The link box in the bottom picture had a loose link. The temperature was measured at 79°C. The bitumen had melted and could have resulted in failure of the link box. Immediate intervention via LV control to replace the link was completed. A revisit was arranged the following day and, while the compound was still soft, the temperature had dropped to 17°C.

Figure 35: Link Box Thermal Imaging

7.0 ED1 Expenditure Requirements for HV Switchgear & LV Plant

7.1 Method: Constructing the Plan

The modelling approach described in section 4 combined with the intervention techniques that follow were used to construct the ED1 volumes and corresponding expenditure. To determine the correct inputs for each modelling approach, an analysis of asset age, condition data, reliability ratings and operational restrictions was made and the outputs were compared to expected design lives for each asset group. A strategic approach was developed to maintain network risk, and this was achieved by keeping the number of HI4 and 5 assets the same at the start and end of the period (as shown in Figures 1-3).

7.2 Intervention Techniques

7.2.1 Intervention Technique for HV Switchgear

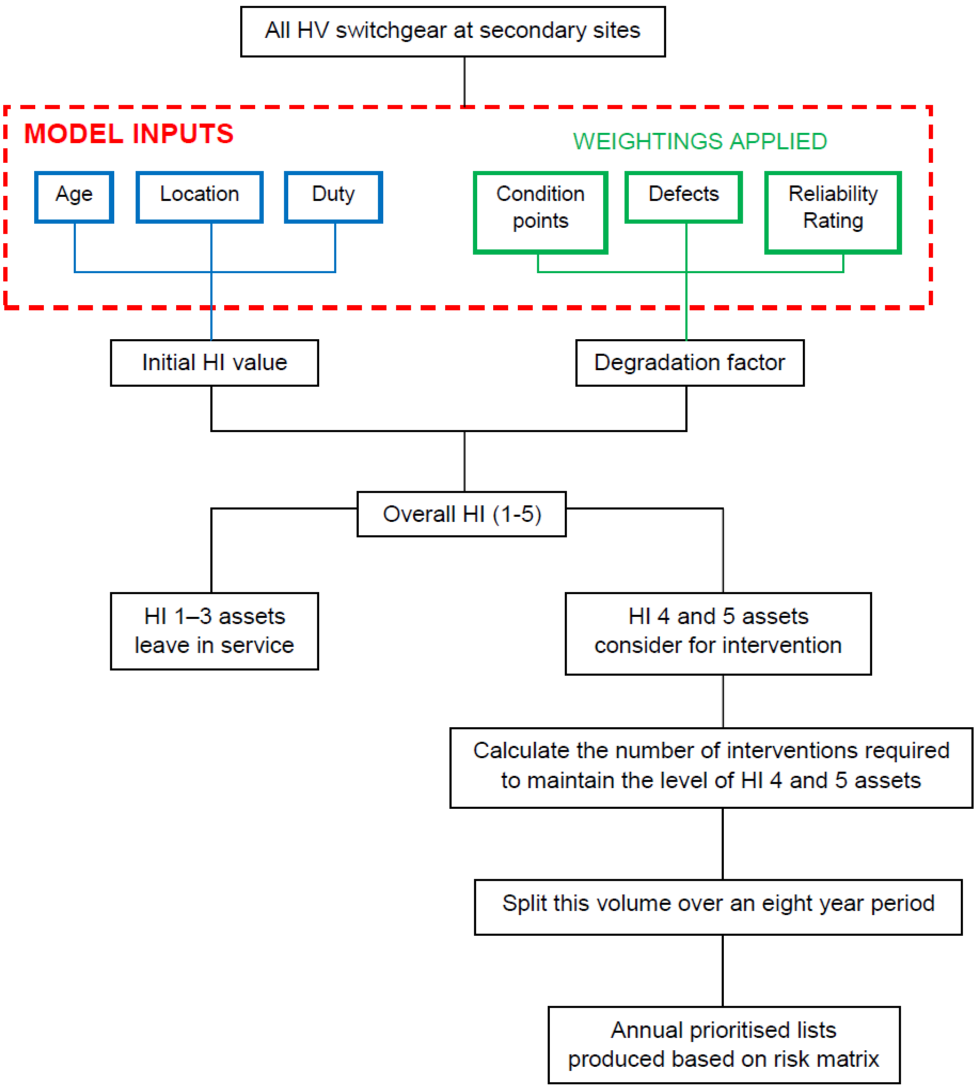


Figure 36: HV Switchgear Intervention Flowchart

It is important to note that the methodology above does not take into account 'consequential' changes. The SPN region will be replacing switch/switch fuse combinations with RMUs in a number of cases, but the whole combination may not be a HI4 or HI5. Similarly, sites with four-panel extensible boards (where only two of the units show high health indices) will be replaced with an extensible RMU and a circuit breaker. As a result, there will be some assets with lower health indices that will need to be replaced. These have been taken into consideration during the analysis of compiling the volumes.

7.2.2 Intervention Technique for LV Switchgear

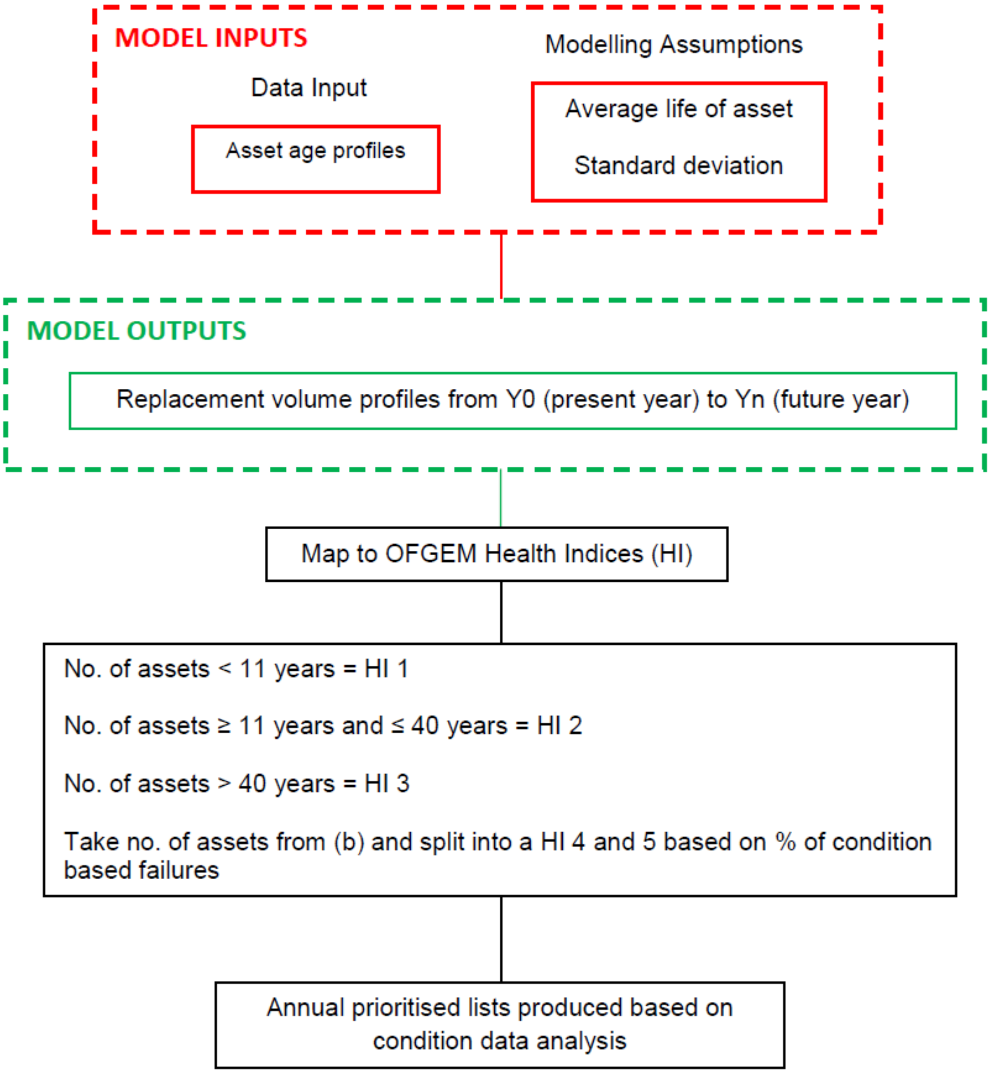


Figure 37: LV Switchgear Intervention Flowchart

7.2.3 Intervention Technique for Link Boxes

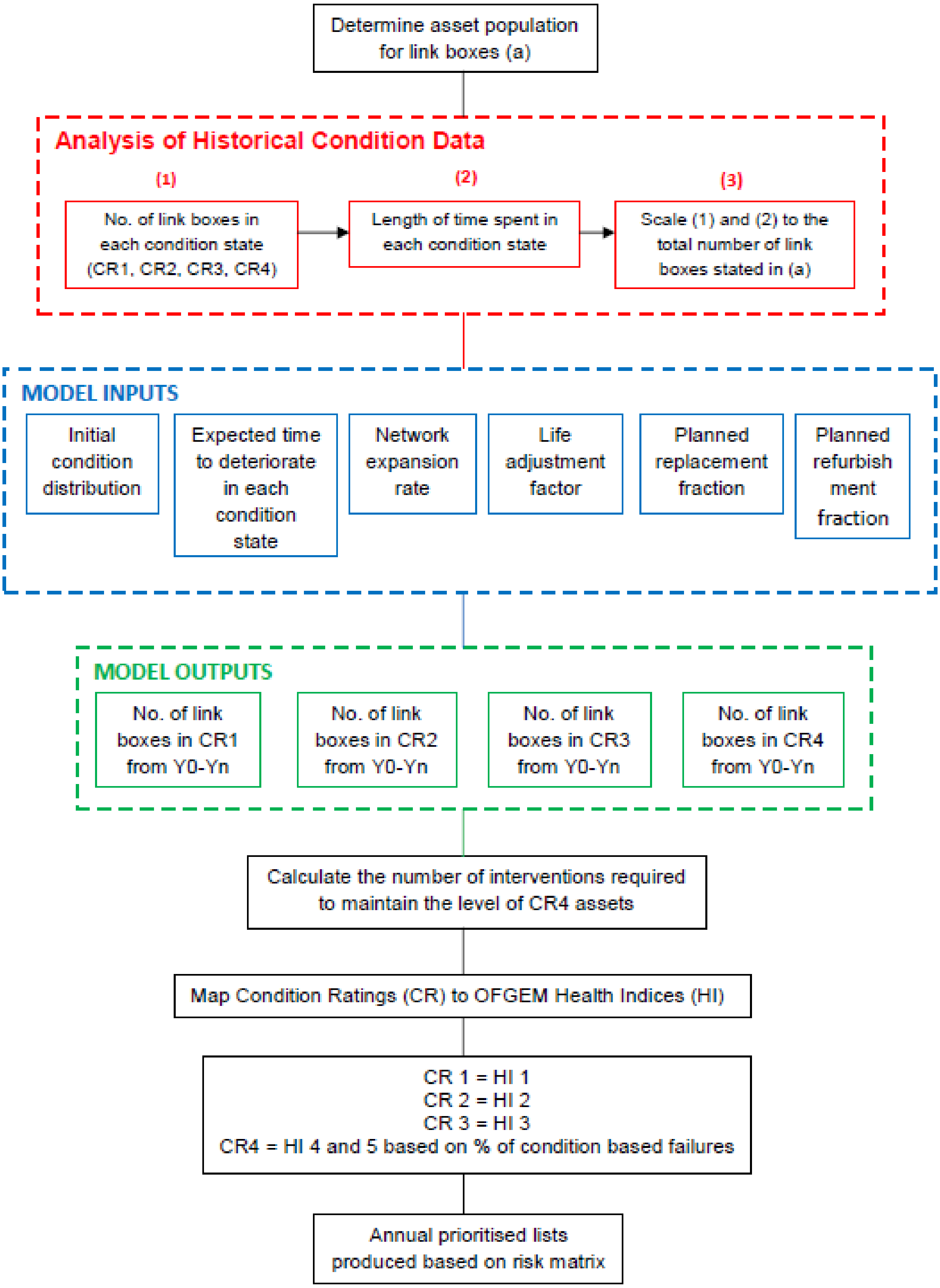


Figure 38: Link Box Intervention Flowchart

7.3 Additional Considerations

The HV remote control retrofit project (a key component in the quality of supply step change programme strategy) was developed to fit remote control facilities to approximately 4,000 items of switchgear across the EPN and SPN regions during DPCR5, in order to manage the network while improving network performance. This was taken into consideration when planning the ED1 volumes for HV switchgear due to numerous types of oil-filled switchgear being considered for automation (including Yorkshire Tyke, Tyke 2A, Long and Crawford J3/J4, T3GF3, T4GF3, Reyrolle JS and Brush NSM). An asset deemed HI4 or 5 by the end of ED1 was not considered for automation, based on the assumption it would be replaced in the forthcoming period.

Furthermore, where HV distribution switchgear has been identified for replacement, the health of all assets in the same substation will be reviewed in order to plan the coordinated replacement of transformers and LV switchgear where necessary. This will yield cost efficiencies, especially where access is via a basement or part of a building.

