Document 8
Asset Category – HV Switchgear and LV Plant
EPN

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 Updated EPN Secondary Switchgear to reflect 13th February S&R NAMP figures. Updated references to align to latest NAMP Addition of Appendices 8,9 & 10 Updated HI profiles to reflect latest RIGs tables Removed HI/CI matrices	Zoe Cornish	Minor Major Minor Minor Minor Minor	Section 1.1 Section 1.2, 1.4 & Appx 5 Throughout document Appx 8, 9 & 10 Sec 1.4, 4.6, 7.6 & Appx 2 Appendix 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	Updated Appendix 10	Zoe Cornish	Minor	Appendix 10
1.4	28/02/2014	Updated Appendix 8	Zoe Cornish	Minor	Appendix 8
1.5	04/03/2014	Updated Exec Summary	Robert Lafferty	Minor	Section 1.3
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 RIGS 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 EPN HV Switchgear and LV Plant

1.1 Scope

This document details UK Power Network's NLRE intervention proposals for EPN 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 32,724 HV switchgear (GM) assets and 13,500 HV switchgear (PM) assets (air break switch disconnectors and auto-reclosers) with a combined estimated Modern Equivalent Asset Valuation (MEAV) of £477m. The proposed investment is £6.2m per annum and this equates to an average annual 1.3% of the MEAV for these asset categories. Furthermore, the LV switchgear population comprises of approximately 30,040 assets and 37,164 link boxes. The estimate MEAV of LV plant is £435m. The proposed investment is £4.1m per annum and this equates to an average annual 1.0% of the MEAV for these asset categories.

Intervention costs total £83m and are held in Ofgem's RIGs reporting plan 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	**£48.7m Asset Replacement** **£5.6m Operational IT&T**
	2.50.33*	V4b 34	V4b 34	CV15a 27	
Install HV Switch at Secondary Sites	1.49.32	CV3 37	CV3 165	CV3 37	
	2.50.35*	V4b 37	V4b 37	CV15a 27	
Install HV RMU at Secondary Sites	1.49.51	CV3 38	CV3 166	CV3 38	
				CV105 6	
	2.50.21*	V4b 38	V4b 38	CV15a 27	
Replace Pole-Mounted Recloser	1.19.27	CV3 32	CV3 160	CV3 32	**£1.3m 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	**£10.5m Asset Replacement**
	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	
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	**£22.7m Asset Replacement** **£0.2m I&M**
Replace Link Boxes	1.44.04				
	2.50.17*				
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: There are £5.5m in associated civil costs that are included in the civils ASR].

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 has been set 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 such that we maintain the level of risk on the network, i.e. the number of assets with a poor health index (HI 4 and HI 5) 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 EPN (excluding civils/automation etc) is £83m. The annual expenditure profile (all costs) 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
EPN	Switchgear	HV Switchgear (GM)	*1.49.30/ 2.50.33*	*Install HV CB at Secondary Sites*	*3,306*	*3,306*	*3,291*	*3,291*	*3,291*	*3,291*	*3,291*	*3,291*
			1.49.32/ 2.50.35	*Install HV Switch at Secondary Sites*	*136*	*136*	*136*	*136*	*136*	*136*	*136*	*136*
			1.49.51/ 2.50.21	*Install HV RMU at Secondary Sites*	*3,846*	*3,846*	*3,863*	*3,863*	*3,863*	*3,863*	*3,863*	*3,863*
			1.22.10	*Switchgear weather cover installation*	*103*	*103*	*103*	*103*	*103*	*103*	*103*	*103*
		HV Switchgear (PM)	*1.19.27*	*Replace Pole Mounted Recloser*	*61*	*61*	*61*	*61*	*61*	*61*	*61*	*61*
			1.20.34	*Replace 11kV ABSD*	*98*	*98*	*98*	*98*	*98*	*98*	*98*	*98*
		LV Switchgear	*1.44.02*	*Replace LV Switchgear - Network Pillar*	*722*	*722*	*722*	*722*	*722*	*722*	*722*	*722*
			1.44.03/ 2.50.25	*LV Pillar - TMFC (ID)*	*260*	*260*	*260*	*260*	*260*	*260*	*260*	*260*
			1.44.03/ 2.50.25	*LV Feeder Pillar and TMFC (OD)*	*534*	*533*	*533*	*533*	*533*	*533*	*533*	*533*
			1.44.05	*Remove Service Turret*	*97*	*97*	*97*	*97*	*97*	*97*	*97*	*97*
			1.44.08	*Replace LV Boards*	*543*	*543*	*543*	*543*	*543*	*543*	*543*	*543*
		Link Boxes	*1.44.04/ 2.50.17*	*Replace Link Boxes*	*2,115*	*2,115*	*2,115*	*2,115*	*2,115*	*2,115*	*2,115*	*2,115*
			1.44.07	*Replace Covers & Frames*	*22*	*22*	*22*	*22*	*22*	*22*	*22*	*22*
		TOTAL (£k)			***11,844***	***11,843***	***11,844***	***11,844***	***11,844***	***11,844***	***11,844***	***11,844***

Table 2: Summary Table of ED1 Investment (£k) *(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].

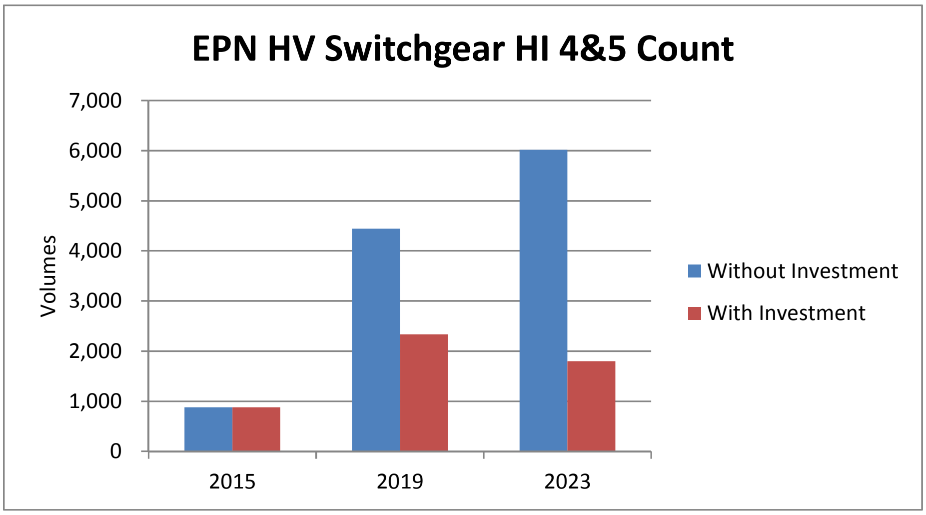


Figure 1: HV Switchgear HI 4 & 5 Count (Source: 25_07_2012 ARP Model)

Figure 1 shows how the HV switchgear HI 4 and 5 count significantly 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.

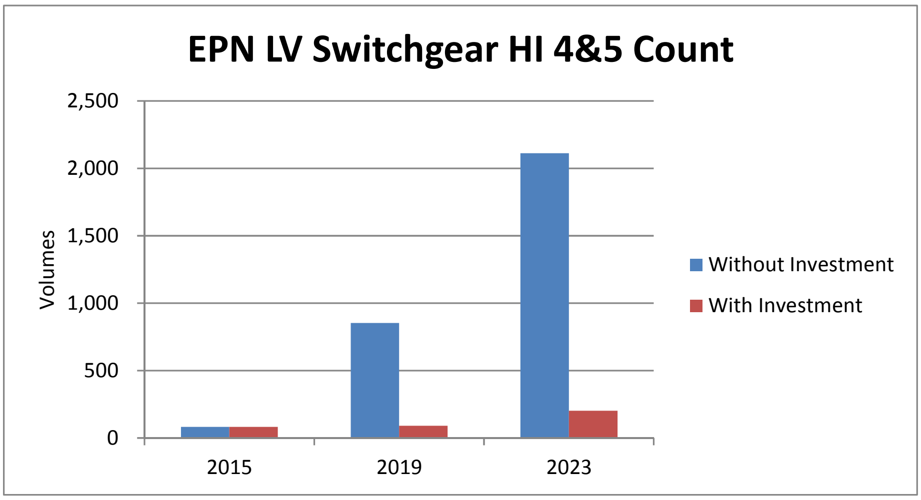


Figure 2: LV Switchgear HI 4 & 5 Count (Source: SARM v0.3 Statistical Model)

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.

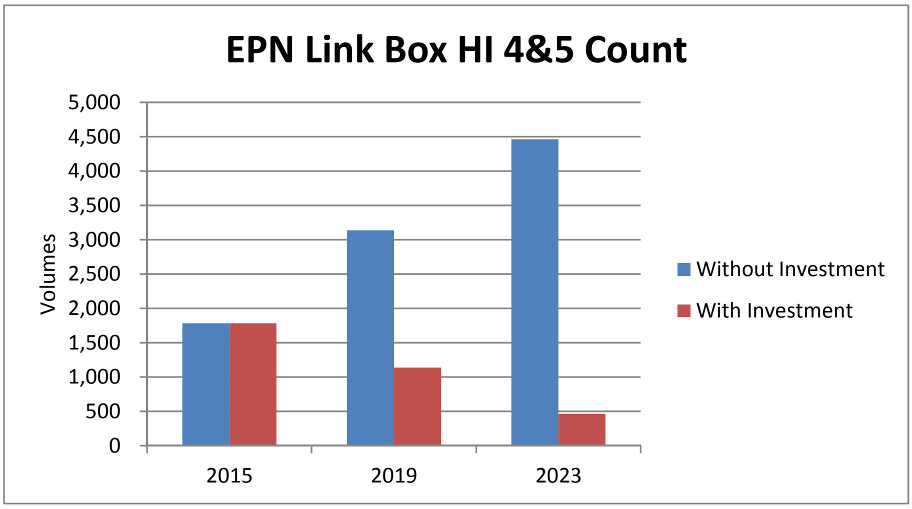


Figure 3: Link Box HI 4 & 5 Count (Source: Stocks & Flows Model V1.1)

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.

Appendix 9 benchmarks our ED1 proposals with reference to other DNOs July 2013 submissions. It shows that for **LV Plant** we are proposing to replace **4%** of our assets while other DNOs were seeking funding to replace **7%** of these assets on average. This demonstrates the effectiveness of our asset risk management systems and the value for money of our proposals.

1.4 Innovation

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 serious 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.	± 6% 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 (ground mounted) on the EPN distribution network include 6.6kV and 11kV units. Its function is to control, protect and isolate electrical equipment. There are approximately 32,724 HV switchgear assets operating within the EPN region of UK Power Networks, consisting of Ring Main Units (RMUs), circuit breakers and switches. Due to the vast amounts of rural areas within this region, many of these installations are outdoors. As shown in Figure 4, just over half of these are SF_6 filled switchgear (51%), with 48% of the population being oil-filled switchgear and 1% vacuum, distributed over more than 26,000 substation sites.

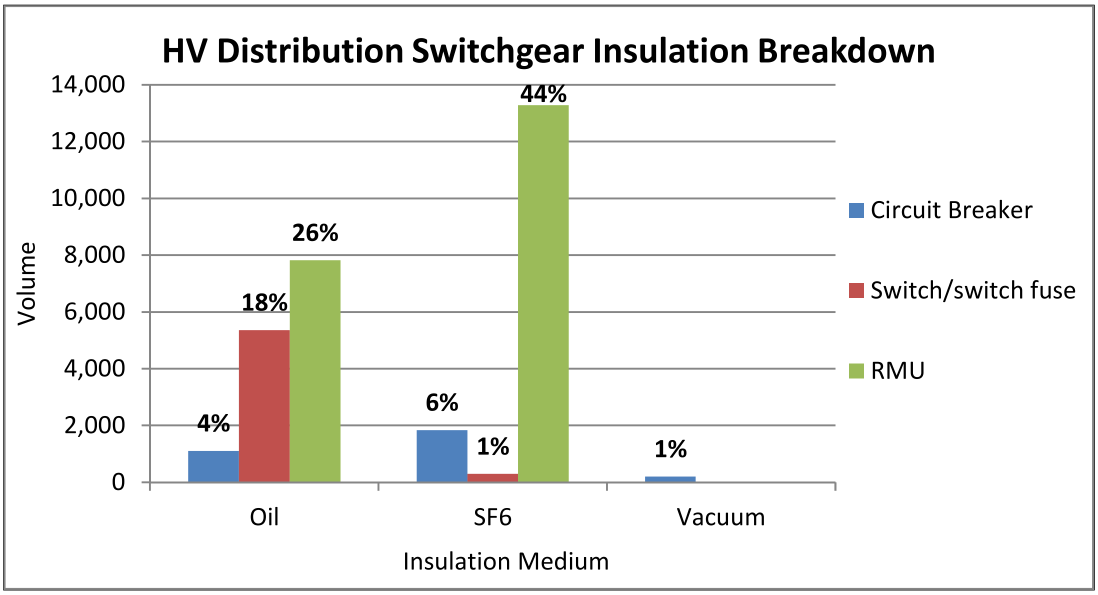


*Figure 4: HV Distribution Switchgear Insulation Breakdown (*Source: 25_07_2012 ARP Model)

Figure 5 demonstrates the large amounts of electrical infrastructure that were commissioned during the 1960s resulting in a high number of assets approaching their end of life. Although age itself does not necessarily drive 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 46 years. Furthermore, without intervention during ED1, 16% of the EPN HV switchgear population will be beyond the average asset life by 2023.