7.4 Asset Volumes & Expenditure

Cost Source for Section 7.4:
DPCR4 & DPCR5 FBPQ - Table NL1 (DPCR5 FBPQ)
DPCR5 (First three years) - 2013/2014 RIGS CV3 table
DPCR5 (Last Two years) - 14_06_2013 NAMP (Table JLI)
ED1 - 19_02_2014 NAMP (Table JLI)
ED2 - From Age-Based Analysis * UCI

Volume Source for Section 7.4:
DPCR4 & DPCR5 FBPQ - Table NL3 (DPCR5 FBPQ)
DPCR5 (First three years) - 2013/2014 RIGS CV3 table
DPCR5 (Last Two years) - 2013/2014 RIGS CV3 table
ED1 - 2013/2014 RIGS CV3 table
ED2 - From Age-Based Analysis

7.4.1 HV Switchgear (GM) Charts

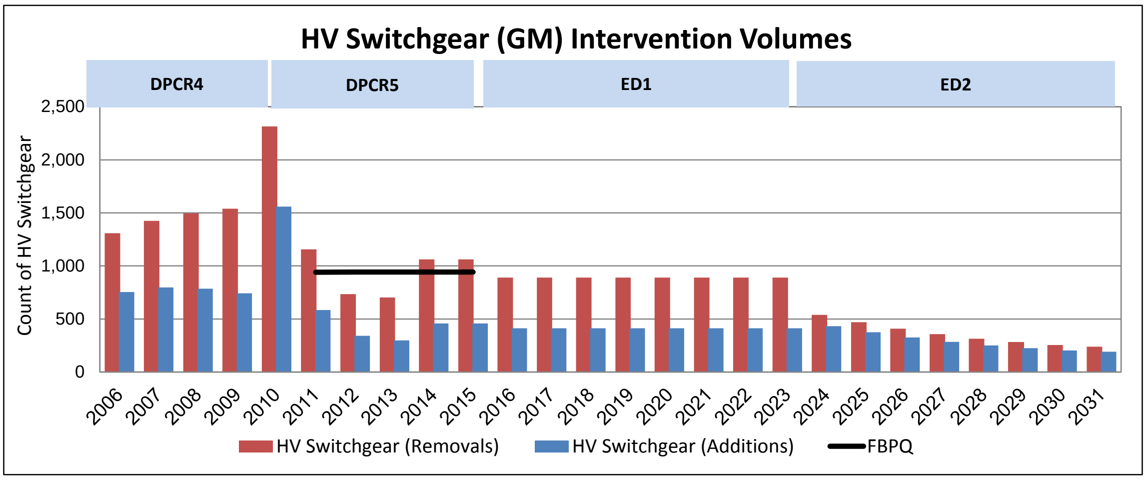


Figure 39: HV Switchgear Intervention Volumes

[Note: removals and additions are approximately a 3:1 ratio as on average, we are removing three switches from a site and replacing them with one RMU. By ED2, high numbers of switches will be removed from the network and most of the HV distribution switchgear replacements will be on a like-for-like basis].

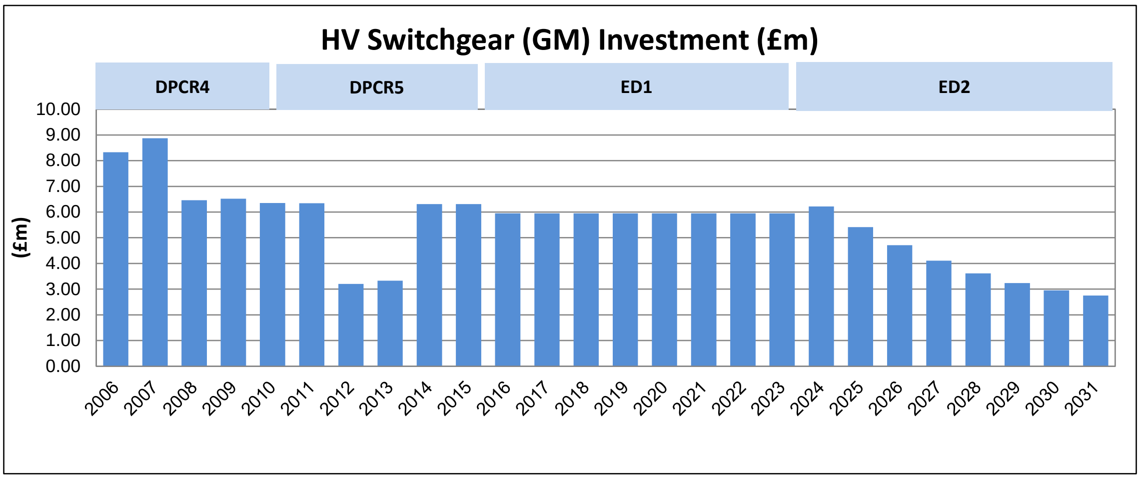


Figure 40: HV Switchgear Investment

7.4.2 HV Switchgear (GM) Commentary

HV distribution switchgear is not always replaced as a 1:1 conversion rate for additions and removals. When calculating the number of additions over the ED1 period, the following assumptions were made:

- A RMU is replaced like for like;
- A stand-alone switch fuse (i.e. Long and Crawford ETV2) will be replaced with an SF_6 circuit breaker;
- Extensible boards (four or five panel) will be replaced with the same number of SF_6 circuit breakers; and
- A site with a mixture of switch/switch fuses (i.e. LCR J/J2) will be replaced with an RMU (75%) or an extensible RMU and a circuit breaker (25%).

Referring to Figure 39, the HV distribution switchgear achievement fell short of the FBPQ target in year two of DPCR5. However, we are currently set to achieve these replacements by the end of March 2015. There has been a slight increase in the year 4 and 5 forecast in order to target certain type defects. Resource issues in year 2 contributed to being behind our forecast and a rise in contractors is set to increase the number of resources (SAPs) for the remainder of DPCR5.

We are maintaining similar levels of replacements throughout DPCR5 and ED1. This is to target primarily the large numbers of defective oil-filled items of switchgear commissioned during the 1960s (as shown in Figure 5) which have a health index of 4 or 5. In addition to this, the strategic view to maintain network risk over the ED1 period means nearly 900 assets per year will need replacing over the eight-year period. Referring to Figure 25, the fault rate has been falling for the past five years, however the condition-based fault rate is steadily increasing for HV distribution switchgear.

As shown in Figure 40, the expenditure levels for HV switchgear reflect a similar level over DPCR5 and ED1. The ED2 figures have been created using the age-based statistical asset replacement model (SARM1) and the reduction in volumes highlights the fact we will be removing high numbers contained within the 1960s peak shown in Figure 5 of section 2.

7.4.3 HV Switchgear (PM) Charts

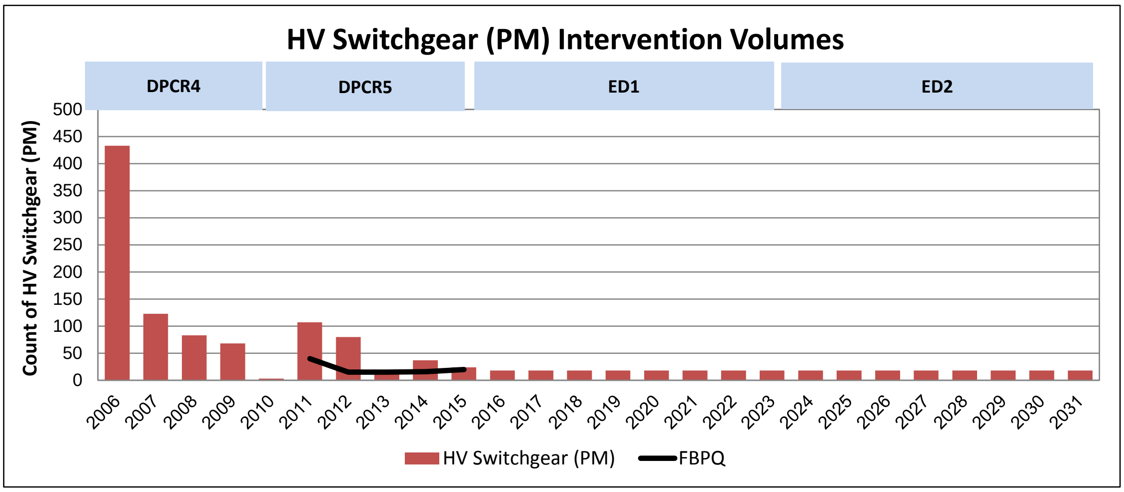


Figure 41: HV Switchgear (PM) Volumes

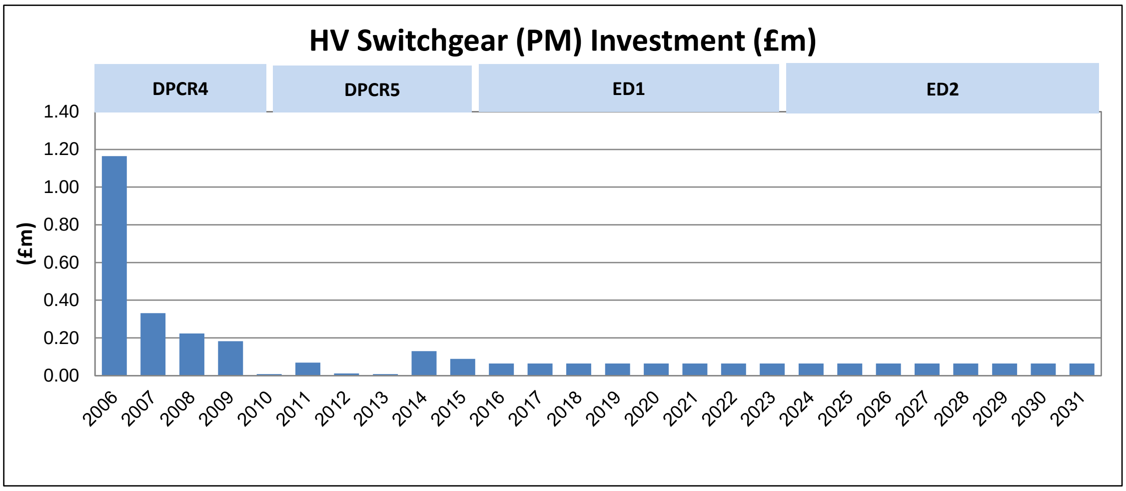


Figure 42: HV Switchgear (PM) Investment

7.4.4 HV Switchgear (PM) Commentary

Historically, as shown in Figure 41, a proactive pole mounted switchgear replacement programme has been carried out. The high numbers of DPCR4-5 volumes is down to the implementation of the hook stick conversion programme, scheduled for completion by the end of this period. Due to this programme, pole-mounted replacements are low during ED1 as switches that are obsolete, older than 25 years, in poor condition or defective are to be removed from the network by 2015. The remaining population of ABSDs are in good condition and this is confirmed in the age profile in Figure 6, demonstrating the young pole-mounted switchgear network in this region.

Expenditure levels for HV switchgear (PM) (Figure 42) reflect the reduction in volumes over the ED1 and ED2 period.

7.4.5 LV Switchgear Charts

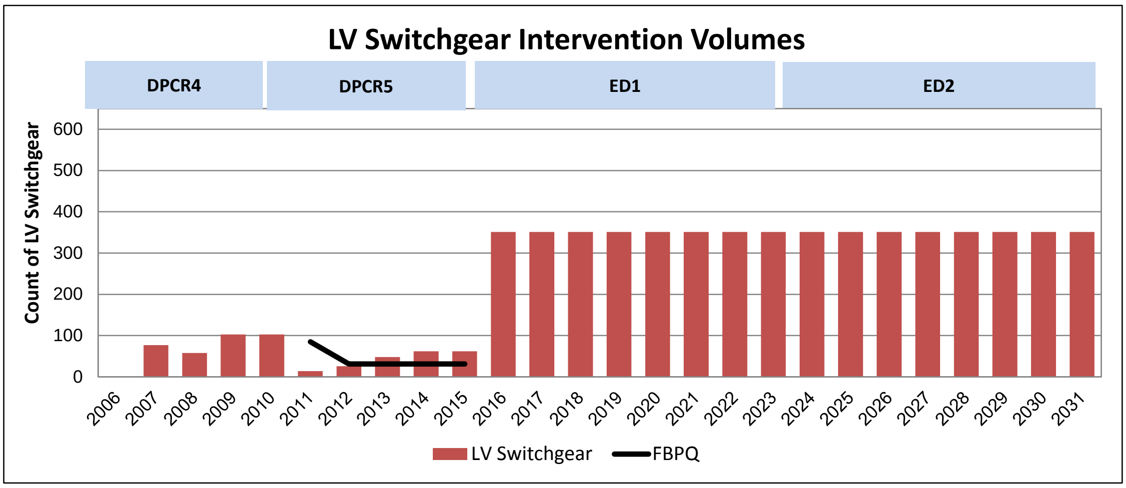


Figure 43: LV Switchgear Intervention Volumes

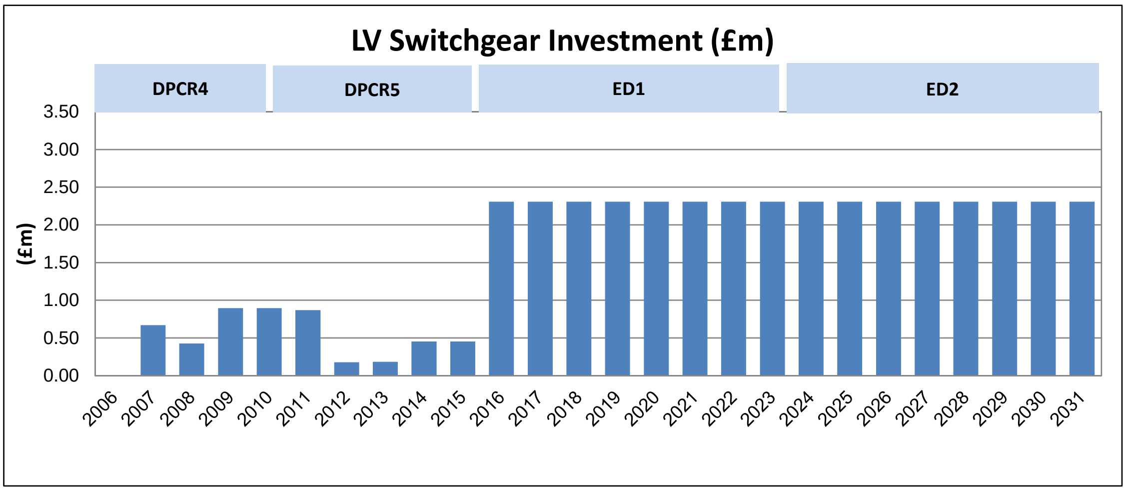


Figure 44: LV Switchgear Investment

7.4.6 LV Switchgear Commentary

Figure 43 confirms that at the current replacement rate, we are set to achieve the FBPQ target for LV switchgear by the end of DPCR5.

A significant capital investment programme is proposed for LV switchgear over the ED1 period. As shown in Figure 26 in section 3, the number of condition-based (i.e. age and wear) faults represents just under 90% of fault causes. High numbers of LV plant were commissioned during the 1960s (as shown in Figure 8) and many have exceeded their nominal design life. Furthermore, the majority of these assets are outdoors which increases the degradation rate. Accurate condition data is currently limited for this asset category and feedback from Network Operations suggests that high numbers of these assets are deteriorating in health. A review of data is set to be carried out over the next two years which will improve data accuracy by the start of ED1. The strategic decision to maintain network risk over the ED1 period means approximately 350 assets per year will need replacing over the eight-year period.