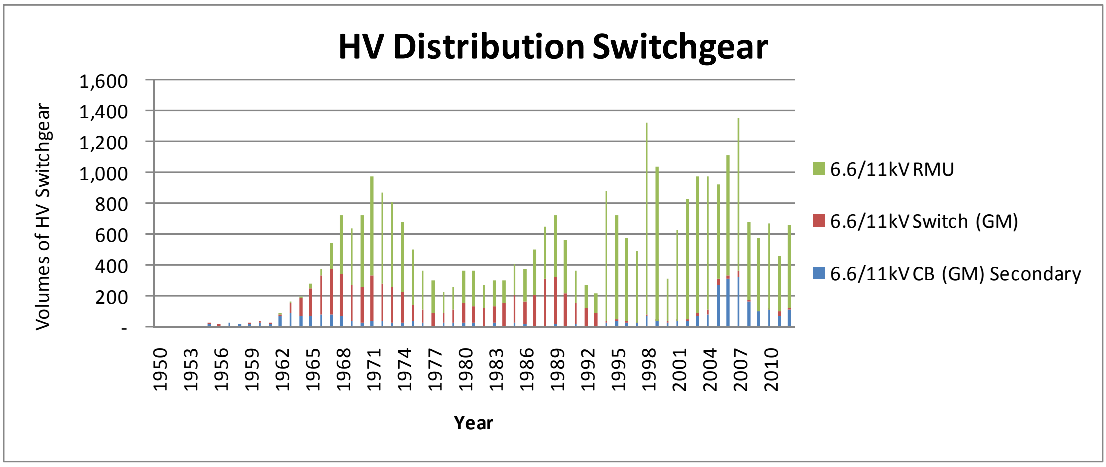


Figure 5: HV Distribution Switchgear Age Profile (Source: 2012 RIGs Table V5)

Oil-filled switchgear is still dominant on the EPN network, the largest population being the Brush NSM RMU (currently 4,404 with an average age of 36 years) followed by the Brush HFE switch fuse (2,965 with an average age of 39 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 or explosions) to personnel and the environment 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 approximately 13,500 within the EPN 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 or defective switches being removed from the network.

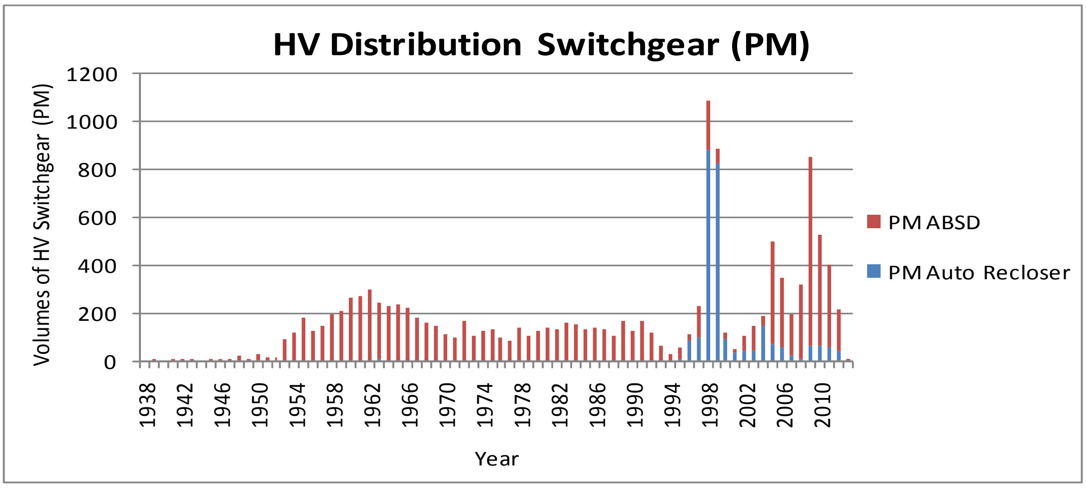


Figure 6: HV Switchgear (PM) Age Profile (Source: Ellipse Extract 14_03_2013)

2.2 LV Switchgear

There are approximately 30,040 LV switchgear assets commissioned on the EPN network comprising feeder pillars, network pillars, Transformer Mounted Fuse Cabinets (TMFCs), distribution boards and mini-pillars (also known as service turrets). The breakdown of these assets is shown in Figure 7.

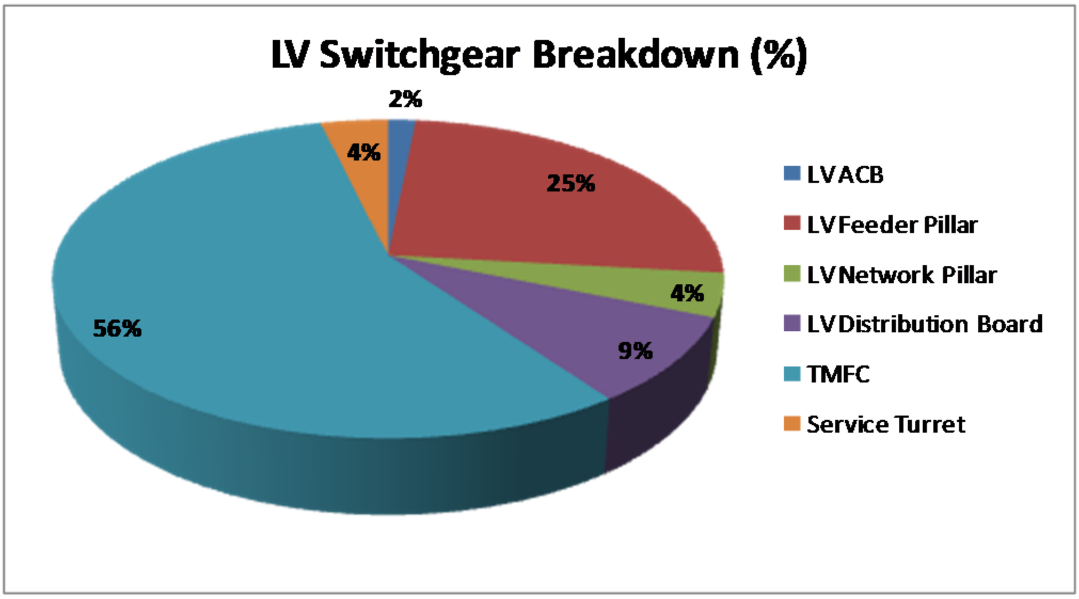


Figure 7: LV Switchgear Breakdown (Source: 27_02_2013 Ellipse Extract)

Similarly to the commissioning of LV switchgear, it can be seen from the age profile in Figure 8 that there was significant investment in the 1960s resulting in an ageing LV switchgear asset-base, with the average age of the oldest 10% of assets being 56 years. Without intervention 6% of the LV switchgear population will be beyond the average asset life by the end of ED1 in 2023.

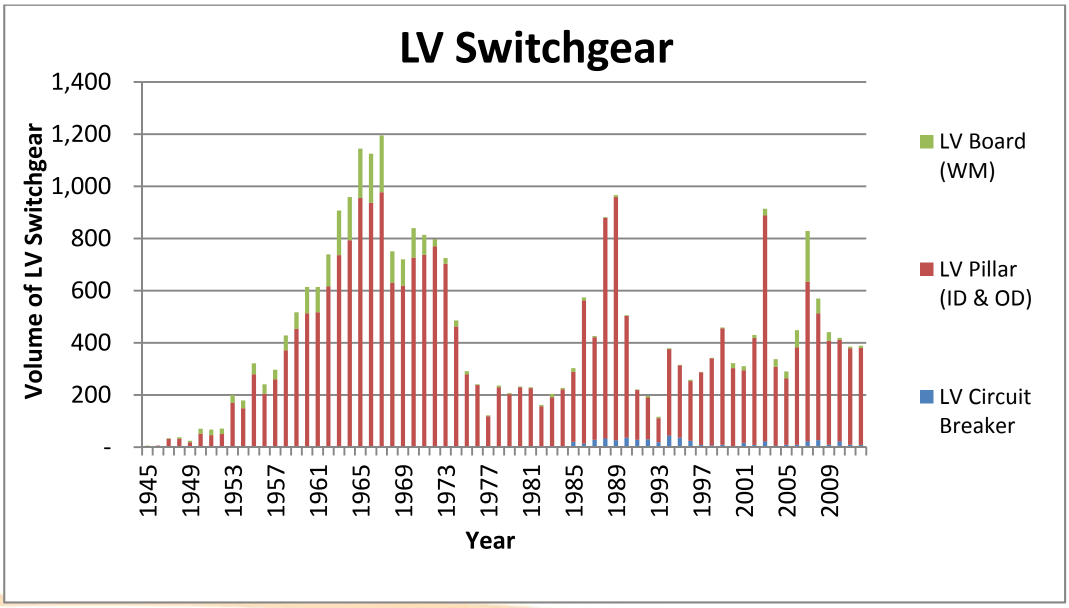


Figure 8: LV Switchgear Age Profile (Source: 2012 RIGs Table V5)

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

2.3 Link Boxes

There are approximately 37,164 link boxes currently operating within the EPN 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 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.

3.1.2 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 new handbook 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 is inspected to confirm that it is operating correctly and safely and to collect key data about its 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, and 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 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 drive maintenance activities. Maintenance tasks will be designed to ensure that the condition of mechanical components and systems is preserved and ensure that the integrity of insulation and 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, to ensure that it 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 EPN 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 ACB</th><th>LV Pillar (TMFC)/ LV Distribution Boards (WM)</th><th>Link Boxes</th></tr>
<tr><td>External condition of housing</td><td rowspan="2">Circuit breaker test trip</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><td rowspan="2">Condition of earth bonding</td></tr>
<tr><td>Condition of external kiosk</td></tr>
<tr><td>Operation of switchgear</td><td rowspan="2">Condition of support structure</td></tr>
<tr><td>Condition of bushings</td><td rowspan="6">External Condition of Housing</td></tr>
<tr><td>Overall internal condition</td><td rowspan="3">External condition of housing</td></tr>
<tr><td>Condition of fusechamber/carriage</td></tr>
<tr><td>Oil acidity measure</td></tr>
<tr><td>Oil moisture measure</td><td rowspan="2">Operation of switchgear</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 substation 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: Severely Corroded BRU HFE Oil Switch Fuse
Astons Road, Moor Park

Free standing LV substation feeder pillars, street pillars and service turrets need to be monitored, specifically for corrosion (as shown in Figure 10) of the enclosure that would allow third party access to live equipment. Plastic covered mini-pillars have to be checked for cracking or damage surroundings that may also expose live parts.

Figure 10: Badly Deteriorated LV Pillars

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 deemed to 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.

GEC Henley dwarf feeder pillars (Figure 11) are showing general deterioration; poor design coupled with increasing age is leading to concerns over safe operation. There is a strategic decision to remove these from the network during ED1.

Figure 11: GEC Henley Dwarf Feeder Pillars

A further strategic decision has been made to remove all service turrets in EPN throughout ED1 and ED2 due to their poor condition and vulnerable location, highlighting the increase in interventions over ED1.

3.2 Defects

3.2.1 Defects used as Replacement Drivers for HV Switchgear

The defects used in the APR 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 then the equipment could fail disruptively if left in service.
Defective shutter mechanism	For withdrawable switchgear only, this is used to record 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 needed immediately but if left unchecked this 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 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 12. It can be seen that the number of defects increases as the plant ages, generally occurring between 35 and 50 years of age. This corresponds to the range of average asset life settings in the ARP model.

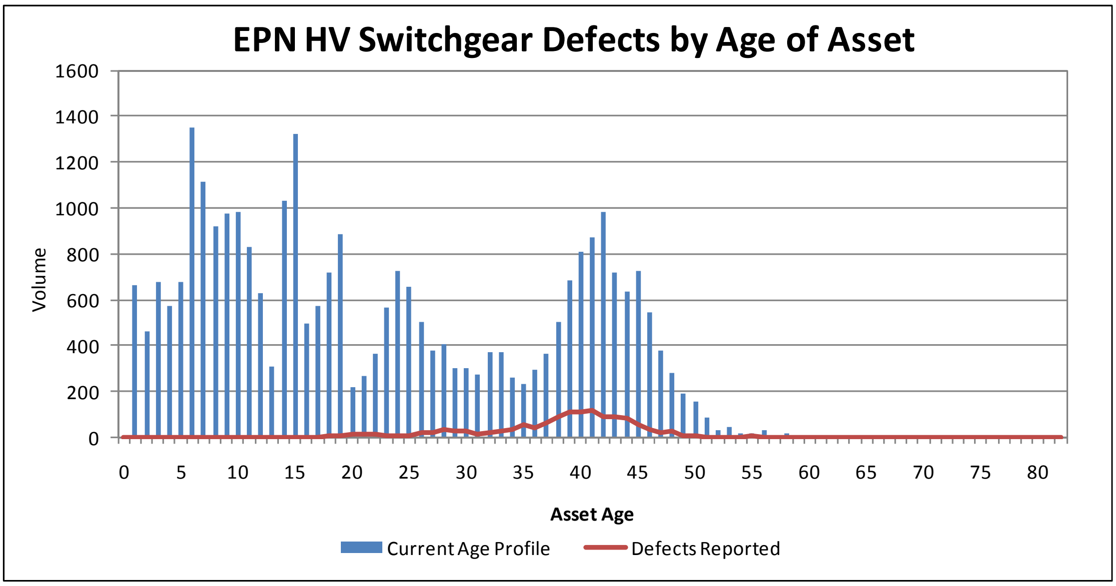


*Figure 12: Defects by Age (*Source: Ellipse Extract 19_02_2013 & RIGs V5)

Figure 13 shows the number of switchgear defects reported since 2007 when the Ellipse asset register was introduced and shows a rising trend of reported defects, with the increase likely to be improvements in reporting due to the substation inspector training programme. However, a clear focus on the defect rectification programme during 2012 allowed a large proportion of defects to be cleared due to a full data cleansing process.

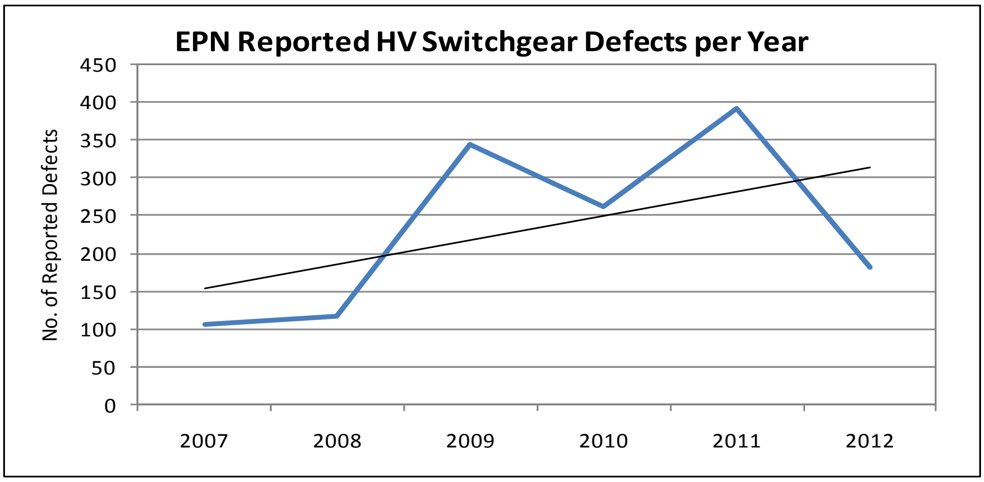


Figure 13: Defects per Year (Source: Ellipse Extract 19_02_2013)

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 14 shows a severe oil leak of a YSE TYKE RMU, inevitably increasing the likelihood of asset failure.

Figure 14: Severe Oil Leak (Yorkshire TYKE RMU)

Similarly, Figure 15 highlights a serious compound leak where the only option is to replace the item of switchgear.

Figure 15: Serious Compound Leaks

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 diagram 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 16: White Deposits on Yellow Phase Bushing Bolts

Figure 17 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 17: Failure of GEC VMX CB due to Partial Discharge

3.2.4 Types of HV Switchgear highlighted for Intervention

The HI 4 and 5 oil-filled units predominant in the EPN area that are the targeted interventions over ED1 are shown in Figure 18. Asset replacement will continue to reduce this oil-filled population in favour of gas insulated switchgear.

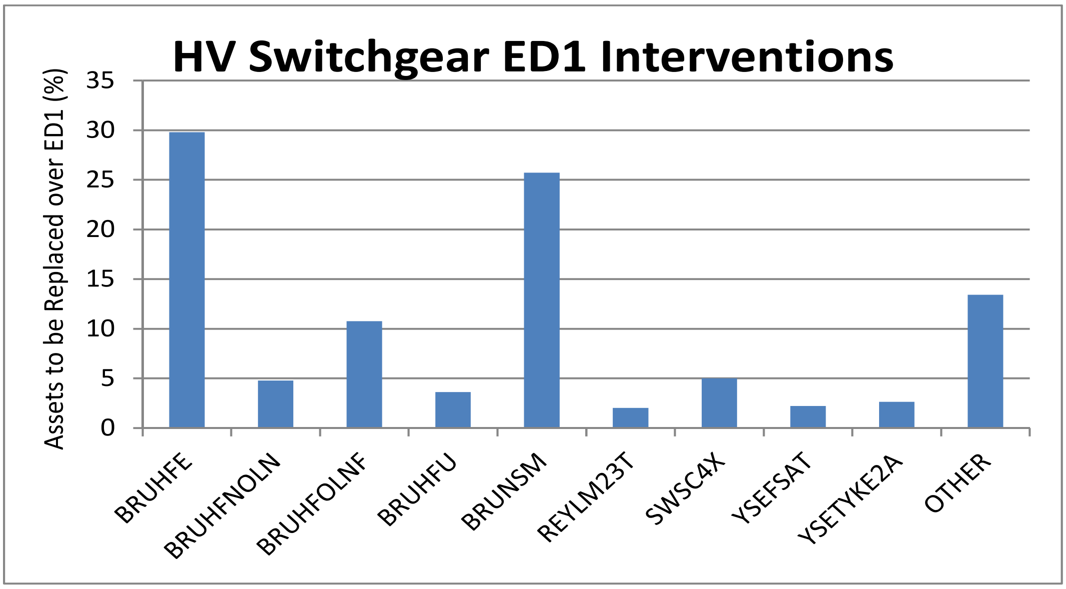


Figure 18: HV Switchgear Intervention Breakdown (Source: 25_07_2012 ARP Model)

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

The Brush 'L' type switch units have an operational restriction (ORE-27) against them due to a number of failures that occurred during operation on units with the replacement metal-flanged-epoxy bushing. Similarly, there have historically been problems with the Yorkshire TYKE 2A RMU in the form of overheating contacts on the fuse carriage.

Between 1989 and 1992, oil supplied by Carless was found to increase the oils susceptibility to oxidation, leading to increased acidity and moisture absorption, and this was found to affect Yorkshire FSAT and TYKE 2A RMUs. Most of the defects found are familiar, such as water in band joints and discharge on isolating contacts, and at distribution sites the environmental conditions are usually worse which 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.
	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.
Link Box	Bell cover cracked/water ingress	Allows water, sand, soil or vermin to enter the link box – can potentially lead to failure
	Defect stalks mis-aligned	Conductor stalks misaligned or damaged 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 drivers that influence the actions and decisions involved in the management of link boxes are 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 19, 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 19: Damaged Fused Barriers

The fuse carriers on a separate LV network pillar (in Figure 20) 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 20: Damaged Fused Barriers

Figure 21 shows a broken bell cover found on inspection, allowing the ingress of water into the link box that could lead to failure.

Figure 21: Broken Bell Cover

The high compound level in the left hand diagram 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.

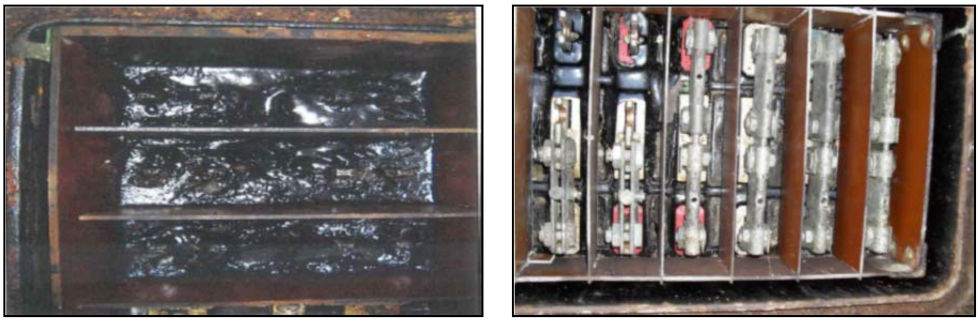


Figure 22: Example of High and Low Compound Level

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 which 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 a reliable range of units. 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 Enmac five year fault rate trend for HV and LV switchgear (including link boxes) are shown in Figures 23 and 24.

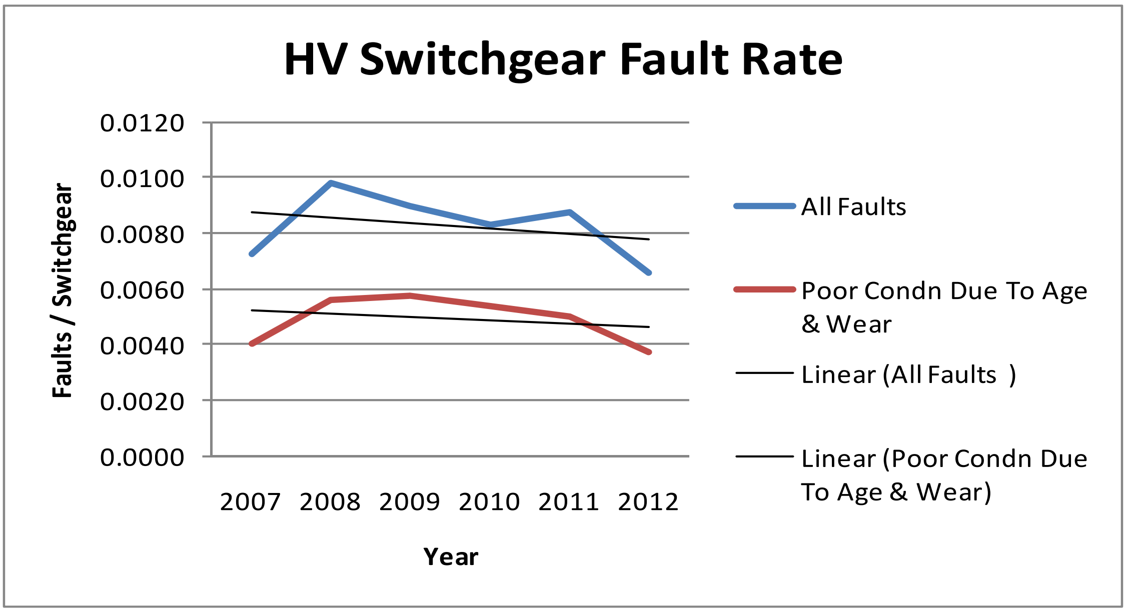


Figure 23: HV Switchgear (GM) Fault Rate (Source: UKPNs Fault Analysis Cube 15_03_2013)

The fault trend 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 approximately 50% of these faults are due to poor condition (age or wear) and furthermore, a steady decline is represented over the last five years for this condition measure.