Expenditure levels for LV switchgear (Figure 44) reflect the intervention volumes over ED1. The ED2 figures have been derived from age-based modelling. The worst case scenario is based on the sensitivity analysis in Appendix 6 showing the high risk assets increasing to 20.8% by the end of ED2. Further work will be done in ED1 to explore additional intervention options that can be used to extend asset life.

7.4.7 Link Box Charts

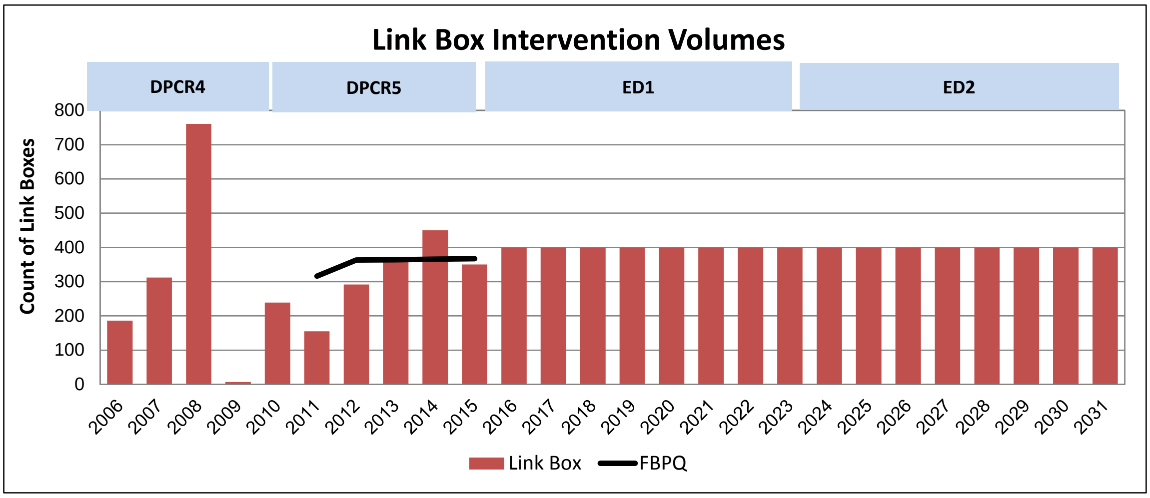


Figure 45: Link Box Intervention Volumes

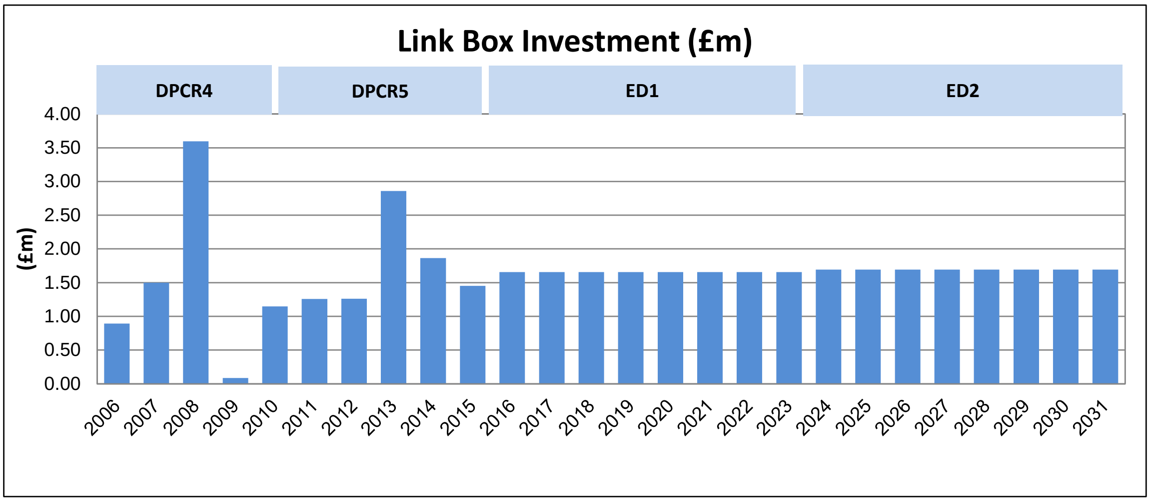


Figure 46: Link Box Investment

7.4.8 Link Box Commentary

As shown in Figure 45, the increase in disruptive failures of link boxes and a review of our asset management policy resulted in an increase in the number of link box replacements over DPCR5. To maximise public safety, intervention are set at 400 link boxes per year over ED1. This will target high numbers of HI 4 and 5 assets by the end of the period. The link box achievement for 2012/13 is 318 units, providing confidence that an increase in resource for year four and five will deliver the volumes scheduled for the remainder of DPCR5.

Expenditure levels for link boxes (Figure 46) reflect the increase in volumes over DPCR5 and a set level of investment over the ED1 period. It is expected that similar volumes and investment levels will need to be allocated for the ED2 period. Further work will be done in ED1 to explore additional intervention options that can be used to extend asset life.

7.5 HI Profiles (With and Without Investment)

The graphs below show the outputs from the models with and without the planned ED1 investment. The HI profiles indicated are derived from condition related investment only and exclude the contribution from load related expenditure.

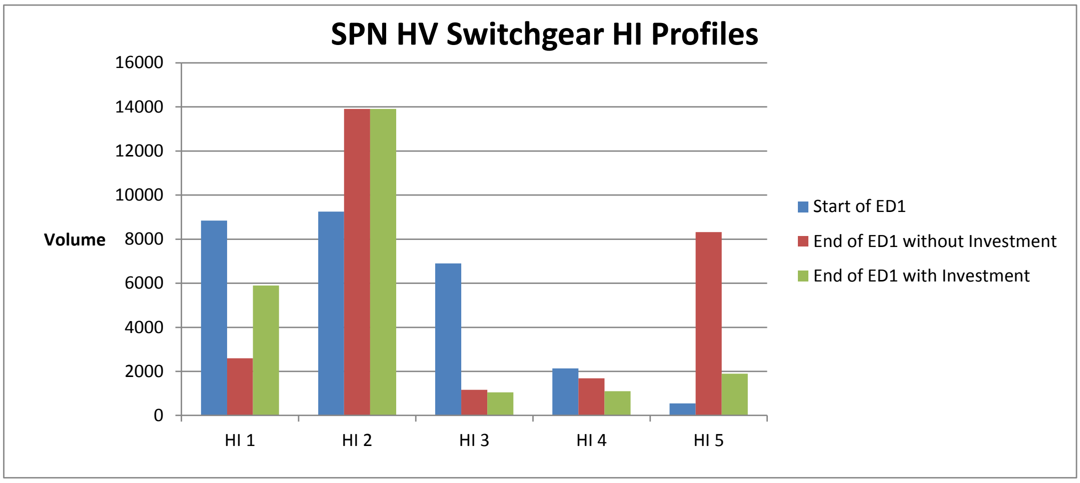


Figure 47: HV Switchgear HI Profiles (Source: 25_07_2012 ARP Model)

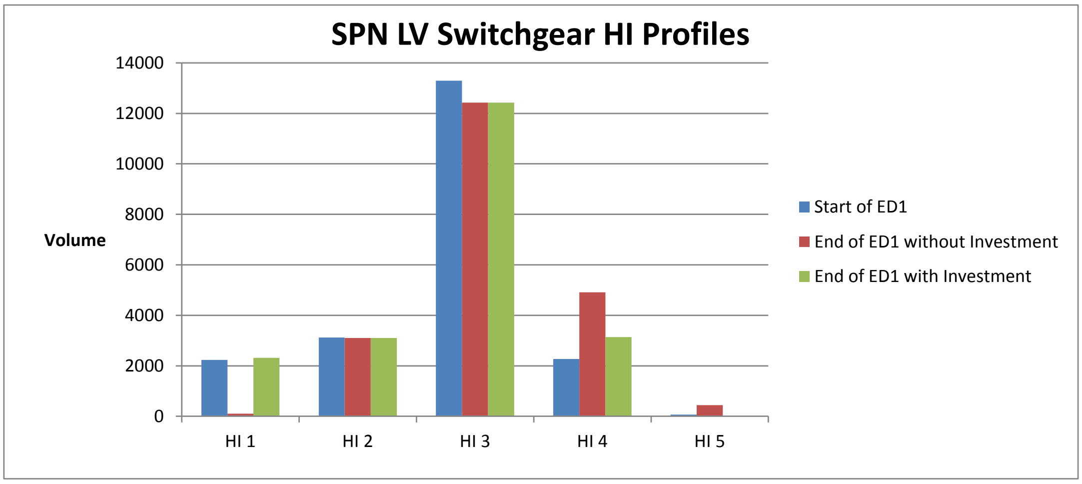


Figure 48: LV Switchgear HI Profiles (Source: SARM v0.3 Statistical Model)

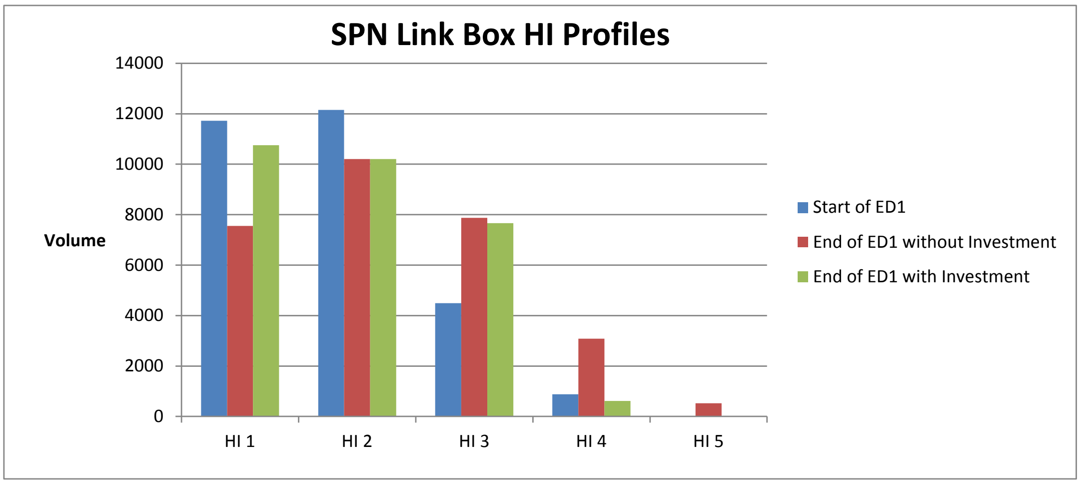


Figure 49: Link Box HI Profiles (Source: Stocks & Flows Model V1.1)

7.6 Sensitivity Analysis and Plan Validation

An independent report has been carried out by Decision Lab to understand how the health index profile of assets may change if the average asset life of assets does not turn out as predicted.

(Source for all HV and LV switchgear charts and tables in section 7.6: DecisionLab Ltd Analysis Feb 13
Source for link box sensitivity analysis: UK Power Networks)

7.6.1 HV Switchgear (GM)

The tables below show each average asset life change of years +/- 1, 2 and 4, represented in percentage of the current population for HV switchgear. With each change in average asset life, there is a subsequent movement in the percentage of population in each health index. An average asset 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 asset life will have on the asset group's HI profile.

Average asset life change	**2015** percentage HI profile				
	HI1	HI2	HI3	HI4	HI5
-4	29.3	34.2	25.8	8.5	2.2
-2	31.2	33.1	25.5	8.2	2.1
-1	31.6	33.2	25.2	8.0	2.0
0	32.0	33.3	25.0	7.7	2.0
1	32.9	32.9	24.7	7.6	2.0
2	33.4	32.9	24.4	7.4	1.9
4	35.2	32.3	23.8	6.9	1.8

Average asset life change	**2023** percentage HI profile				
	HI1	HI2	HI3	HI4	HI5
-4	20.1	60.3	6.0	4.6	8.9
-2	20.5	62.1	5.1	3.7	8.6
-1	21.5	61.8	5.8	3.3	8.4
0	21.6	62.6	4.5	3.0	8.3
1	22.1	62.7	4.1	3.0	8.1
2	23.5	61.9	3.6	3.2	7.8
4	25.4	60.9	3.0	3.4	7.3

Table 11: Average Asset Life Percentage Movements

Figure 50 represents summed HI4s and HI5s as a percentage of the population, showing the change at each average asset life iteration comparing 2015 and 2023.

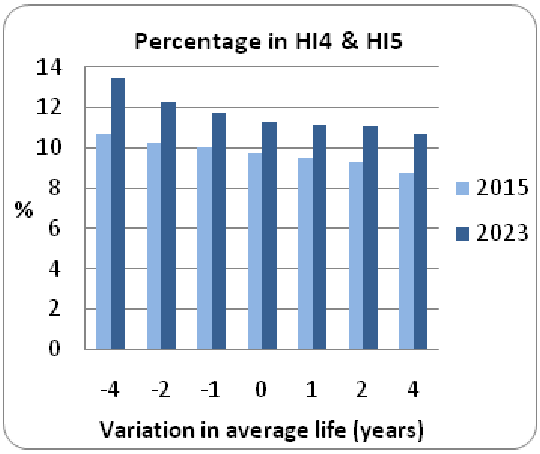


Figure 50: Percentage in HI4 and HI5 (HV Switchgear)

The results confirm that the ED1 replacement plan for SPN HV secondary switchgear is mildly sensitive to a variation in average asset life of up to four years.

7.6.2 LV Switchgear

The investment plan for LV switchgear was tested by varying the average asset life change of years ±1, 2 and 4 as shown in Figures 51 and 52 (note base case average asset life = 65 years).