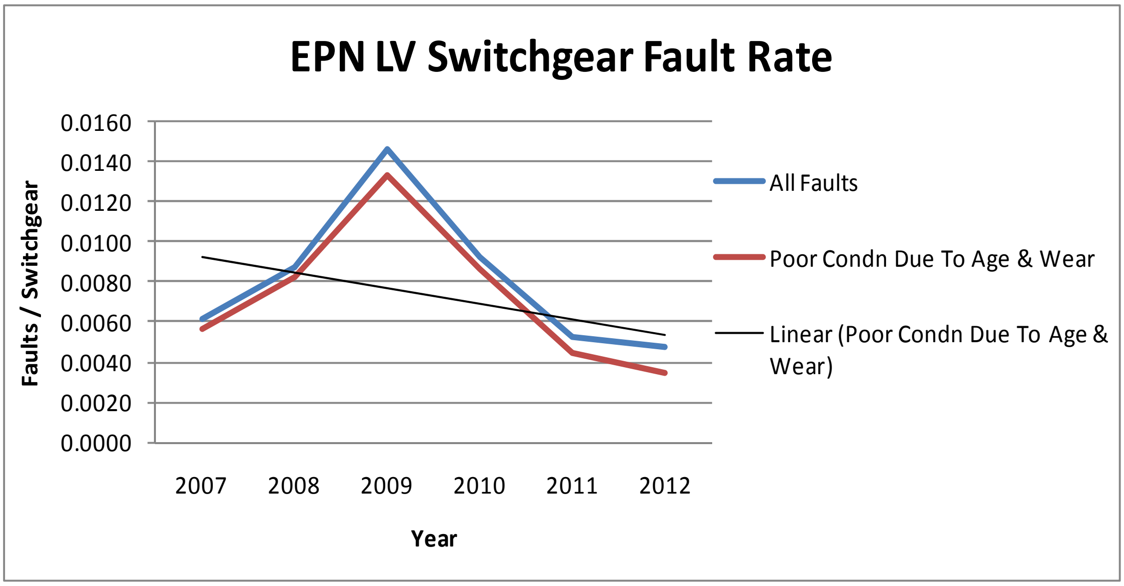


Figure 24: LV Plant Fault Rate (Incl. Link Boxes) (Source: UKPNs Fault Analysis Cube 15_03_2013)

As shown in Figure 24, the fault trend is showing an overall decline over the last five years for LV switchgear, mainly due to the abnormally high volumes in 2009/10 and a reduced fault rate in 2011/12. A breakdown of fault causes shows that it is evident that the number of condition-based faults (i.e. due to age and wear) represents over 90% of fault causes.

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.

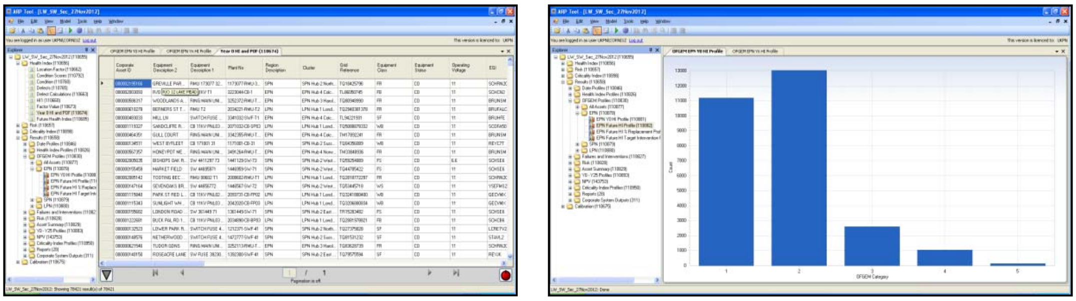


Figure 25: ARP Model

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 shows signs of increased deterioration. The 'average asset life' is defined as the life 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 HI 3 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 as 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 which 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 '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), which if left, 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.

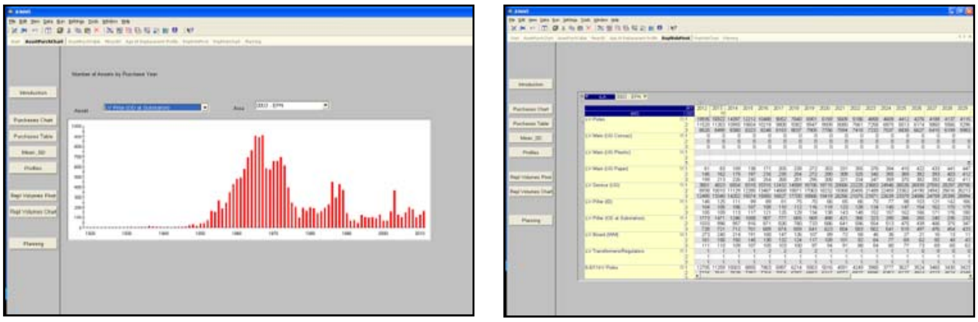


Figure 26: Statistical Model

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 EPN network of 65 years (with a standard deviation of 5 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 56 years (rising to 66 years by 2023).

4.1.3 Stocks and Flows Model

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

Figure 27: 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); and
- 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.

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 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. Each algorithm is mimicked by the tester in a spreadsheet, 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	68%	89%	96%
LV switchgear	79%	*	*
Link Boxes	71%	*	82%

Table 10: CAT Scores as of 8th February 2013

**Not applicable as data quality standards 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 68% 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 79% 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

Two categories of interventions have been considered for HV switchgear and LV plant:

- 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 (HI 4 or 5). 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 28.

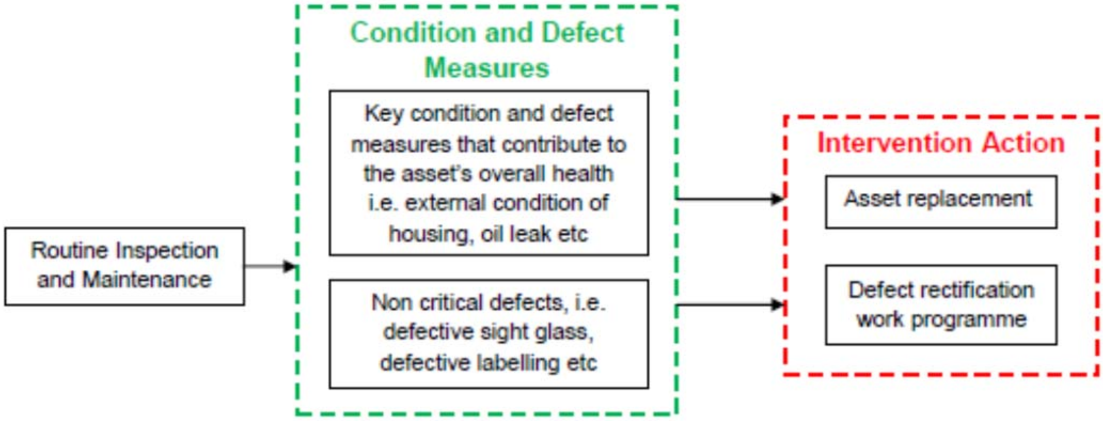


Figure 28: Intervention Decision Flow Chart

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 optimizing 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 Weather Covers

A new innovative approach within the EPN region (sought to maximise the useful life of existing switchgear) includes the fitting of weather covers to outdoor oil-filled units (in line with EOS 03-0016). Existing designs of oil-filled switchgear are susceptible to water ingress and corrosion problems. As described in section 3, moisture can enter oil-filled compartments and debris is prone to accumulate on main covers and lead to severe corrosion requiring the premature replacement of the switchgear. All of these potential problems are generally associated with secondary access covers on the top cover or tank entries at the top of the switch-tank (operating shafts, indicator windows, earth studs etc). The fitting of weather covers to selected existing outdoor oil-filled switchgear (as shown in Figure 29), will minimise these problems, maintain the assets HI and maximise the useful life of the switchgear.

Figure 29: Before and After (Prototype Brush NSM Weather hood)

6.2 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 30, with 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-optimization. This technique allows the effect of any proposed variation from the optimum level of replacement to be quickly assessed.

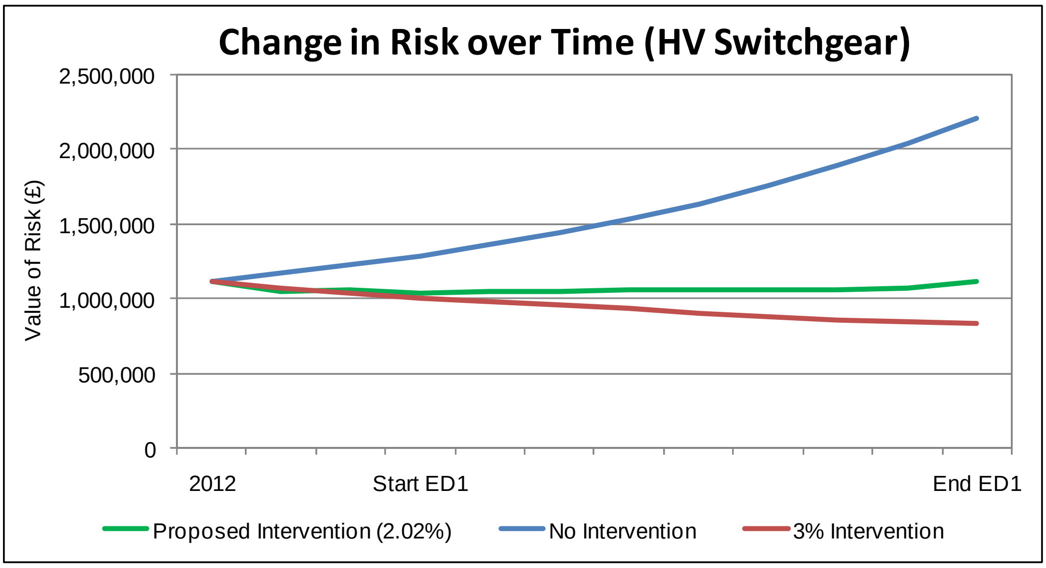


Figure 30: Change in Risk over Time (Source: 25_07_2012 ARP Model)

6.3 LV Remote Control and Automation

The IFI team within UK Power Networks are currently exploring the benefits provided by an integrated LV remote control and automation system, which is presently 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 31) and RTUs (Remote Terminal Units) that provides remote control of the LV devices.

Figure 31: LV CBs installed on an LV board

Similarly, an ESQC driven project for link boxes, 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 32 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 32: Before and After: Switches Installed to a LB in place of Standard Links

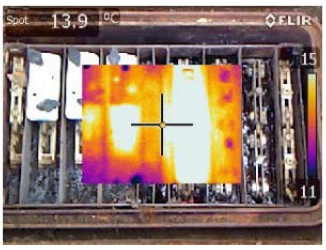
This will enable UK Power Networks to improve network performance and gain higher granular visibility to improve our understanding and management of the LV network.

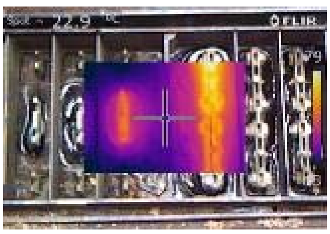
6.4 Link Boxes

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 33.

Figure 33: Exploring Different types of Link Box Covers

Furthermore, thermal imaging of link boxes is being investigated.





The top picture pin-points 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 be used to 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 whilst the compound was still soft, the temperature had dropped to 17°C.