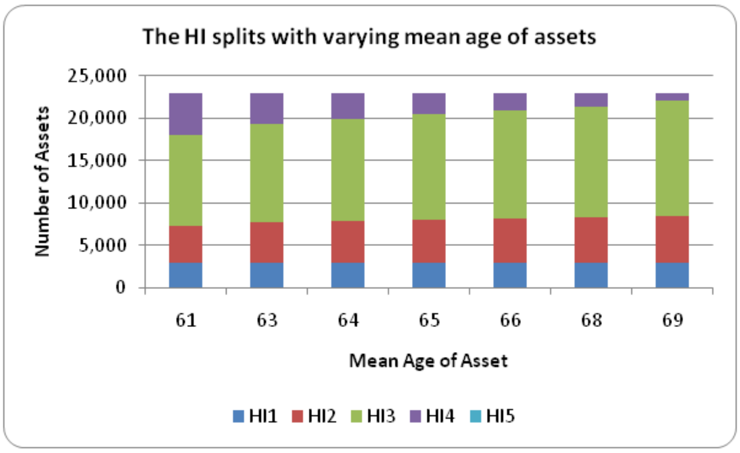


Figure 51: HI Splits for Various Average Asset Lives, with Investment

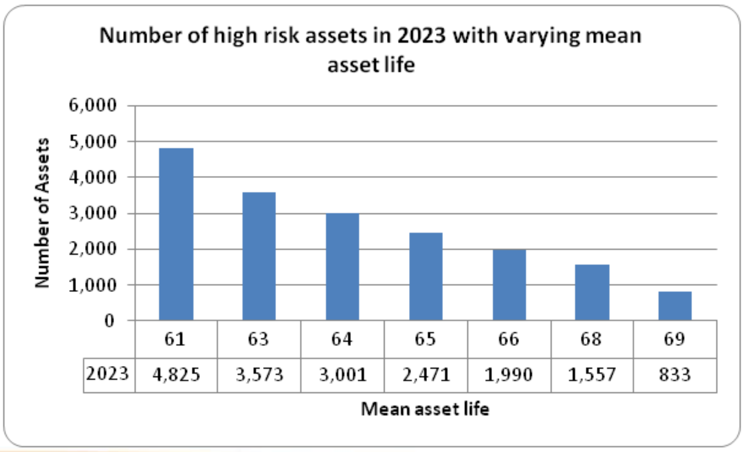


Figure 52: High Risk Asset Volumes for Various Average Asset Lives, with Investment

It has concluded that changing the LV switchgear average asset life by -4 years could cause the number of high-risk assets to rise by 10.3% to 21.1% of the population under the current ED1 investment plan.

7.6.3 Link Boxes

Analysis of historical condition data and trends in movements from each condition rating CR1 to CR4 led to a value being given for the total time spent in CR1-4. A review of the different outputs from the Stocks and Flows model shows that there is a high degree of sensitivity. Table 12 shows a summary of the sensitivity analysis.

Inputs		CR4 Outputs (With Investment)		Sensitivity Analysis	
Total Time Spent in CR 1-4	Adjustment Factor	2015	2023	Change in high risk assets	% Change in high risk assets
54	1.2	656	-545	-957	-232%
50	1.1	755	-116	-528	-128%
45	1	881	412	0	0
41	0.9	1045	1072	+660	+160%
36	0.8	1264	1908	+1496	+363%

Table 12: Link Box Sensitivity Analysis (Source: Stocks and Flows Model V1.1)

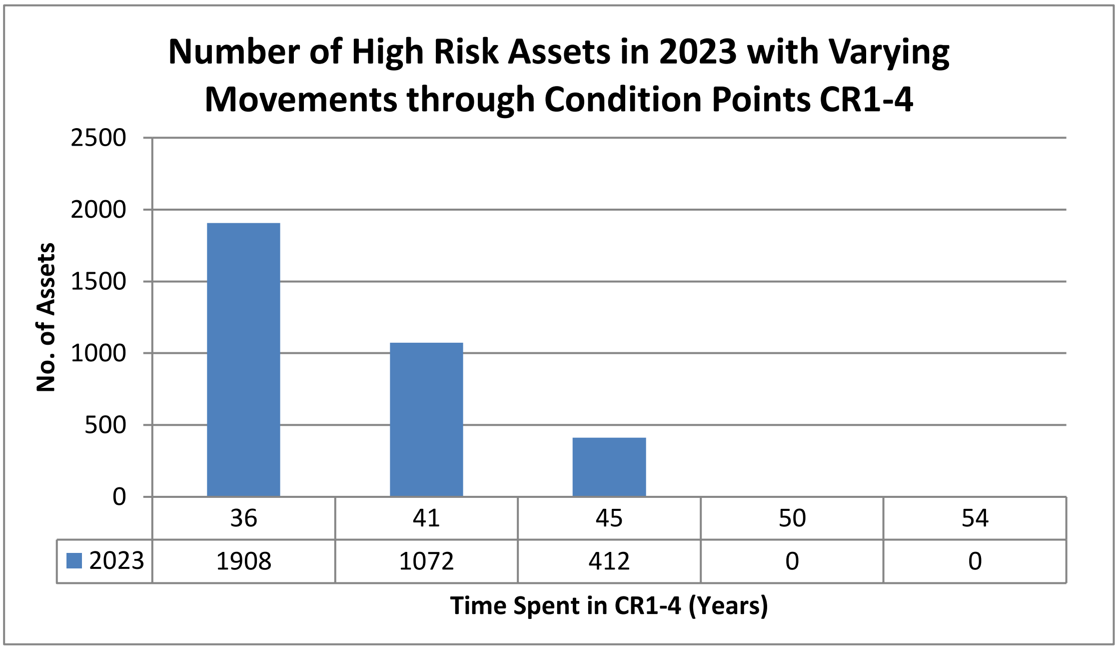


Figure 53: *High Risk Volumes for Various Movements through CR1-4, with Investment*

The closest correlation to the number of failures in the last year is when the total time spent in CR1-4 is 45 (highlighted in Table 12) and this has been used for the ED1 plan.

7.7 Network Risk

As described in section 4 of this document, the ARP model (and in-house criticality modelling techniques for non-ARP assets) has the capability of producing a criticality index (C1-4) for each individual asset, although this is a new concept that 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 14 show the health and criticality matrix for 2015 and 2023 with investment.

(Source: Strategy Decision for the RIIO-ED1 Electricity Distribution Price Control – Reliability and Safety 04/03/2012. Criticality & Health Index Working Group – Recommendations for Common Principles for Criticality Index Measures 13/12/2012).

Asset categories	Criticality	Units	Estimated Asset Health and Criticality Profile 2015					Asset Register
			Asset health index					2015
			HI1	HI2	HI3	HI4	HI5	
HV Switchgear (GM)	Low	No. Assets	3,169	1,294	117	22	4	4,606
	Average	No. Assets	5,578	7,761	6,551	2,065	522	22,477
	High	No. Assets	91	195	229	49	21	585
	Very high	No. Assets	0	0	0	0	0	-
LV Switchgear	Low	No. Assets	0	0	1	0	0	1
	Average	No. Assets	1,531	1,533	9,111	1,558	46	13,779
	High	No. Assets	644	1,451	3,831	655	19	6,600
	Very high	No. Assets	59	133	352	60	2	606
Link Box	Low	No. LBs	4,238	4,345	1,624	319	0	10,526
	Average	No. LBs	2,738	2,945	1,049	206	0	6,938
	High	No. LBs	4,739	4,858	1,815	356	0	11,768
	Very high	No. LBs	6	6	2	0	0	14

Table 13: Asset Health and Criticality 2015 *(Source: ARP, Statistical and Stocks & Flows Models)*

Asset categories	Criticality	Units	Estimated Asset Health and Criticality Profile 2023					Asset Register
			Asset health index					2023
			HI1	HI2	HI3	HI4	HI5	
HV Switchgear (GM)	Low	No. Assets	339	4,101	52	28	0	4,520
	Average	No. Assets	5,392	9,700	927	1,042	1,891	18,952
	High	No. Assets	169	105	74	29	0	377
	Very high	No. Assets	0	0	0	0	0	-
LV Switchgear	Low	No. Assets	0	0	1	0	0	1
	Average	No. Assets	1,322	1,480	8,545	2,432	0	13,779
	High	No. Assets	911	1,489	3,551	649	0	6,600
	Very high	No. Assets	87	137	326	56	0	606
Link Box	Low	No. LBs	3,879	3,642	2,846	159	0	10,526
	Average	No. LBs	2,507	2,489	1,659	283	0	6,938
	High	No. LBs	4,365	4,072	3,153	178	0	11,768
	Very high	No. LBs	4	5	4	1	0	14

Table 14: Asset Health and Criticality 2023 *(Source: ARP, Statistical and Stocks & Flows Models)*

[Note: Due to the HV switchgear 3:1 replacement ratio (as mentioned in section 7.4.1), the total asset volume reduces by the end of ED1].

8.0 Deliverability

8.1 Network Access and Outage Availability

There are no significant issues with regards to outages as customers will be back fed on the LV network or supplied from generators where necessary during the planned replacement work.

8.2 Consistency and Management

Proposed replacement volumes in ED1 have increased for LV switchgear. Contracts are continually reviewed to ensure that we support the level of contractor resource (Senior Authorised Persons [SAPs] and fitters) to deliver the work.

8.3 Implications of Standards and Specifications

Serious operational difficulties can result if a restriction needs to be applied to a particular type of switchgear following the discovery of a potentially dangerous defect. This situation can be made worse where networks contain ‘strings’ of identical items of switchgear. EDS 08-0105 specifies the maximum number of any type of distribution switchgear that may be installed on the network to avoid operational difficulties in the event of a type defect.

Prioritised lists of HV switchgear are determined using the condition- and risk-based ARP model. LV switchgear and link box replacement lists are determined by condition data taken from Ellipse/Enmac. Priority lists are given to the distribution planning teams annually to plan their replacement, before being issued to the delivery teams.

Appendices

Appendix 1 Age Profiles

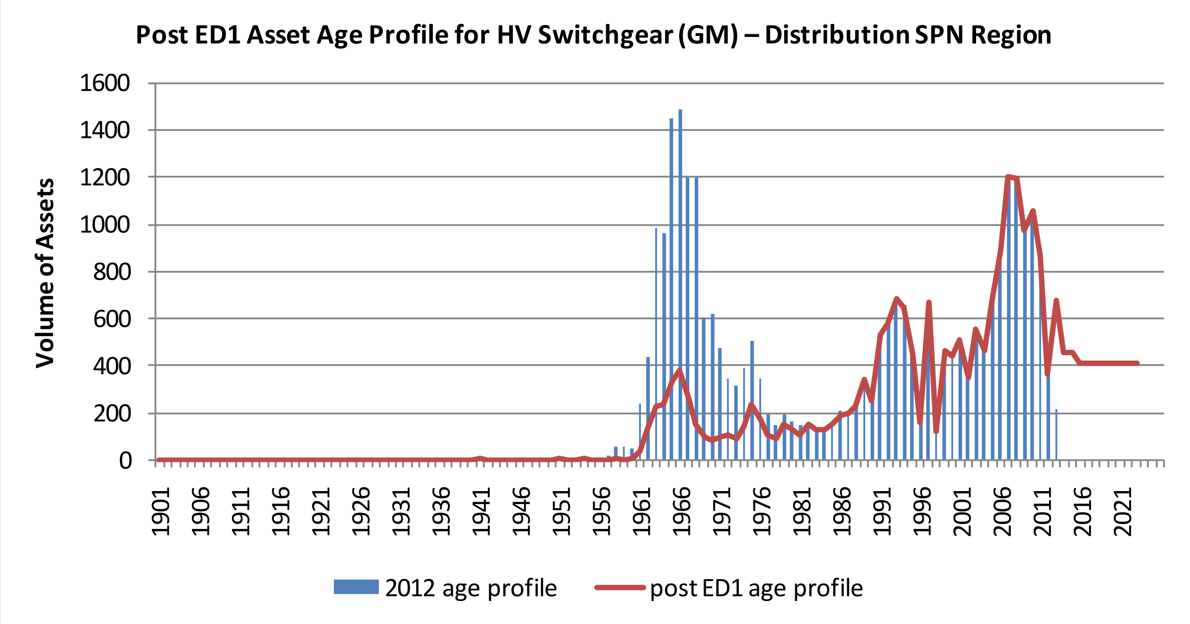


Figure 54 : Post ED1 Age Profile (Source: DecisionLab Ltd Analysis 2013)

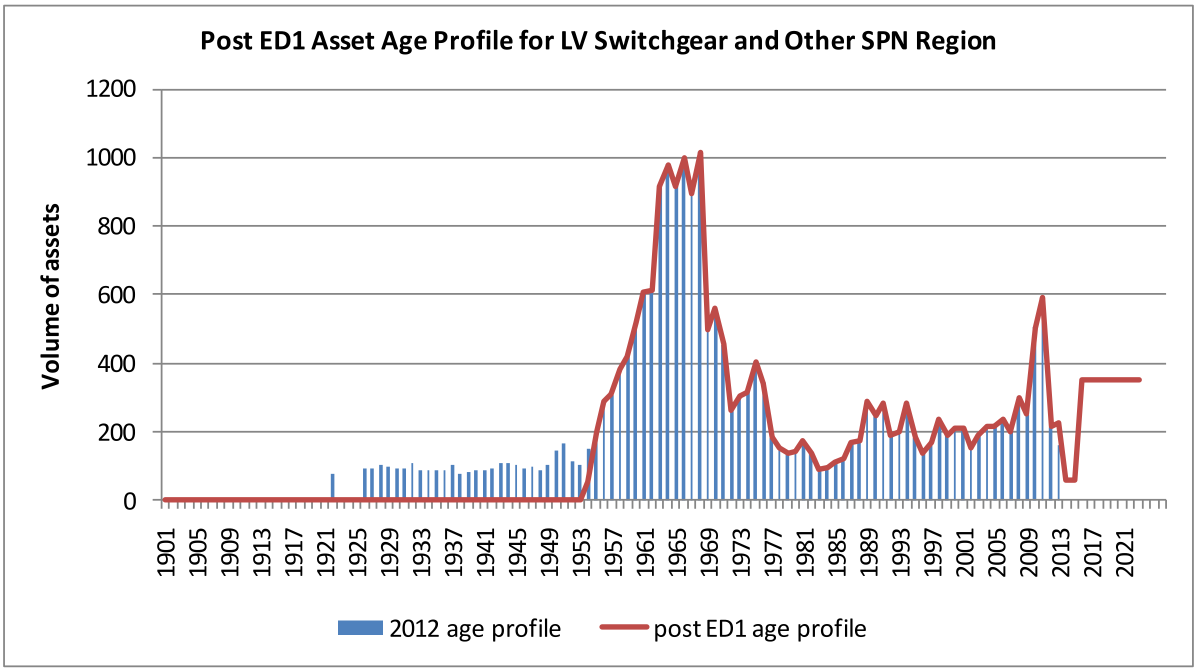


Figure 55 : Post ED1 Age Profile (Source: DecisionLab Ltd Analysis 2013)

[Note: the workings for LV switchgear are based purely on removing the oldest assets first].

Appendix 2 HI and Criticality Profiles

Asset Health and Criticality

(Source: Strategy Decision for the RIIO-ED1 Electricity Distribution Price Control – Reliability and Safety 04/03/2012. Criticality & Health Index Working Group – Recommendations for Common Principles for Criticality Index Measures 13/12/2012).

Asset Health and Criticality 2015

Asset categories	Criticality	Units	Estimated Asset Health and Criticality Profile 2015					Asset Register
			Asset health index					2015
			HI1	HI2	HI3	HI4	HI5	
HV Switchgear (GM)	Low	No. Assets	3,169	1,294	117	22	4	4,606
	Average	No. Assets	5,578	7,761	6,551	2,065	522	22,477
	High	No. Assets	91	195	229	49	21	585
	Very high	No. Assets	0	0	0	0	0	-
LV Switchgear	Low	No. Assets	0	0	1	0	0	1
	Average	No. Assets	1,531	1,533	9,111	1,558	46	13,779
	High	No. Assets	644	1,451	3,831	655	19	6,600
	Very high	No. Assets	59	133	352	60	2	606
Link Box	Low	No. LBs	4,238	4,345	1,624	319	0	10,526
	Average	No. LBs	2,738	2,945	1,049	206	0	6,938
	High	No. LBs	4,739	4,858	1,815	356	0	11,768
	Very high	No. LBs	6	6	2	0	0	14

Table 15: Asset Health and Criticality 2015 *(Source: ARP, Statistical and Stocks & Flows Models)*

Asset Health and Criticality 2023

Asset categories	Criticality	Units	Estimated Asset Health and Criticality Profile 2023					Asset Register
			Asset health index					2023
			HI1	HI2	HI3	HI4	HI5	
HV Switchgear (GM)	Low	No. Assets	339	4,101	52	28	0	4,520
	Average	No. Assets	5,392	9,700	927	1,042	1,891	18,952
	High	No. Assets	169	105	74	29	0	377
	Very high	No. Assets	0	0	0	0	0	-
LV Switchgear	Low	No. Assets	0	0	1	0	0	1
	Average	No. Assets	1,322	1,480	8,545	2,432	0	13,779
	High	No. Assets	911	1,489	3,551	649	0	6,600
	Very high	No. Assets	87	137	326	56	0	606
Link Box	Low	No. LBs	3,879	3,642	2,846	159	0	10,526
	Average	No. LBs	2,507	2,489	1,659	283	0	6,938
	High	No. LBs	4,365	4,072	3,153	178	0	11,768
	Very high	No. LBs	4	5	4	1	0	14

Table 16: Asset Health and Criticality 2023 *(Source: ARP, Statistical and Stocks & Flows Models)*

Appendix 3 Fault Data

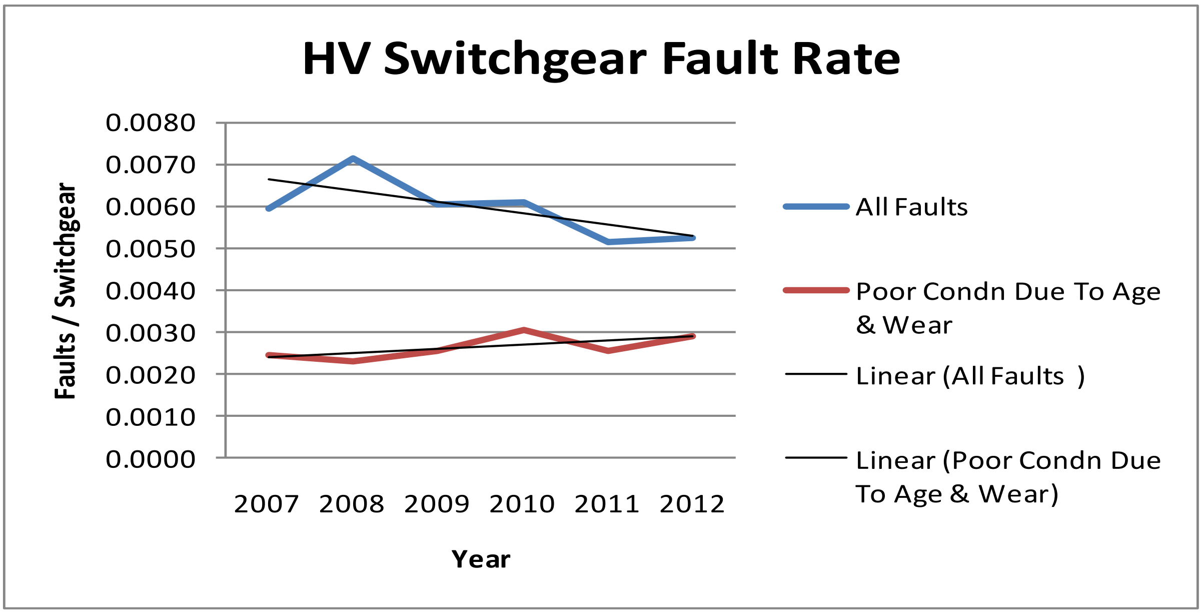


Figure 56: HV Switchgear (GM) Fault Rate (Source: UKPNs Fault Analysis Cube 15/03/2013)

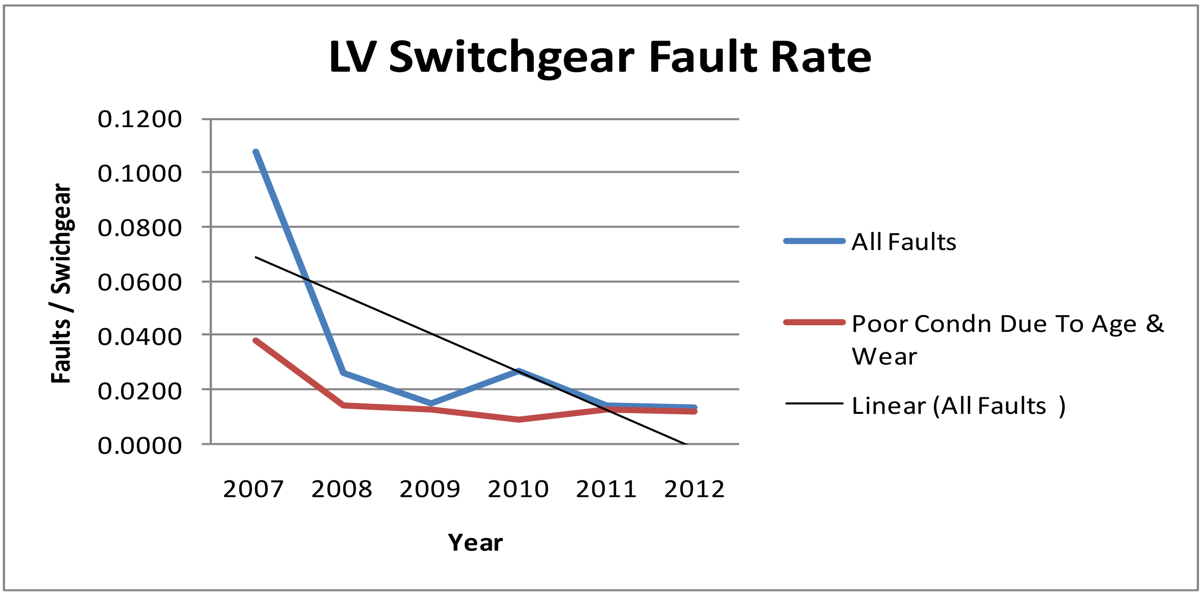


Figure 57: LV Switchgear Fault Rate (Source: UKPNs Fault Analysis Cube 15/03/2013)

Appendix 4 WLC Studies – Risk, Cost, Performance and Condition Profiles for Various Options

Not relevant for distribution assets: Intentionally left blank

Appendix 5 NLRE Expenditure Plan

Volumes

		Sub-Category	NAMP line(s)	NAMP Description	2015/ 2016	2016/ 2017	2017/ 2018	2018/ 2019	2019/ 2020	2020/ 2021	2021/ 2022	2022/ 2023
SPN	Switchgear	HV Switchgear (GM)	1.49.30/ 2.50.33	Install HV CB at Secondary Sites	35	35	35	35	35	35	35	35
			1.49.32/ 2.50.35	Install HV Switch at Secondary Sites	45	45	45	45	45	45	45	45
			1.49.51/ 2.50.21	Install HV RMU at Secondary Sites	333	333	333	333	333	333	333	333
			1.22.10	Switchgear weather cover installation	90	90	90	90	90	90	90	90
		HV Switchgear (PM)	1.19.27	Replace Pole Mounted Recloser	3	3	3	3	3	3	3	3
			1.19.08/ 1.20.34	Replace 11kV ABSD	15	15	15	15	15	15	15	15
		LV Switchgear	1.44.02	Replace LV Switchgear - Network Pillar	85	85	85	85	85	85	85	85
			1.44.03/ 2.50.25	LV Pillar - TMFC (ID)	31	31	31	31	31	31	31	31
			1.44.03/ 2.50.25	LV Feeder Pillar and TMFC (OD)	134	134	134	134	134	134	134	134
			1.44.05	Replace Service Turret	74	74	74	74	74	74	74	74
			1.44.08	Replace LV Boards	27	27	27	27	27	27	27	27
		Link Boxes	1.44.04/ 2.50.17	Replace Link Boxes	400	400	400	400	400	400	400	400
			1.44.07	Replace Covers & Frames	300	300	300	300	300	300	300	300
				TOTAL	**1,572**	**1,572**	**1,572**	**1,572**	**1,572**	**1,572**	**1,572**	**1,572**

Table 17: ED1 Volumes (19/02/2014 NAMP Table O)

Expenditure (£k)

		Sub-Category	NAMP line(s)	NAMP Description	2015/ 2016	2016/ 2017	2017/ 2018	2018/ 2019	2019/ 2020	2020/ 2021	2021/ 2022	2022/ 2023
SPN	Switchgear	HV Switchgear (GM)	1.49.30/ 2.50.33	Install HV CB at Secondary Sites	380	380	380	380	380	380	380	380
			1.49.32/ 2.50.35	Install HV Switch at Secondary Sites	309	309	309	309	309	309	309	309
			1.49.51/ 2.50.21	Install HV RMU at Secondary Sites	5,405	5,405	5,405	5,405	5,405	5,405	5,405	5,405
			1.22.10	Switchgear weather cover installation	48	48	48	48	48	48	48	48
		HV Switchgear (PM)	1.19.27	Replace Pole Mounted Recloser	26	26	26	26	26	26	26	26
			1.19.08/ 1.20.34	Replace 11kV ABSD	38	38	38	38	38	38	38	38
		LV Switchgear	1.44.02	Replace LV Switchgear - Network Pillar	652	652	652	652	652	652	652	652
			1.44.03/ 2.50.25	LV Pillar - TMFC (ID)	204	204	204	204	204	204	204	204
			1.44.03/ 2.50.25	LV Feeder Pillar and TMFC (OD)	878	878	878	878	878	878	878	878
			1.44.05	Replace Service Turret	313	313	313	313	313	313	313	313
			1.44.08	Replace LV Boards	286	286	286	286	286	286	286	286
		Link Boxes	1.44.04/ 2.50.17	Replace Link Boxes	1,693	1,693	1,693	1,693	1,693	1,693	1,693	1,693
			1.44.07	Replace Covers & Frames	23	23	23	23	23	23	23	23
		TOTAL (£k)			**10,225**	**10,225**	**10,225**	**10,225**	**10,225**	**10,225**	**10,225**	**10,225**

Table 18: ED1 Expenditure (19/02/2014 NAMP Table JLI)

Appendix 6 Sensitivity Analysis

Sensitivity Analysis for SPN HV Secondary Switchgear (written by Decision Lab)

Introduction

This is a report on the sensitivity analysis conducted on the Asset Risk and Prioritisation (ARP) Model developed by EA Technology, It has been used to support the asset replacement and investment strategy for SPN HV Secondary 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 asset 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 asset life.

Sensitivity Analysis

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

Standard average asset lives are used in the ARP model. These are from 30 to 55 years. In 2012, about 53% had a current average asset life of 45 years; about 26% of 40 years; and about 14% of 50 years. This study covered the full population of SPN HV Secondary Switchgear.

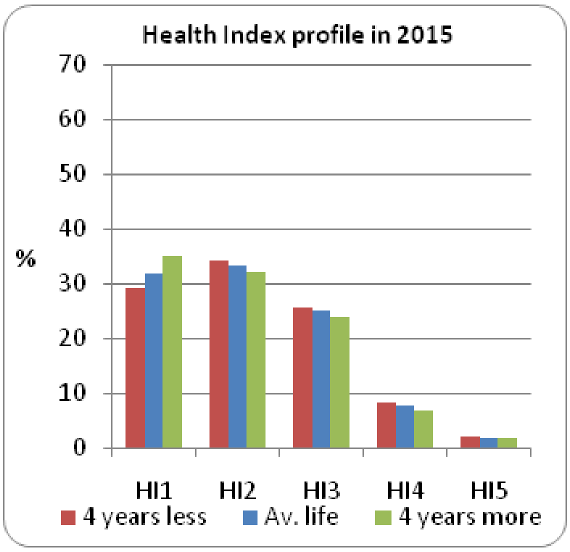
Using 2012 asset data and the replacement plans up to 2023, the ARP model was used to predict the Health Index of each asset at the beginning and end of ED1. This was then repeated, varying each current average asset life by ±1, 2 & 4 years.