Figure 34: 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, analysis of asset age, condition data, reliability ratings and operational restrictions was performed 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 HI 4 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

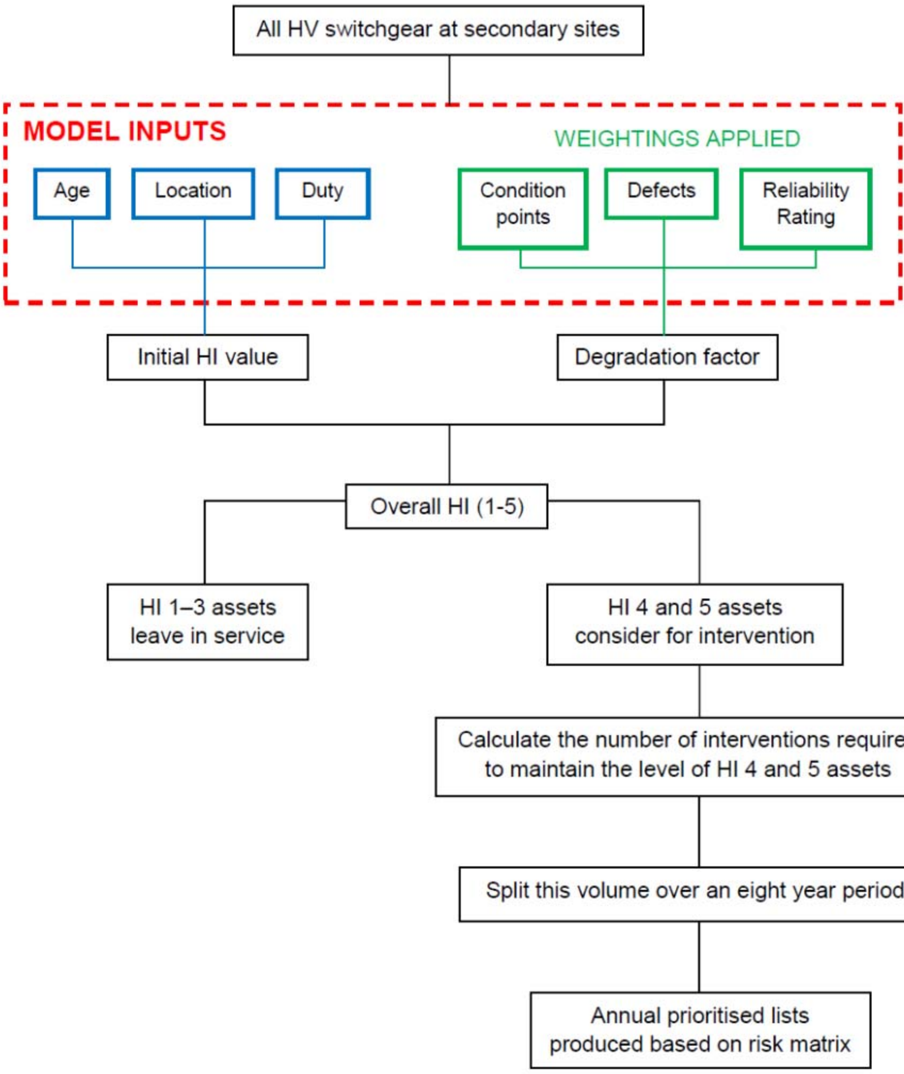


Figure 35: HV Switchgear Intervention Flowchart

It is important to note that the methodology above does not take into account 'consequential' changes. The EPN region will be replacing switch/switch fuse combinations with RMUs in a number of cases, but the whole combination may not be a HI 4 or 5. 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 CB/switch. As a result, there will be some assets with lower health indices which 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

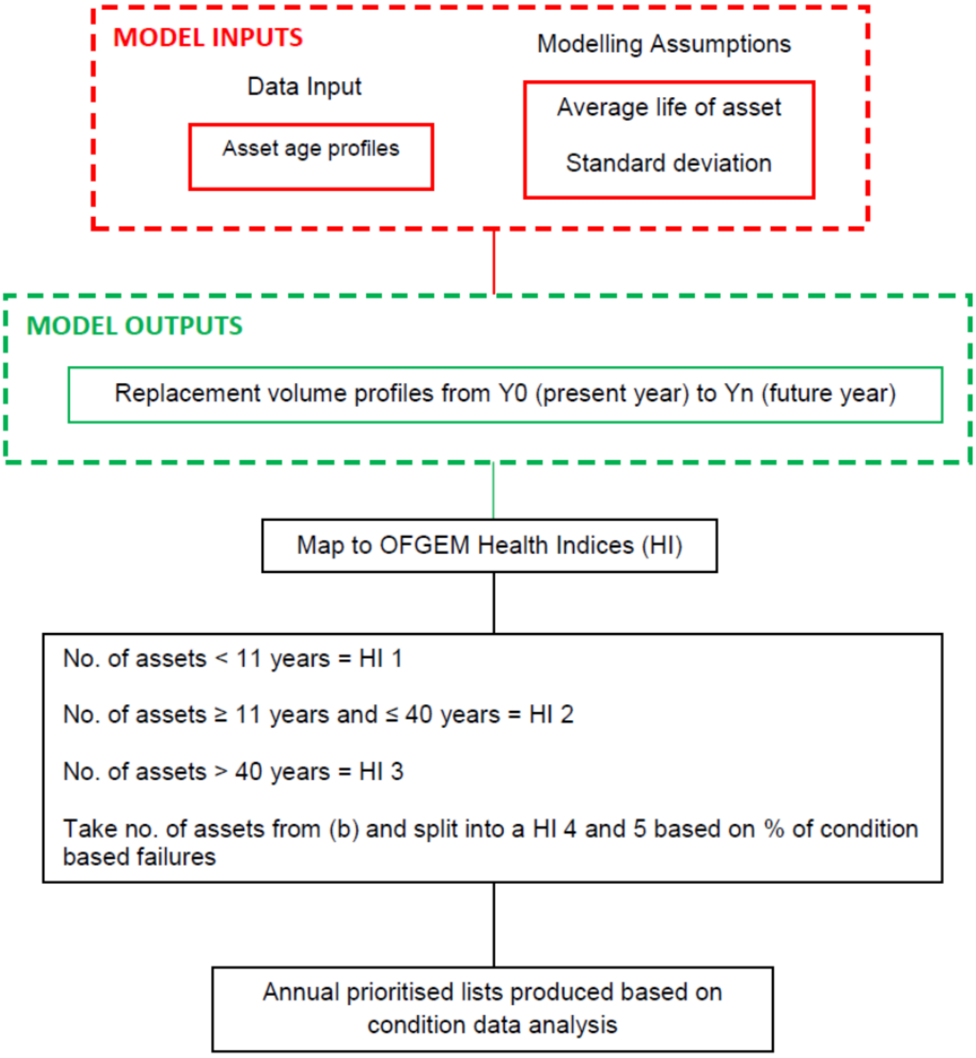


Figure 36: LV Switchgear Intervention Flowchart

7.2.3 Intervention Technique for Link Boxes

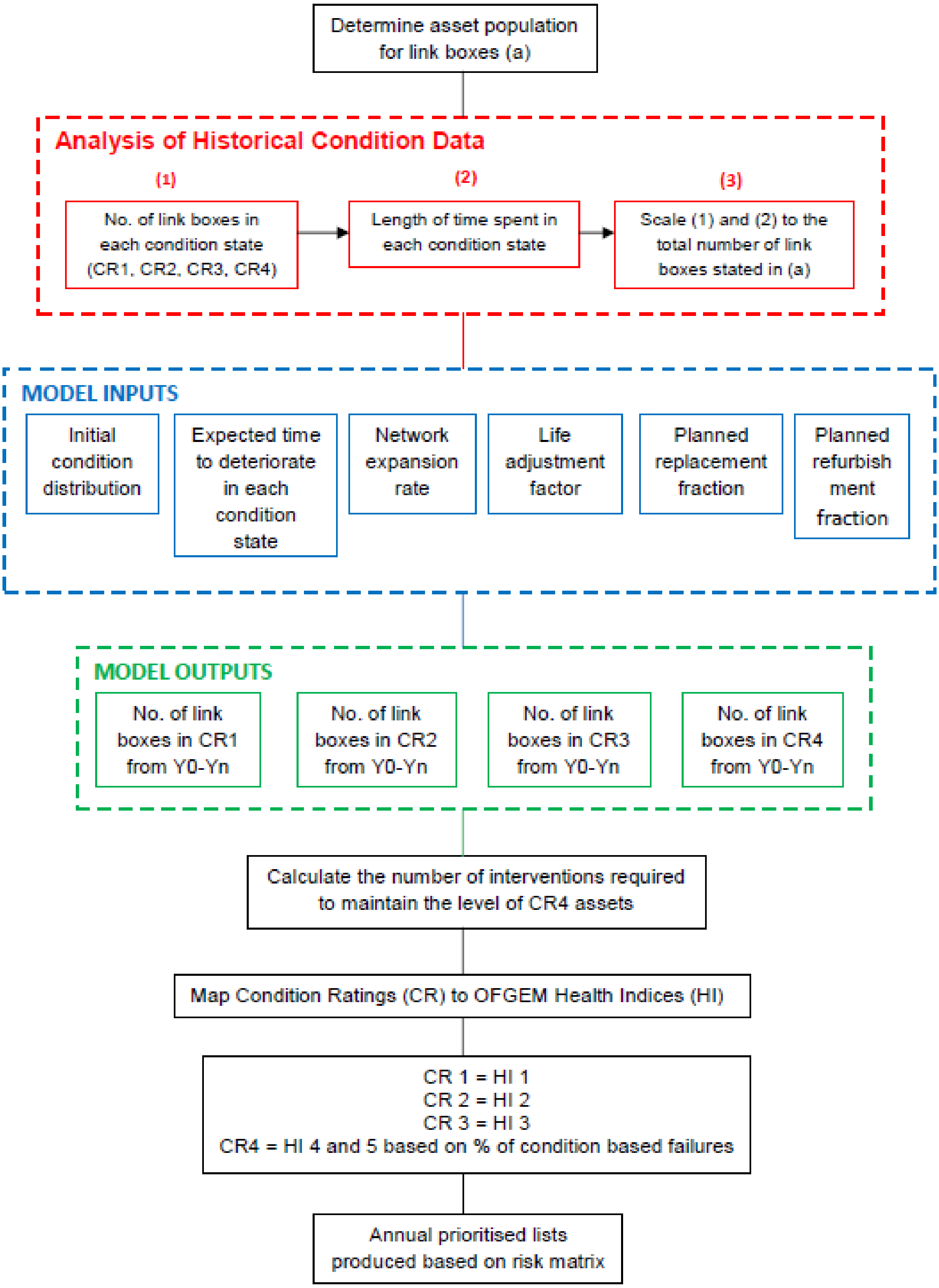


Figure 37: Link Box Intervention Flowchart

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 to manage the network whilst improving network performance. This was taken into consideration when planning the ED1 volumes for HV switchgear due to numerous types of oil-filled being considered for automation (including Yorkshire Tyke, Tyke2A, Long and Crawford J3/J4, T3GF3, T4GF3, Reyrolle JS and Brush NSM). An asset deemed HI 4 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

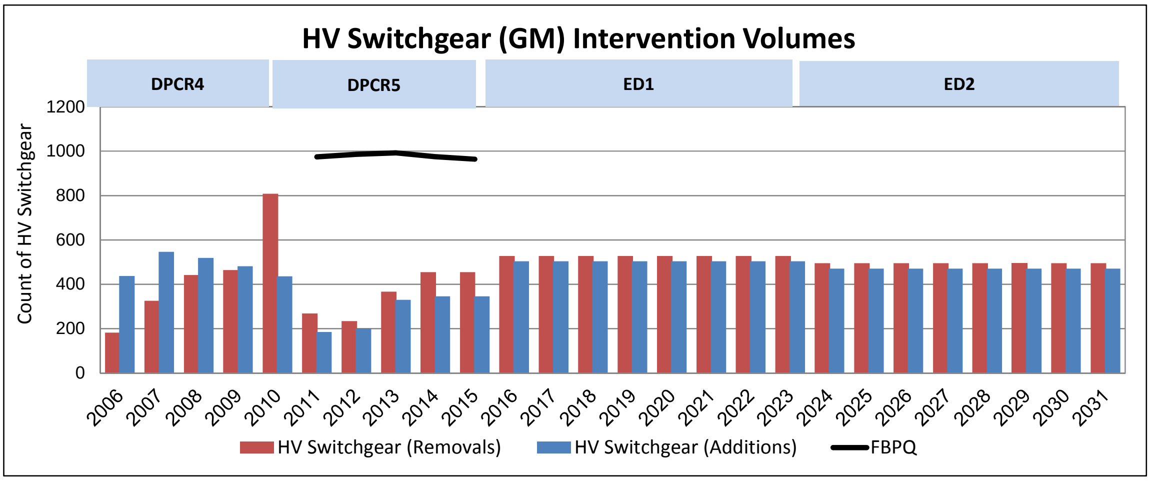


Figure 38: HV Switchgear Intervention Volumes

[Note: removals and additions are not always a 1:1 ratio as in some cases there are three switches removed from a site and one RMU installed in its place. By ED1, high numbers of switch/switch fuse mixes will be removed from the network and most of the HV distribution switchgear replacements will be on a like-for-like basis, i.e. one BRU HFE switch fuse will be replaced with one SF_6 circuit breaker].