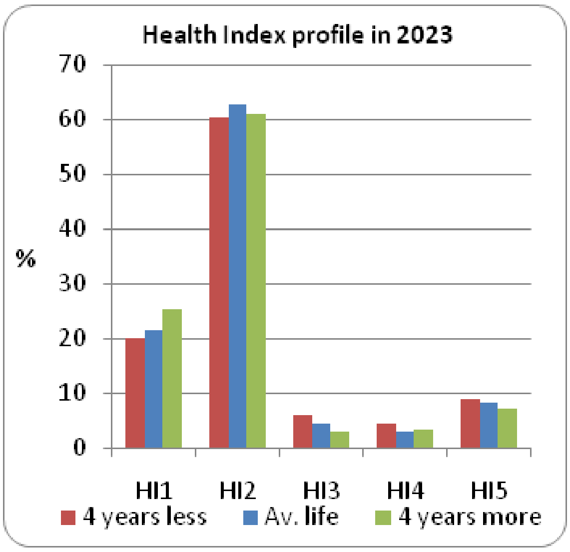
All results are shown below as the percentages of the population.

Average asset life change	2015 percentage HI profile				
	HI1	HI2	HI3	HI4	HI5
-4	29.3	34.2	25.8	8.5	2.2
-2	31.2	33.1	25.5	8.2	2.1
-1	31.6	33.2	25.2	8.0	2.0
0	32.0	33.3	25.0	7.7	2.0
1	32.9	32.9	24.7	7.6	2.0
2	33.4	32.9	24.4	7.4	1.9
4	35.2	32.3	23.8	6.9	1.8

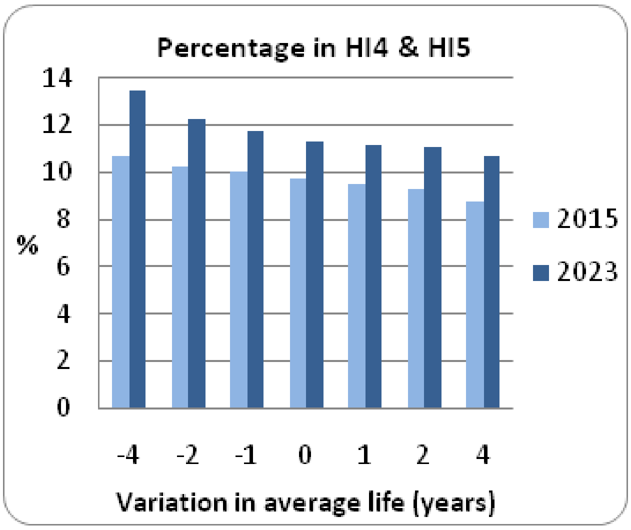
Average asset life change	2023 percentage HI profile				
	HI1	HI2	HI3	HI4	HI5
-4	20.1	60.3	6.0	4.6	8.9
-2	20.5	62.1	5.1	3.7	8.6
-1	21.5	61.8	5.8	3.3	8.4
0	21.6	62.6	4.5	3.0	8.3
1	22.1	62.7	4.1	3.0	8.1
2	23.5	61.9	3.6	3.2	7.8
4	25.4	60.9	3.0	3.4	7.3

As the percentages above are rounded, the sum of a row may not be exactly 100%. The upper and lower and current average asset life cases are charted below.





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



The results show:

- a variation in average asset life will affect the proportions of HI4 and HI5 assets in 2015 and 2023
- in 2015, if average asset life is four years longer, the proportion of HI4s and HI5s will reduce from 9.7% to 8.7%; but if four years shorter, it will increase to 10.7%
- in 2023, if average asset life is four years longer, the proportion of HI4 and HI5 will reduce from 11.3% to 10.7%; but if four years shorter, it will increase to 13.5%.

Conclusion

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

Sensitivity Analysis for SPN LV Switchgear (written by Decision Lab)

Executive Summary

Sensitivity Analysis has been conducted on the asset replacement strategy for LV Switchgear.

The sensitivity of the SARM1 model is a function of the *mean age of the asset*, and *the standard deviation about that mean* (approximately 95% of the assets will need to be replaced at ages within two standard deviations either side of the mean). The initial population and age of assets is not consistent for all regions, and this means that sensitivity analysis must be conducted on a region-by-region basis.

SPN Base Case

- The ED1 plan for the SPN region is 2,800 replacements (12.2% of the population) between 2015 and 2023.
- Without ED1 investment, the number of assets classified as high risk (HI4 and HI5 assets) will rise from 2,408 to 5,457 by 2023. This represents a rise from 10.5% to 23.8% of the population.
- With investment, the number of high-risk assets is 10.8%, which is close to the 2015 figure of 10.5%.
- In 2015, without investment, 12% of the population is already older than the average asset life. This is a very big proportion to be in this age group.
- The ED1 investment programme maintains the number of high-risk assets during the ED1 period.
- Looking beyond 2023, if there are no planned replacements during ED2 (no replacements between 2024 and 2031), then by 2031, 33% of the population will be high-risk assets.
- Applying the ED1 plan to ED2 (2,800 replacements between 2024 and 2031) means that, by 2031, the number of high-risk assets is 20.8% of the population. This is an increase on today's figure, and the expected figure by 2023. This suggests that higher investment will be needed in ED2 than in ED1.
- By the end of the ED1 investment plan, 50% of the population will be between 50 and 70 years old. This is a very high proportion to be close to the average asset life and explains why the ED2 plan will not work when the ED1 plan is applied to the ED2 plan.

SPN Sensitivity to 'End-of-Life'

- Sensitivity to end-of-life was tested by varying the average asset life by +/- 1, 2 and 4 years. The results of this are shown in Figure 10.
- If the average asset life was one year lower than the base case, with the current ED1 investment plan, the number of high-risk assets rises from 2,471 to 3,001 (from 10.8% to 13.1% of the LV Switchgear population).
- If the average asset life was two years lower than the base case, with the current investment plan, the number of high-risk assets rises from 2,471 to 3,573 (from 10.8% to 15.6% of the LV Switchgear population).

- If the average asset life was four years lower than the base case, with the current investment plan, the number of high-risk assets rises from 2,471 to 4,825 (from 10.8% to 21.1% of the LV Switchgear population).
- The number of high-risk assets (Category HI4 and HI5) is sensitive to average asset life. If the average asset life is anywhere between 61 years and 65 years, the number of high-risk assets can range between 2,471 and 4,825 (10.8% to 21.1% of the entire population).

The Base Case (SPN Region)

<u>Model inputs</u>

Mean = 65 years

Standard Deviation = 5 years

Investment plan for ED1 = 928 asset replacements between 2015 and 2023 (1,528 asset replacements when including 2012 to 2015).

These inputs result in the age profile of the LV Switchgear shown in Figure 1.

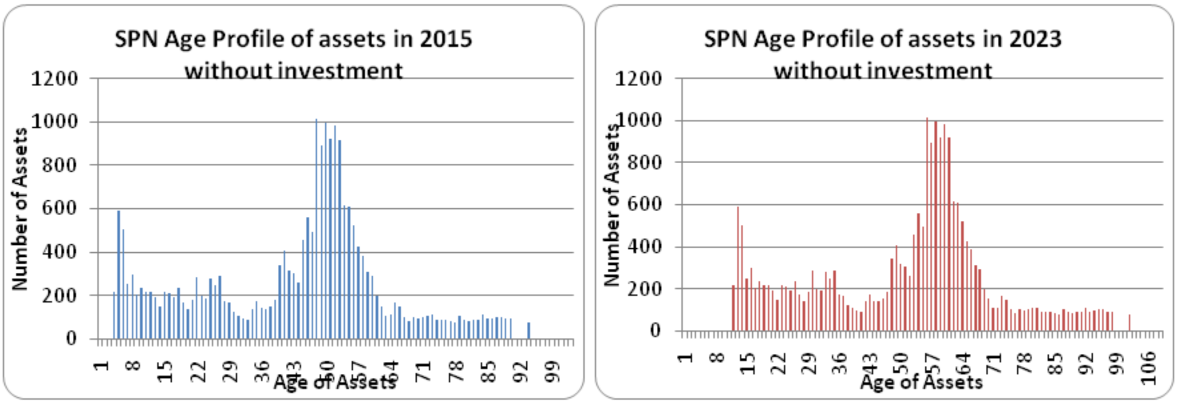


Figure 1. Comparison of age profiles for 2012 to 2023

In 2015, 12% of the population is already older than the average asset life. This is a very big proportion to be in this age group.

In 2015, 53% of the asset population is between the ages of 40 and 60 years old. By the end of ED1, without investment, this large proportion of the population will be approaching its average asset life.

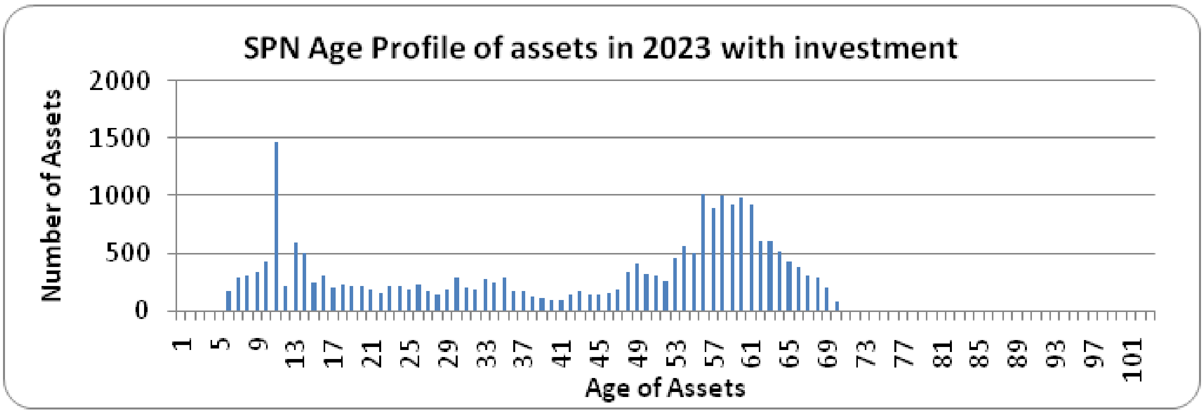


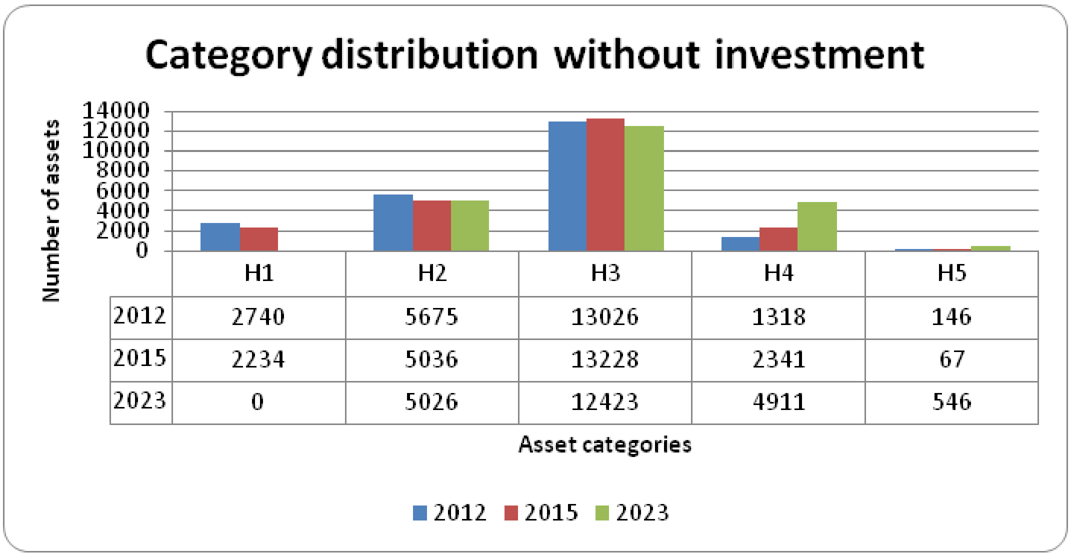
Figure 2. Age profile of the assets in 2023 with investment

Figure 2 shows that, by the end of the ED1 investment plan, 50% of the population is between 50 and 70 years old. This is a very high proportion to be close to the average asset life.

HI Scoring

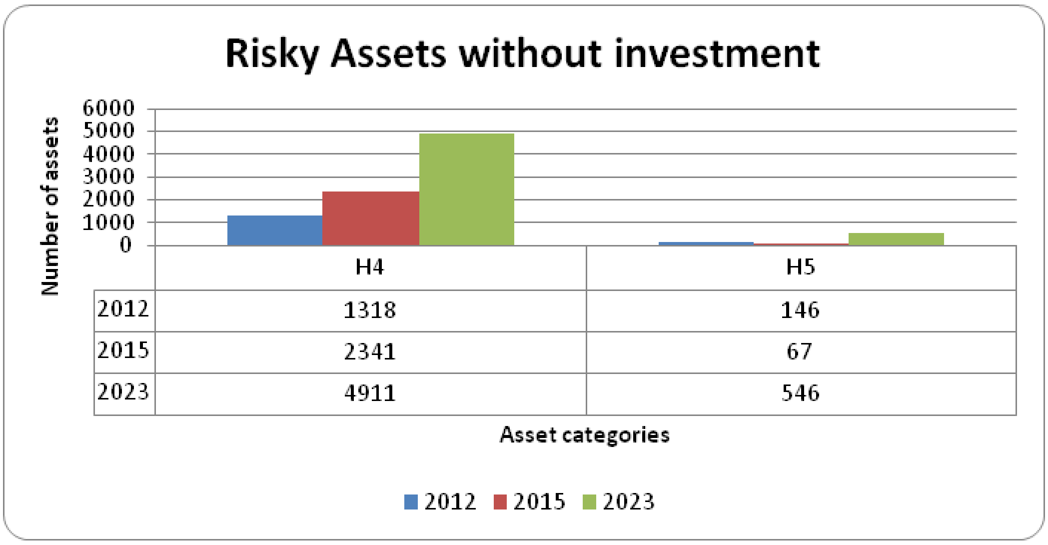
The volume of new HI4 and HI5 each year is calculated by taking the number of replacements indicated by SARM1, and then splitting at a 9:1 ratio between HI4 and HI5. This method was developed by UK Power Networks and has not been subjected to SA.

How effective is the investment plan? What would happen if there was no investment replacements made each year?



	H1	H2	H3	H4	H5
2012	2740	5675	13026	1318	146
2015	2234	5036	13228	2341	67
2023	0	5026	12423	4911	546

Figure 3. HI split without investment

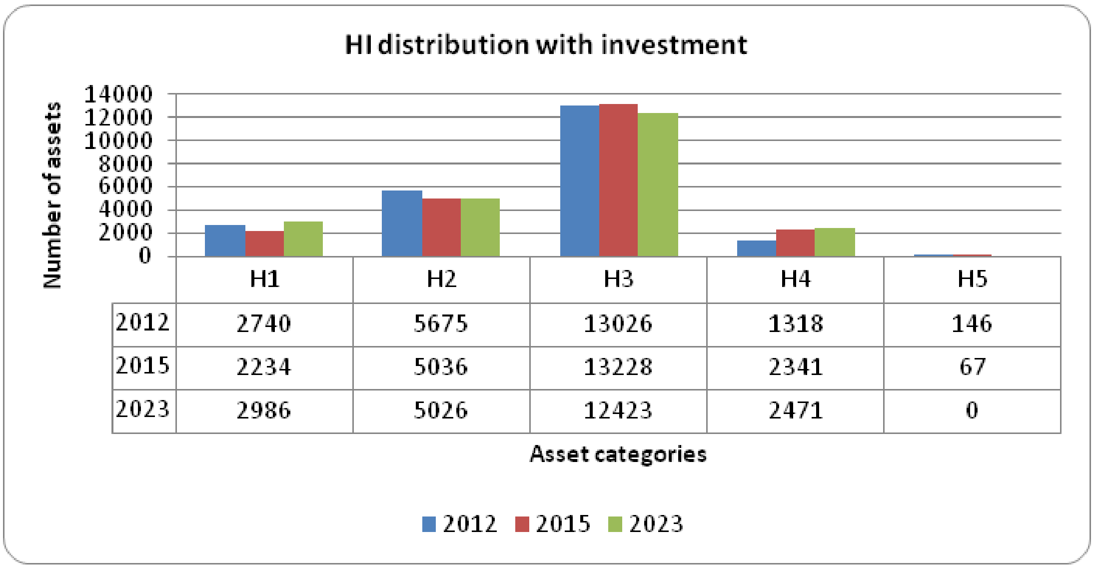


	H4	H5
2012	1318	146
2015	2341	67
2023	4911	546

Figure 4. High risk asset volumes without investment

Clearly, there is a significant rise in the number of LV Switchgear in the high-risk categories (HI4 and HI5) from 2012 to 2023. In the period 2015 to 2023, the number of high-risk assets rises from 2,408 to 5,457 (From 10.5% to 23.8% of the whole population). The risk has risen and investment must be made to reduce the number of high-risk assets.

When the ED1 investment plan is introduced, it can clearly be seen, by comparing Figure 6 below with Figure 4 above, that the volume of high-risk assets is reduced.



	H1	H2	H3	H4	H5
2012	2740	5675	13026	1318	146
2015	2234	5036	13228	2341	67
2023	2986	5026	12423	2471	0

Figure 5. HI split with investment

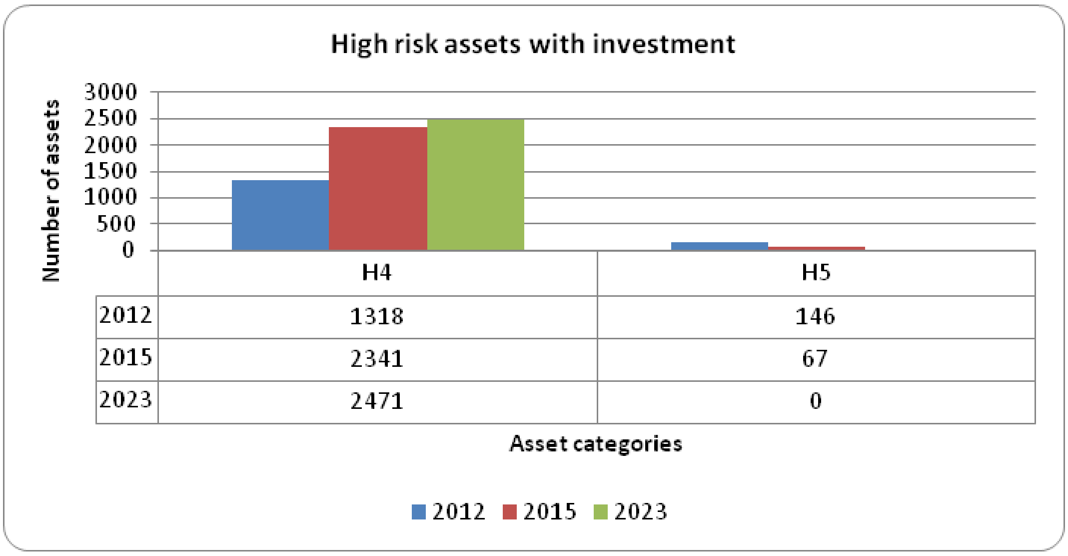


Figure 6. High-risk assets volumes with investment

By 2015, there are 2,408 high-risk assets. Figure 6 above shows that the investment plan ensures that, over the period 2015 to 2023, the number of high-risk assets is maintained at a similar level, accordingly high risk assets only rise from 2,408 to 2,471 (10.5% to 10.8%). The investment programme in ED1 of 350 replacements per year maintains the 2015 level of risk.

What happens to the number of high-risk assets when the ED1 period finishes and there is no ED2 intervention (no replacements are made after 2023)?

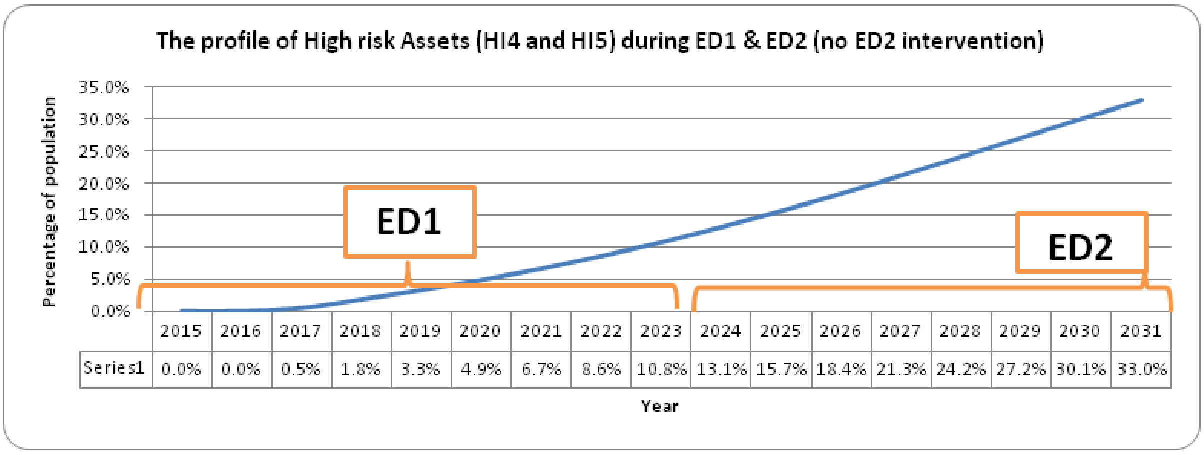
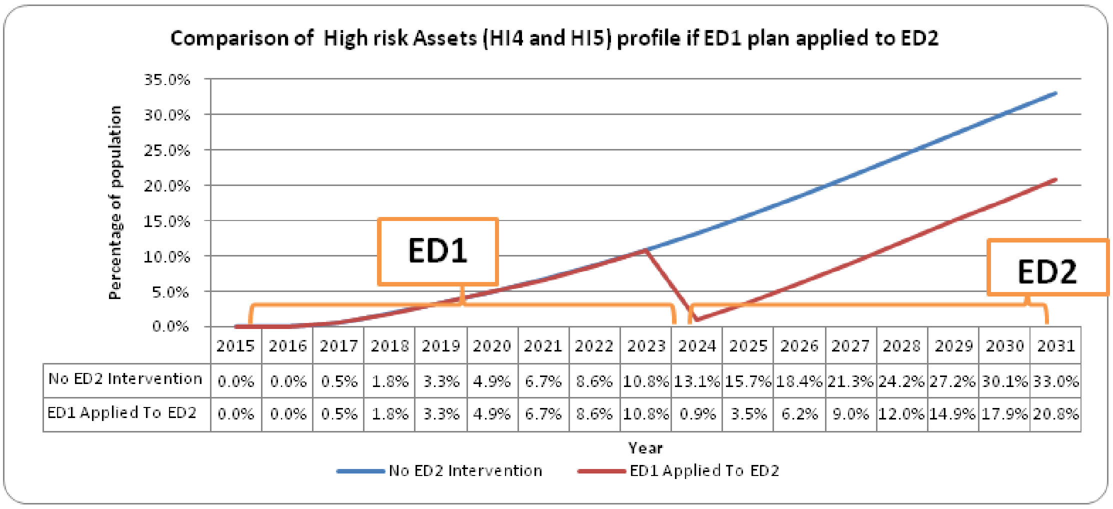


Figure 7. Proportion of high-risk assets with investment in ED1

The plan to replace 2,986 assets between the years 2012 and 2023 means that, by 2023, 10.8% of the entire population will be high-risk assets (HI4s and HI5s). If there is no ED2 plan (no replacements between 2024 and 2031), by 2031 33% of the population will be high-risk assets.

The chart below shows the comparison between no ED2 investment and if the ED1 plan was applied to ED2 (2,800 replacements between the years 2024 and 2031).



	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
No ED2 Intervention	0.0%	0.0%	0.5%	1.8%	3.3%	4.9%	6.7%	8.6%	10.8%	13.1%	15.7%	18.4%	21.3%	24.2%	27.2%	30.1%	33.0%
ED1 Applied To ED2	0.0%	0.0%	0.5%	1.8%	3.3%	4.9%	6.7%	8.6%	10.8%	0.9%	3.5%	6.2%	9.0%	12.0%	14.9%	17.9%	20.8%

Figure 8. Proportion of high-risk assets with investment in ED1 and ED2

In 2024, the ED2 plan (2,800 replacements between 2024 and 2031) has commenced. This is why there is a dip in the "ED1 Applied To ED2" line in 2024, when compared to the "No ED2 Intervention" line.

By applying the ED1 plan to ED2 (2,800 replacements between 2024 and 2031), by 2031 the number of high-risk assets is 20.8% of the population. This is the result of an ageing population of assets.

Although the risk is reduced, this is a very large proportion of the population and suggests that a greater investment will be required in ED2 than the ED1 plan.

Sensitivity Analysis

What happens to the investment plan in 2023 if the average asset life varies by +/- 1, 2 and 4 years?

Under the current base case inputs, the number of high-risk assets is maintained. How sensitive is the average asset life value to the number of high-risk assets at the end of the ED1 planning period?

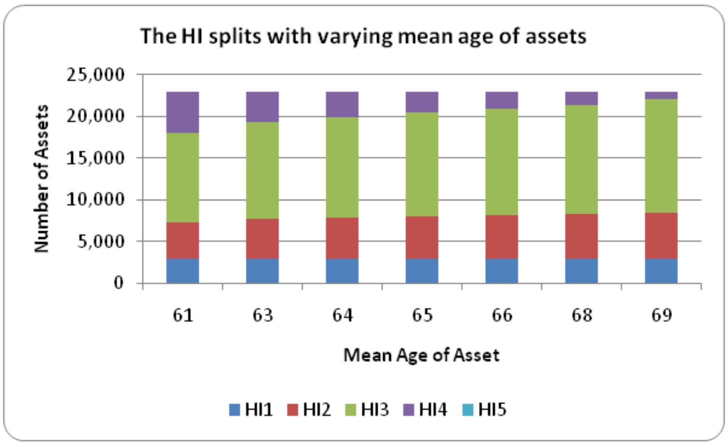


Figure 9. HI splits for various average asset lives with investment (base case life = 70 years)

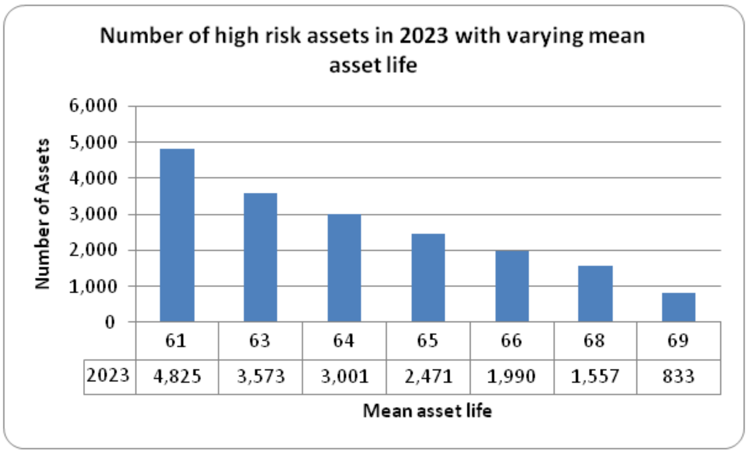


Figure 10. High-risk asset volumes for various average asset lives, with investment (base case life = 70 years)

Figure 10 shows that the number of high-risk assets (Category HI4 and HI5) is sensitive to average asset life with the current ED1 investment plan. If the average asset life is anywhere between 61 years and 65 years, the number of high-risk assets can range between 2,471 and 4,825 (10.8% to 21.1% of the entire population).

If the average asset life were one year lower than the base case, the number of high-risk assets rises from 2,471 to 3,001 (10.8% to 13.1% of the LV Switchgear population) with the current ED1 investment plan.

If the average asset life were two years lower than the base case then the number of high-risk assets rises from 2,471 to 3,573 (10.8% to 15.6% of the LV Switchgear population) with the current ED1 investment plan.

If the average asset life were four years lower than the base case then the number of high-risk assets rises from 2,471 to 4,825 (10.8% to 21.1% of the LV Switchgear population) with the current ED1 investment plan.

These are important points, because a small error in mean age of an LV Switchgear (-4 years) could cause the number of high-risk assets to rise by 10.3% to 21.1% of the population under the current ED1 investment plan.