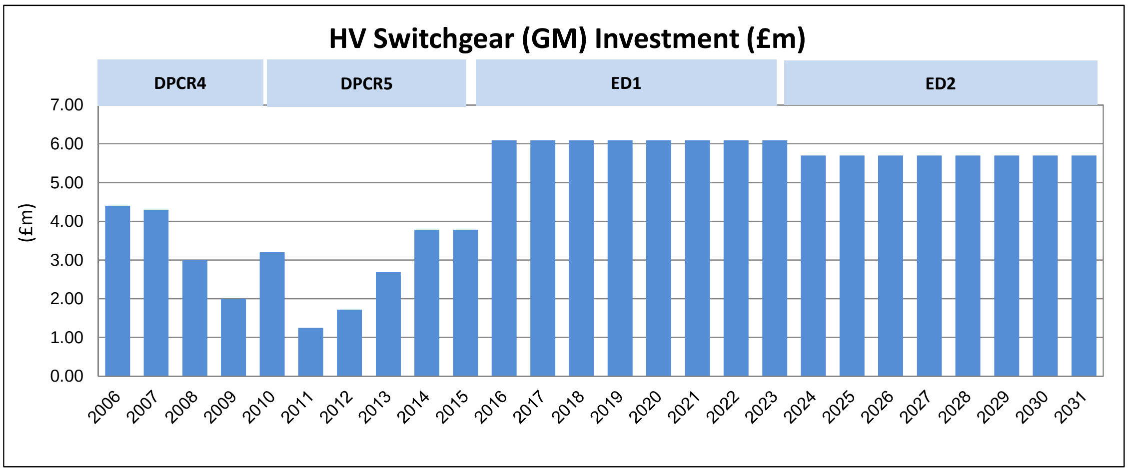


Figure 39: HV Switchgear Investment

7.4.2 HV Switchgear (GM) Commentary

As already described, 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:

- It is assumed that a RMU is replaced like-for-like;
- A stand-alone switch fuse (i.e. Brush HFE) 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. Reyrolle JK/JS) will be replaced with a RMU (75%) or an extensible RMU and a circuit breaker (25%).

Referring to Figure 38, the original strategy submitted as part of the DPCR5 FBPQ for HV distribution switchgear was to replace all of the predominant oil-filled switchgear on the network. Following a risk review of this methodology, a new strategy has been adopted and a large number of HI 3 assets originally in the plan are no longer set to be replaced. Furthermore, resource issues in year 1 and 2 have contributed to being behind our forecast and an increase in contractors is set to increase the number of resources (SAPs) for the remainder of DPCR5.

We are increasing the level of secondary switchgear replacements throughout the ED1 period. This is to target primarily the defective oil-filled peak commissioned during the 1960s (as shown in Figure 5) which have a health index of 4 or 5. The fault rate for HV switchgear (shown in Figure 23 of section 3) shows a steady decline for secondary switchgear, however high numbers of Brush units are experiencing familiar defects. The Brush ‘L’ type switch units have an operational restriction (ORE-27) against them due to a number of failures that occurred during operation on units with the replacement metal-flanged-epoxy bushing. The environmental conditions are

usually worse at outdoor distribution sites which results in faster deterioration of the plant which is likely to escalate over the ED1 period. In addition to this, there is a strategic view to maintain network risk over the ED1 period.
As shown in Figure 39, the expenditure increases significantly over ED1. This is due to high numbers of oil-filled RMUs and stand-alone switch fuses scheduled to be replaced. Up to now, large numbers of replacements have been a 3:1 (removal: addition) ratio whereas future replacements will be on a like-for-like basis with a similar unit cost.

The ED2 figures have been created using the age-based statistical asset replacement model (SARM1), highlighting a similar replacement profile post-ED1. Further work will be done in ED1 to explore additional intervention options that can be used to extend asset life.

7.4.3 HV Switchgear (PM) Charts

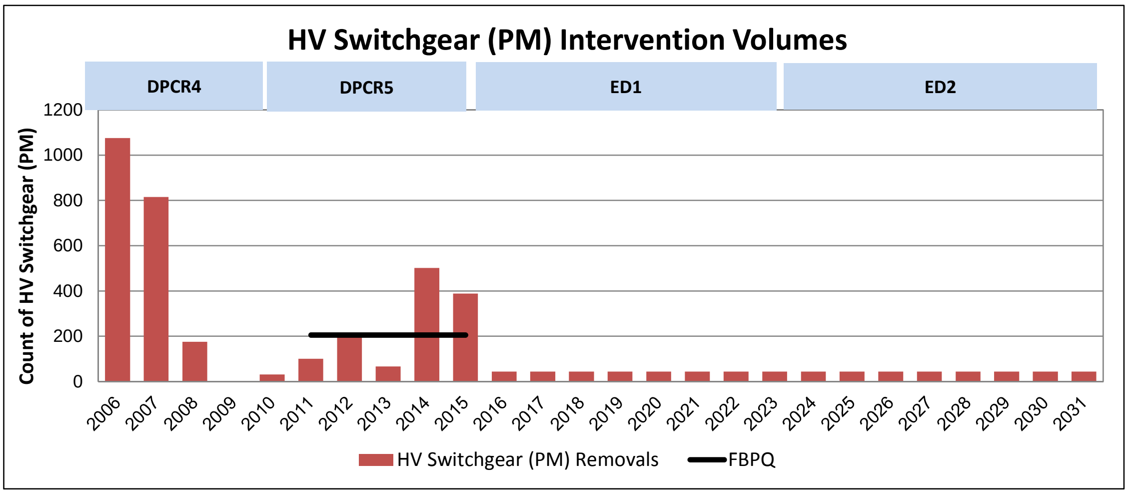


Figure 40: HV Switchgear (PM) Intervention Volumes

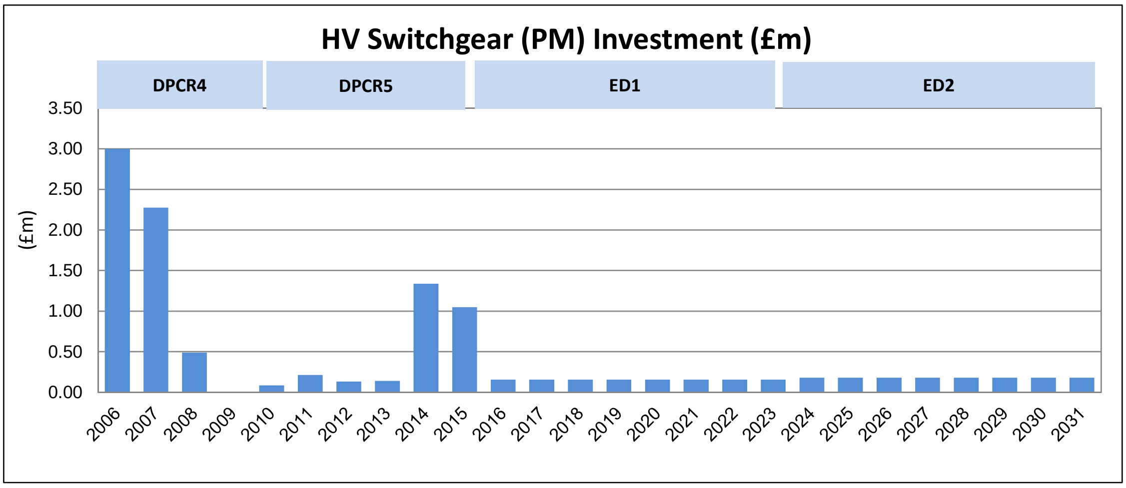


Figure 41: HV Switchgear (PM) Investment

7.4.4 HV Switchgear (PM) Commentary

Historically, as shown in Figure 40, a proactive pole mounted switchgear replacement programme has been carried out. The increase in DPCR5 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, in poor condition or defective will 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. The ED1 programme will target the small population of older assets commissioned during the 1960s.

Expenditure levels for HV (PM) switchgear (Figure 41) reflect the reduction in volumes over the ED1 and ED2 period.

7.4.5 LV Switchgear Charts

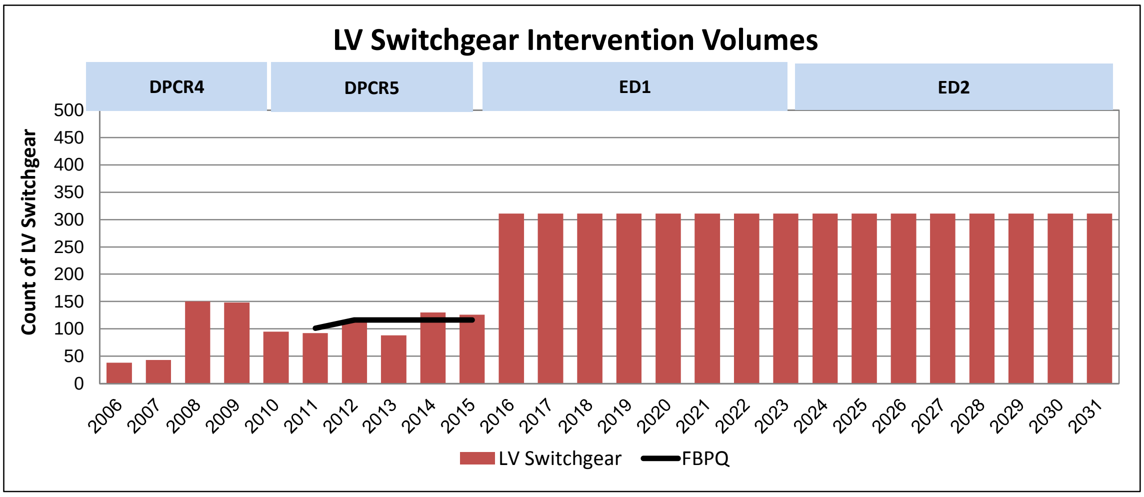


Figure 42: LV Switchgear Intervention Volumes

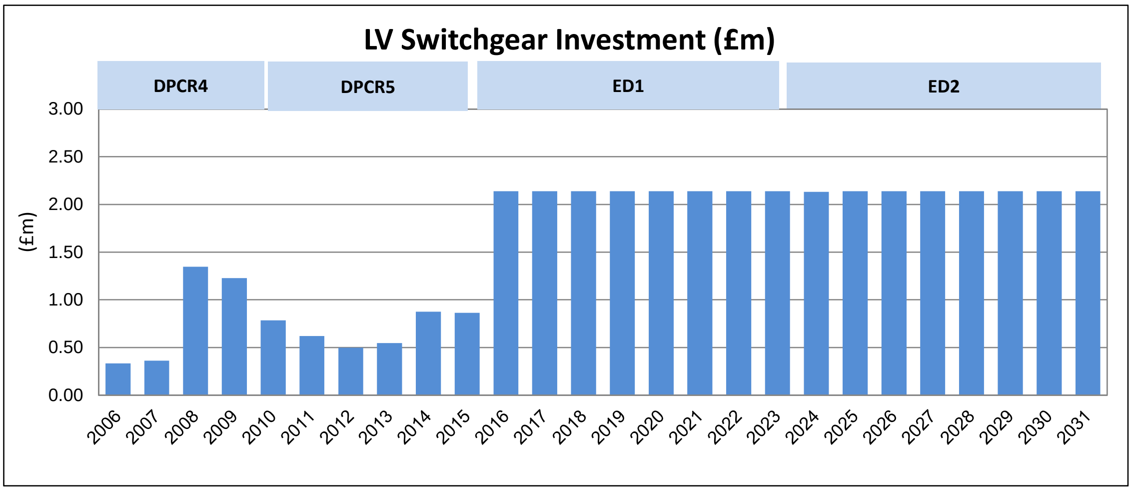


Figure 43: LV Switchgear Investment

7.4.6 LV Switchgear Commentary

Figure 42 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 the age profile chart (Figure 8), high numbers of LV plant were commissioned during the 1960s 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. Although Figure 24 of section 3 shows a decreasing fault, this is due to abnormally high volumes in 2009/10 and a reduced fault rate in 2011/12.

A strategic decision has been made by UK Power Networks to remove all service turrets over the ED1 period due to their vulnerable location and poor condition. GEC Henley dwarf feeder pillars are showing signs of general deterioration due to their poor design. Concerns over their safe operation have led to them all being scheduled for replacement over ED1. This means that approximately 300 LV switchgear assets per year will need replacing over ED1 to maintain network risk.

Expenditure levels for LV switchgear (Figure 43) reflect the intervention volumes over ED1. The ED2 figures have been derived from age-based modelling. 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

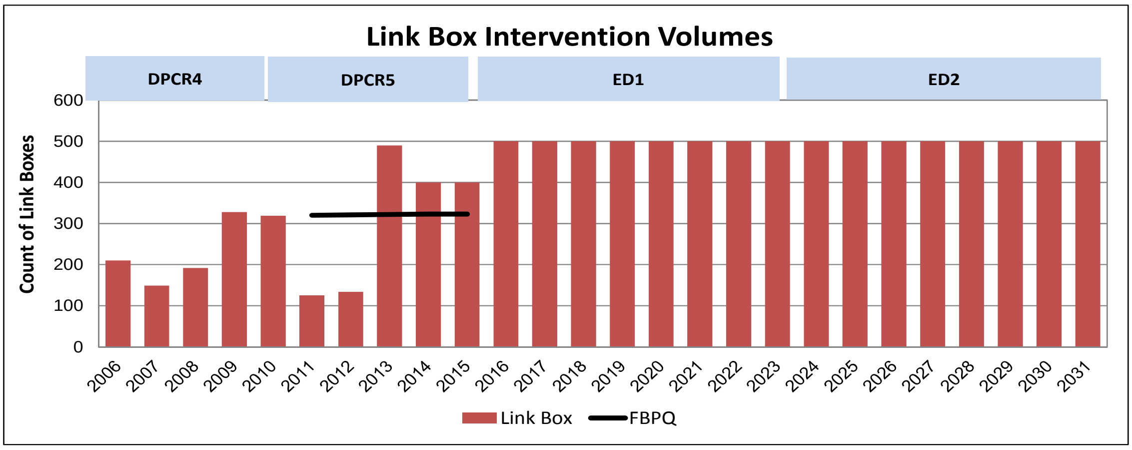


Figure 44: Link Box Intervention Volumes

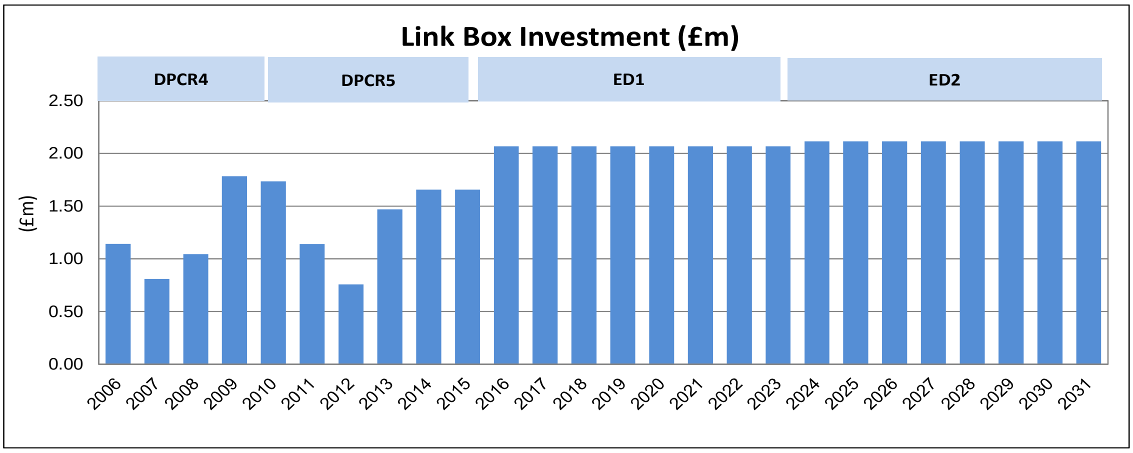


Figure 45: Link Box Investment

[Note: Investment is higher than expected in 2011/12 as it includes asset replacement plus network additions, i.e. where an LV network pillar is replaced with a link box].

7.4.8 Link Box Commentary

As shown in Figure 44, 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. A recent review of the number of CR4 link boxes raised versus the rate of replacement suggests we need to increase the volumes of replacements during ED1. To maximise public safety, intervention volumes are set at 500 link boxes per year over ED1. This will target high numbers of HI 4 and 5 assets by the end of the period, aligning to the strategic decision to maintain network risk over ED1. The link box achievement for 2012/13 is 490 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 45) 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.

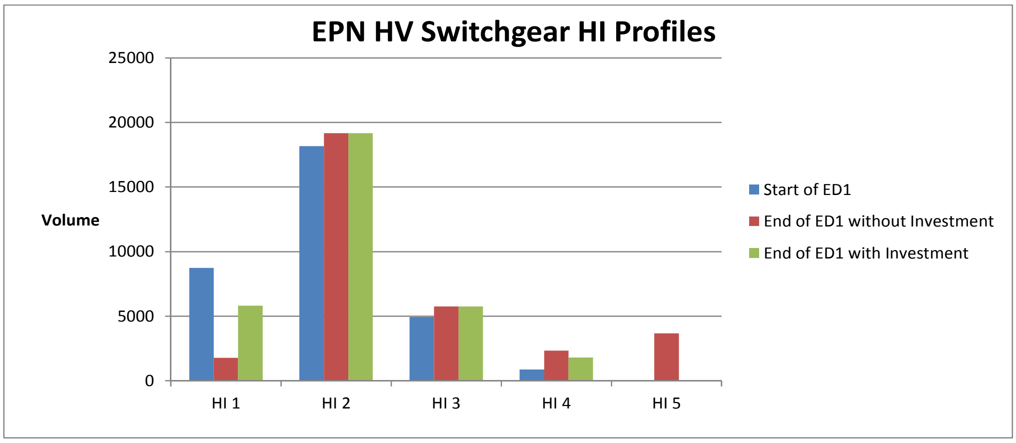


Figure 46: HV Switchgear HI Profiles (Source: 25_07_2012 ARP Model)

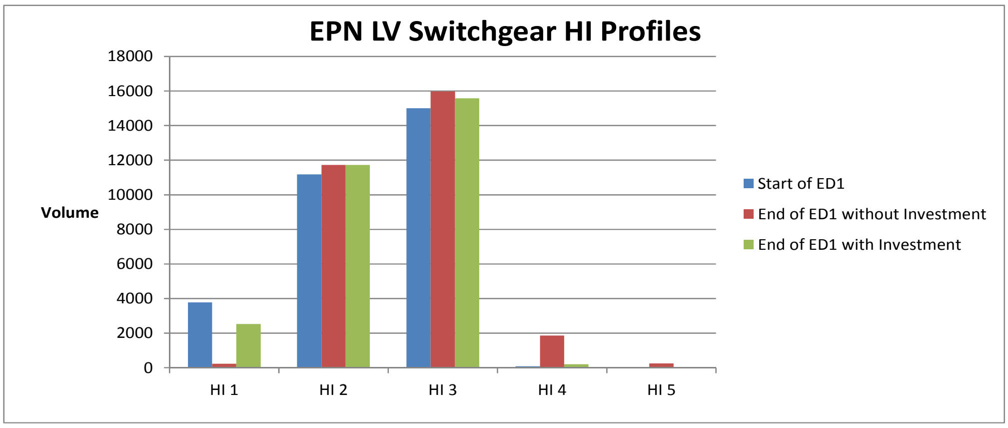


Figure 47: LV Switchgear HI Profiles (Source: SARM v0.3 Statistical Model)

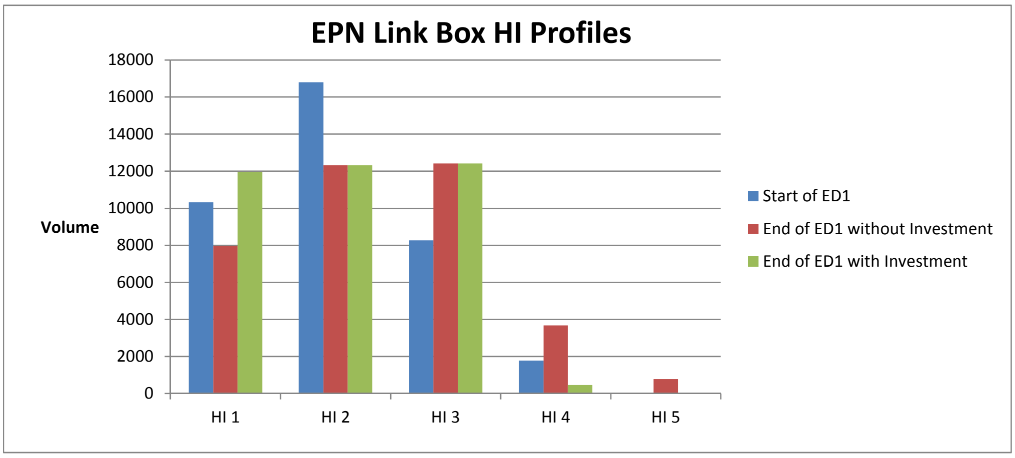


*Figure 48: Link Box HI Profiles (*Source: Stocks & Flows Model V1.1)

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 8 year period and the impact any change in average asset life will have on the asset groups HI profile.

Average asset life change	**2015** percentage HI profile				
	HI1	HI2	HI3	HI4	HI5
-4	25.8	54.6	18.0	1.4	0.2
-2	28.0	55.5	15.7	0.7	0.0
-1	29.1	56.1	14.4	0.4	0.0
0	29.4	57.3	13.2	0.1	0.0
1	31.3	57.4	11.2	0.1	0.0
2	32.6	57.2	10.1	0.1	0.0
4	34.5	57.9	7.7	0.0	0.0

Average asset life change	**2023** percentage HI profile				
	HI1	HI2	HI3	HI4	HI5
-4	16.7	59.1	16.0	7.0	1.2
-2	17.3	61.4	17.0	4.1	0.1
-1	18.8	61.6	17.5	2.1	0.0
0	19.0	62.8	18.1	0.1	0.0
1	19.3	64.2	16.5	0.0	0.0
2	20.6	64.3	15.3	0.0	0.0
4	21.5	66.7	12.1	0.0	0.0

Table 11: Average Asset Life Percentage Movements

Figure 49 represents summed HI 4 and 5 assets as a percentage of the population showing the change at each average life iteration comparing 2015 and 2023.

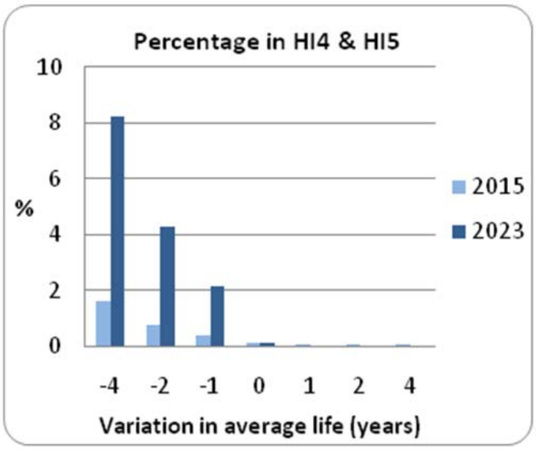


Figure 49: Percentage in HI 4 & 5 (HV Switchgear)

The results confirm that the ED1 replacement plan for EPN HV secondary switchgear is mildly sensitive to a variation in average asset life of up to 4 years.

7.6.2 LV Switchgear

The investment plan for LV switchgear was tested by varying the average life change of years ±1,2 and 4 as shown in Figures 50 and 51 (note base case life = 60 years):

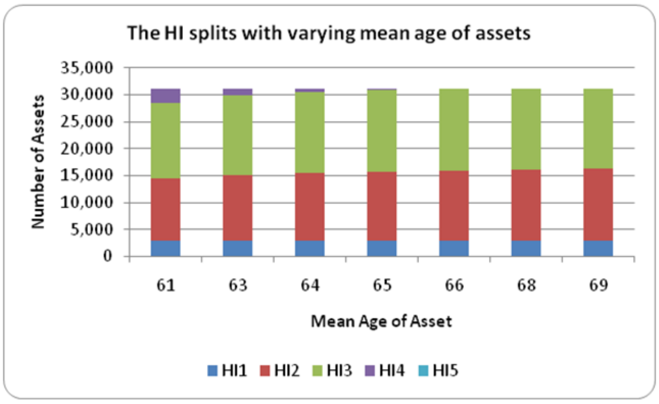
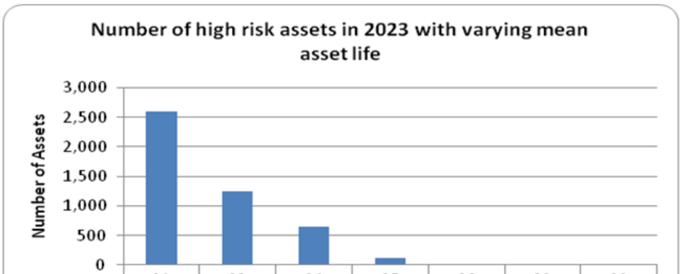


Figure 50: HI Splits for Various Average Asset Lives, with Investment



	61	63	64	65	66	68	69
2023	2,594	1,247	651	113	0	0	0

Figure 51: High Risk Volumes for Various Average Asset Lives, with Investment

These are important points to take notice of because a 4 year reduction in the mean age of LV Switchgear could cause the number of high risk assets to rise to 8.3% 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	1466	-579	-1043	-225%
50	1.1	1606	-109	-573	-123%
45	1	1781	464	0	0
41	0.9	2004	1172	+708	+153%
36	0.8	2299	2058	+1594	+344%