Appendix 7 Named Schemes

Not relevant for distribution assets: Intentionally left blank

Appendix 8 Output NAMP/ED1 Business Plan Data Table Reconciliation

		VOLUMES																				
	Outputs	Asset Stewardship Reports										Business Plan Data Tables										
Asset Type	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
HV Switchgear (GM)	Install HV CB at Secondary Sites	1.49.30	30	30	30	30	30	30	30	30	240	CV3	*34	30	30	30	30	30	30	30	30	240
	Install HV Switch at Secondary Sites	1.49.32	35	35	35	35	35	35	35	35	280	CV3	*37	35	35	35	35	35	35	35	35	280
	Install HV RMU at Secondary Sites	1.49.51	295	295	295	295	295	295	295	295	2,360	CV3	*38	295	295	295	295	295	295	295	295	2,360
	Install HV CB at Secondary Sites (Faults)	2.50.33	5	5	5	5	5	5	5	5	40	V4B	*34	5	5	5	5	5	5	5	5	40
	Install HV Switch at Secondary Sites (Faults)	2.50.35	10	10	10	10	10	10	10	10	80	V4B	*37	10	10	10	10	10	10	10	10	80
	Install HV RMU at Secondary Sites (Faults)	2.50.21	38	38	38	38	38	38	38	38	304	V4B	*38	38	38	38	38	38	38	38	38	304
	EPN Weather Cover Installation	1.22.10	90	90	90	90	90	90	90	90	720	CV6	11	90	90	90	90	90	90	90	90	720
														418	418	418	418	418	418	418	418	3,344
HV Switchgear (PM)	Replace Pole Mounted Recloser	1.19.27	3	3	3	3	3	3	3	3	24	CV3	160	3	3	3	3	3	3	3	3	24
	Replace 11kV ABSD	1.19.08/ 1.20.34	15	15	15	15	15	15	15	15	120	CV3	164	15	15	15	15	15	15	15	15	120
LV Switchgear	LV Pillar - TMFC (ID)	1.44.03	30	30	30	30	30	30	30	30	240	CV3	144	30	30	30	30	30	30	30	30	240
	Capital Replacement of LV Pillar - TMFC (ID)	2.50.25	1	1	1	1	1	1	1	1	8	V4B	16	1	1	1	1	1	1	1	1	8
	LV Feeder Pillar and TMFC (OD)	1.44.03	129	129	129	129	129	129	129	129	1,032	CV3	145	129	129	129	129	129	129	129	129	1,032
	Capital Replacement LV Feeder Pillar & TMFC (OD)	2.50.25	5	5	5	5	5	5	5	5	40	V4B	17	5	5	5	5	5	5	5	5	40
	Remove Service Turret	1.44.05	74	74	74	74	74	74	74	74	592	V4A	19	74	74	74	74	74	74	74	74	592
	Replace LV Boards	1.44.08	27	27	27	27	27	27	27	27	216	CV3	146	27	27	27	27	27	27	27	27	216
	Replace LV Switchgear - Network Pillar	1.44.02	85	85	85	85	85	85	85	85	680	CV3	147	485	485	485	485	485	485	485	485	3,880
Link Boxes	Replace Link Boxes	1.44.04	330	330	330	330	330	330	330	330	2,640											
	Replace Link Boxes (Fault)	2.50.17	70	70	70	70	70	70	70	70	560											
	Replace Covers & Frames	1.44.07	300	300	300	300	300	300	300	300	2,400	CV13	11	300	300	300	300	300	300	300	300	2,400
														768	776	782	797	810	844	778	779	6,334
	Total		1,572	1,572	1,572	1,572	1,572	1,572	1,572	1,572	12,576	Total		1,572	1,572	1,572	1,572	1,572	1,572	1,572	1,572	12,576

Table 19: NAMP to ED1 Business Plan Data Table Reconciliation

(Source: 19/02/2014 NAMP Table O / 21/02/2014 ED1 ED1 Business Plan)

[Note: *represents asset additions]

The highlighted RIGs rows have volumes from other projects unrelated to this document mapping to them. The volume differences are described below:

- A further 3,344 assets map to CV6 11. The total volumes mapping to this line is 4,064.
- A further 6,334 assets map to CV13 11. The total volumes mapping to this line is 8,734.

Appendix 9 Efficiency Benchamarking with other DNOs

HV Switchgear

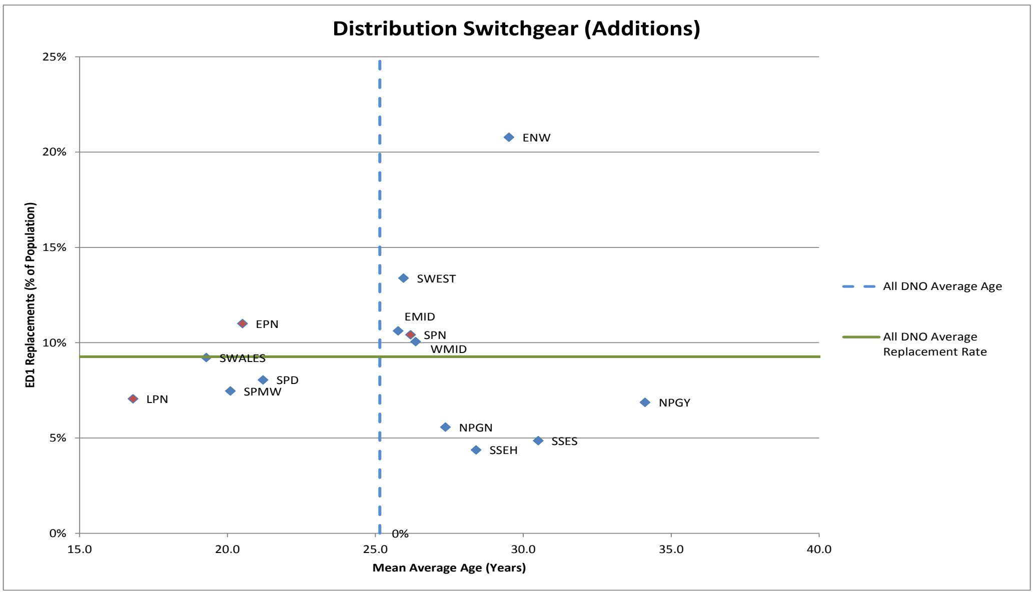


Figure 58: Efficiency Benchmarking (Source: DNO Datashare 2013)

The graph above shows that SPN has a slightly higher replacement rate than the industry average per percentage of population and a higher average age. As discussed in Section 4.1, the ED1 plan is based on the output from the ARP model where no asset is replaced purely on age. The plan is to target primarily the large numbers of defective oil-filled items of switchgear commissioned during the 1960s (as shown in Figure 5) which have a health index of 4 or 5.

LV Switchgear

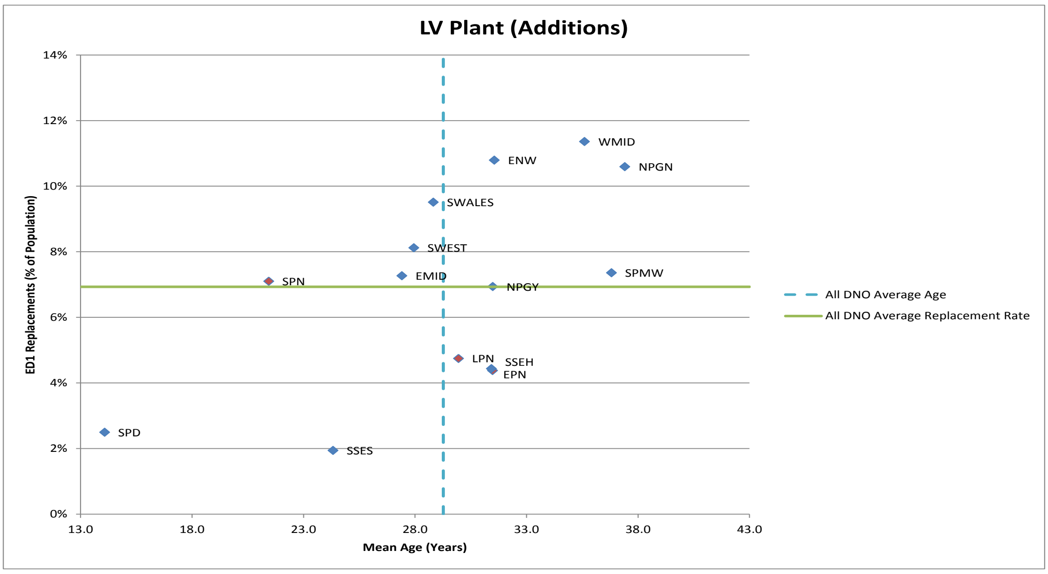


Figure 59: Efficiency Benchmarking (Excl Link Boxes) (Source: DNO Datashare 2013)

The graph above shows that SPN aligns to the industry average replacement rate per percentage of population but has a lower average age. The plan for ED1 has been based not only on the output from the age based statistical model but also compared to historical replacement rates, fault rates and condition of the oldest 10% of the population to determine the right outputs to use for investment forecasts.

High numbers of LV pillars in SPN are situated on the coast, increasing corrosion and deterioration. A recent risk review highlights UKPNs concerns over data accuracy. Accurate condition data is currently limited for this asset category and feedback from Network Operations suggests that high numbers of these assets are deteriorating in health. This was taken into consideration with the submitted ED1 volumes.

Link Boxes

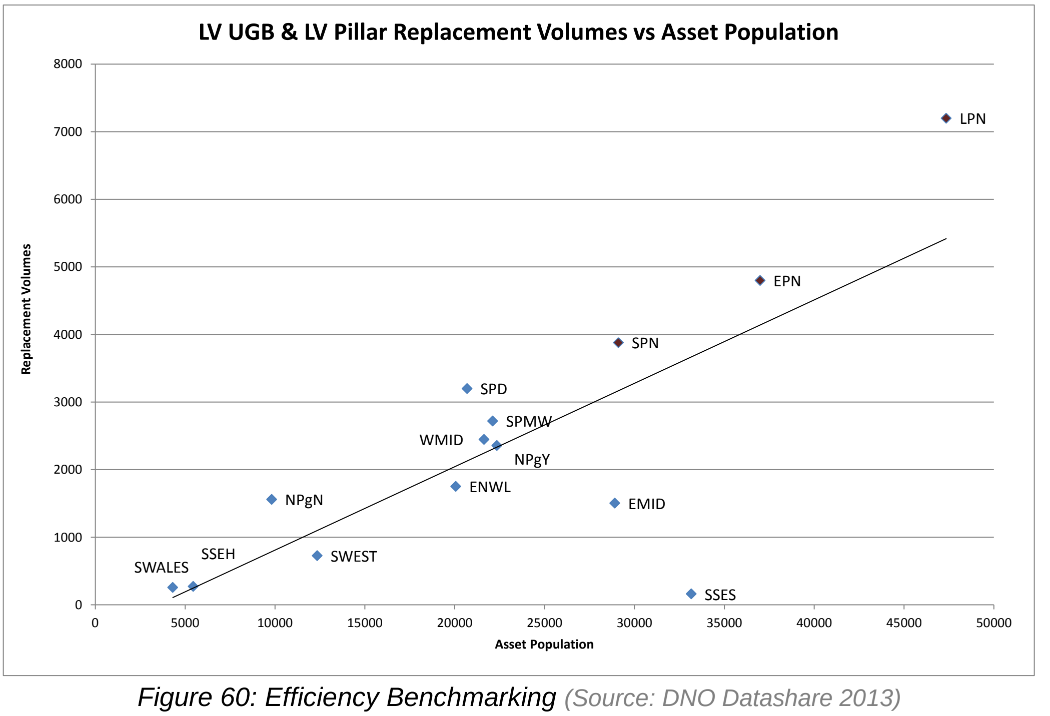


Figure 60: Efficiency Benchmarking *(Source: DNO Datashare 2013)*

[Note: Age-based data is limited for this asset category]

Figure 60 shows that SPN is higher than the industry average in the number of replacements proposed for the ED1 period (per asset population for link boxes). A disruptive failure of a link box in 2012 resulted in an injury to a member of the public and consequently an improvement notice was issued to UK Power Networks by the health and safety executive. As a company we are still experiencing a high number of disruptive failures – there has been a steady increase in the number of reported incidents involving link boxes over the period from 2007 to present.

Proximity to members of the public means that as the assets age and condition deteriorates, they expose the public to risk of injury and damage to nearby property. UK Power Networks consider this an unacceptable level of risk and believe it essential to complete the proposed level of investment.

Appendix 10 Material Changes Since July 2013 ED1 Submission

The changes between the July 2013 submission and the March 2014 re-submission are summarised below.

Asset Replacement (CV3)

Asset Type	Action	Change Type	2013 Submission	2014 Submission	Difference
HV Switchgear (GM)	Replace	Volume (Additions)	2,880	2,884	4
		Volume (Removals)	6,224	6,224	0
		Investment (£m)	38.50	38.24	(0.26)
		UCI (£k)	13.37	13.26	(0.11)
HV Switchgear (PM)	Replace	Volume (Additions)	144	144	0
		Volume (Removals)	144	144	0
		Investment (£m)	0.51	0.51	0
		UCI (£k)	3.54	3.54	0
LV Switchgear	Replace	Volume (Additions)	1,488	1,488	0
		Volume (Removals)	1,488	1,488	0
		Investment (£m)	10.89	10.89	0
		UCI (£k)	7.32	7.32	0
Link Boxes (incl LV Network Pillars)	Replace	Volume (Additions)	3,880	3,880	0
		Volume (Removals)	3,880	3,880	0
		Investment (£m)	18.76	18.76	0
		UCI (£k)	4.84	4.84	0

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

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

UKPN propose to make no changes to the July 2013 submission for HV switchgear and LV plant. [Note: The small changes in cost and volumes are due to consequential changes from major projects].

Faults (V4b/CV15a)

Asset Type	Action	Change Type	2013 Submission	2014 Submission	Difference
HV Switchgear (GM)	Replace	Volume (Additions)	424	424	0
		Volume (Removals)	903	903	0
		Investment (£m)	Changes to capitalised fault restoration expenditure can be found in Document 14: SPN I&M & Faults		
		UCI (£k)			
LV Switchgear	Replace	Volume (Additions)	48	48	0
		Volume (Removals)	48	48	0
		Investment (£m)	Changes to capitalised fault restoration expenditure can be found in Document 14: SPN I&M & Faults		
		UCI (£k)			
Link Boxes	Replace	Volume	Included in CV3		

Table 21 – Material Changes to July ED1 Submission (V4b)

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