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

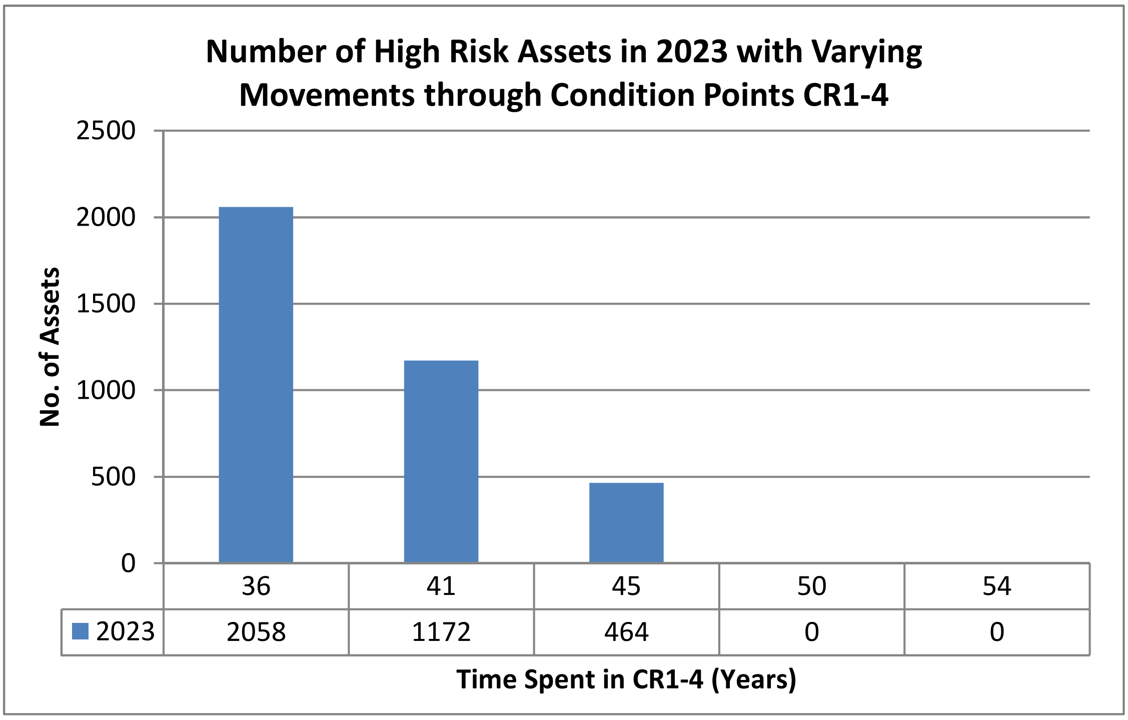


Figure 51: *High Risk Volumes for Various Movements through CR1-4, with Investment*

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 during ED1.

(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	7,581	8,348	596	426	0	16,951
	Average	No. Assets	1,149	9,824	4,343	454	0	15,770
	High	No. Assets	2	1	0	0	0	3
	Very high	No. Assets	0	0	0	0	0	-
LV Switchgear	Low	No. Assets	8	25	31	0	0	64
	Average	No. Assets	3,760	11,129	14,935	84	0	29,908
	High	No. Assets	8	25	30	0	0	63
	Very high	No. Assets	1	2	2	0	0	5
Link Box	Low	No. LBs	4,042	6,510	3,238	697	0	14,487
	Average	No. LBs	3,011	5,022	2,412	520	0	10,965
	High	No. LBs	3,261	5,253	2,613	563	0	11,690
	Very high	No. LBs	6	10	5	1	0	22

Table 13: Asset Health and Criticality 2015

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	966	14,318	1,090	577	0	16,951
	Average	No. Assets	4,853	4,850	4,656	1,219	0	15,578
	High	No. Assets	2	1	0	0	0	3
	Very high	No. Assets	0	0	0	0	0	-
LV Switchgear	Low	No. Assets	6	24	31	3	0	64
	Average	No. Assets	2,486	11,673	15,551	198	0	29,908
	High	No. Assets	40	23	0	0	0	63
	Very high	No. Assets	3	2	0	0	0	5
Link Box	Low	No. LBs	4,656	4,758	4,861	212	0	14,487
	Average	No. LBs	3,515	3,715	3,622	113	0	10,965
	High	No. LBs	3,790	3,839	3,922	139	0	11,690
	Very high	No. LBs	7	8	7	0	0	22

Table 14: Asset Health and Criticality 2023

[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

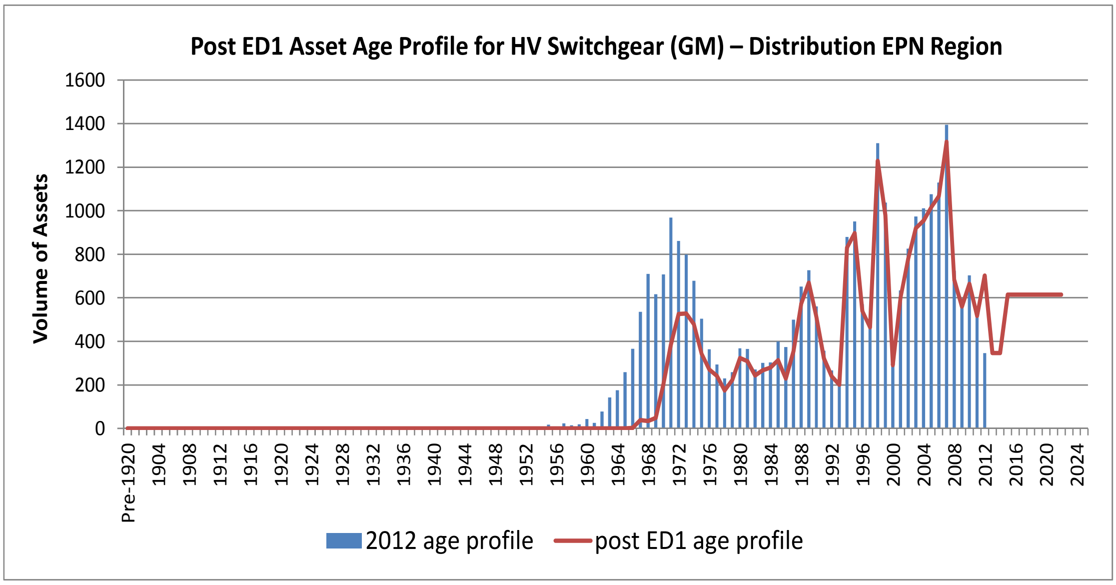


Figure 52: Post ED1 Age Profile (Source: DecisionLab Ltd Analysis 2013)

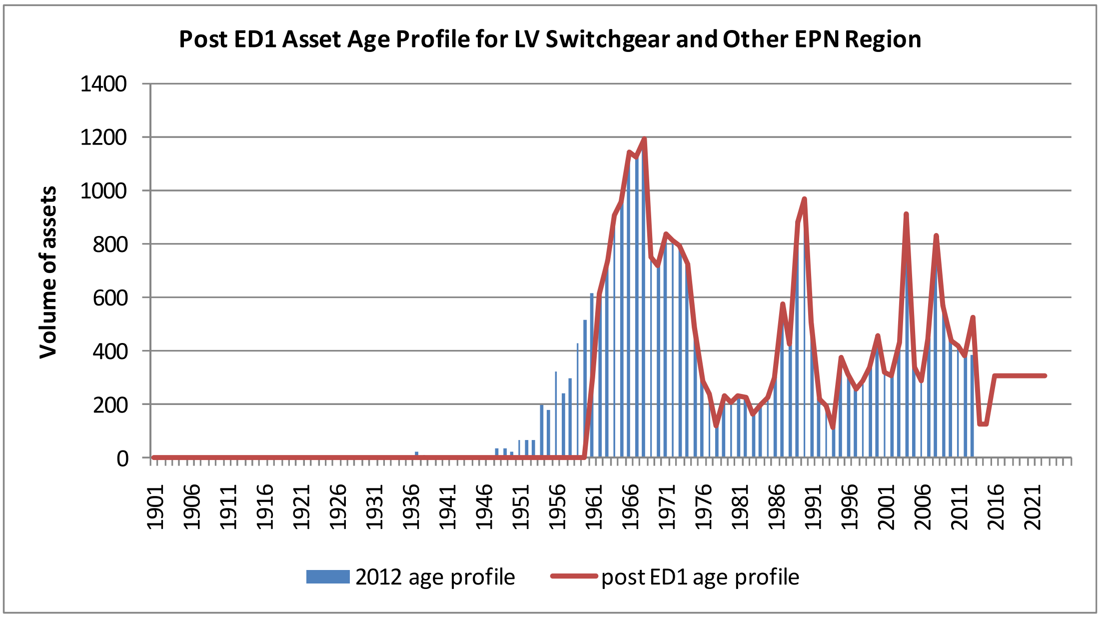


Figure 53: Post ED1 Age Profile (Source: DecisionLab Ltd Analysis 2013)

[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	7,581	8,348	596	426	0	16,951
	Average	No. Assets	1,149	9,824	4,343	454	0	15,770
	High	No. Assets	2	1	0	0	0	3
	Very high	No. Assets	0	0	0	0	0	-
LV Switchgear	Low	No. Assets	8	25	31	0	0	64
	Average	No. Assets	3,760	11,129	14,935	84	0	29,908
	High	No. Assets	8	25	30	0	0	63
	Very high	No. Assets	1	2	2	0	0	5
Link Box	Low	No. LBs	4,042	6,510	3,238	697	0	14,487
	Average	No. LBs	3,011	5,022	2,412	520	0	10,965
	High	No. LBs	3,261	5,253	2,613	563	0	11,690
	Very high	No. LBs	6	10	5	1	0	22

Table 15: Asset Health and Criticality 2015

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	966	14,318	1,090	577	0	16,951
	Average	No. Assets	4,853	4,850	4,656	1,219	0	15,578
	High	No. Assets	2	1	0	0	0	3
	Very high	No. Assets	0	0	0	0	0	-
LV Switchgear	Low	No. Assets	6	24	31	3	0	64
	Average	No. Assets	2,486	11,673	15,551	198	0	29,908
	High	No. Assets	40	23	0	0	0	63
	Very high	No. Assets	3	2	0	0	0	5
Link Box	Low	No. LBs	4,656	4,758	4,861	212	59	14,487
	Average	No. LBs	3,515	3,715	3,622	113	33	10,965
	High	No. LBs	3,790	3,839	3,922	139	47	11,690
	Very high	No. LBs	7	8	7	0	0	22

Table 16: Asset Health and Criticality 2023

Appendix 3 Fault Data

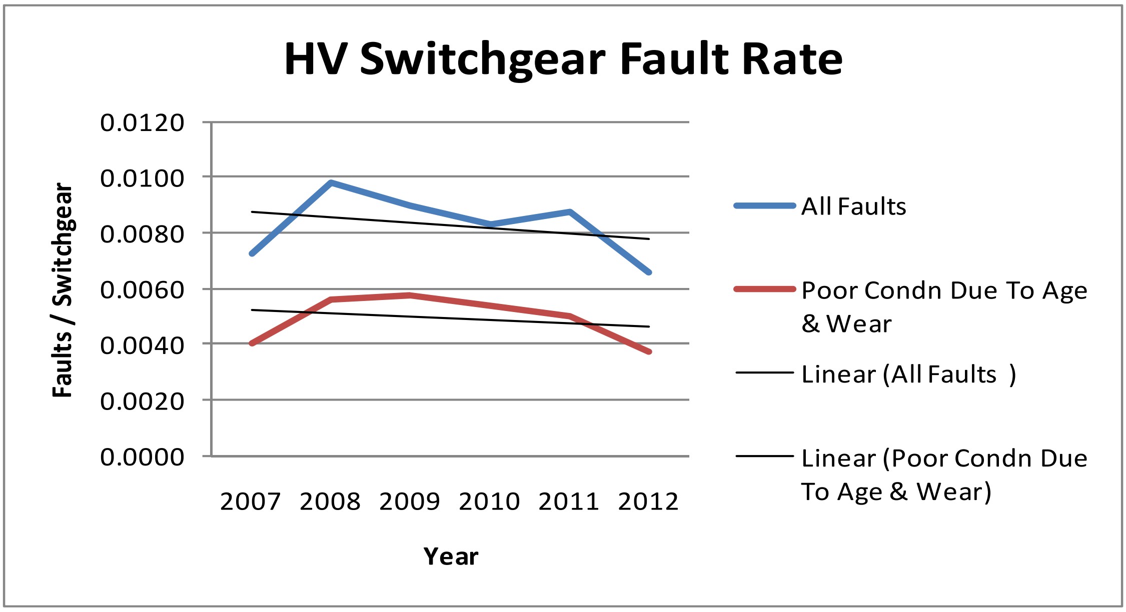


Figure 54: HV Switchgear (GM) Fault Rate (Source: UKPNs Fault Analysis Cube 15_03_2013)

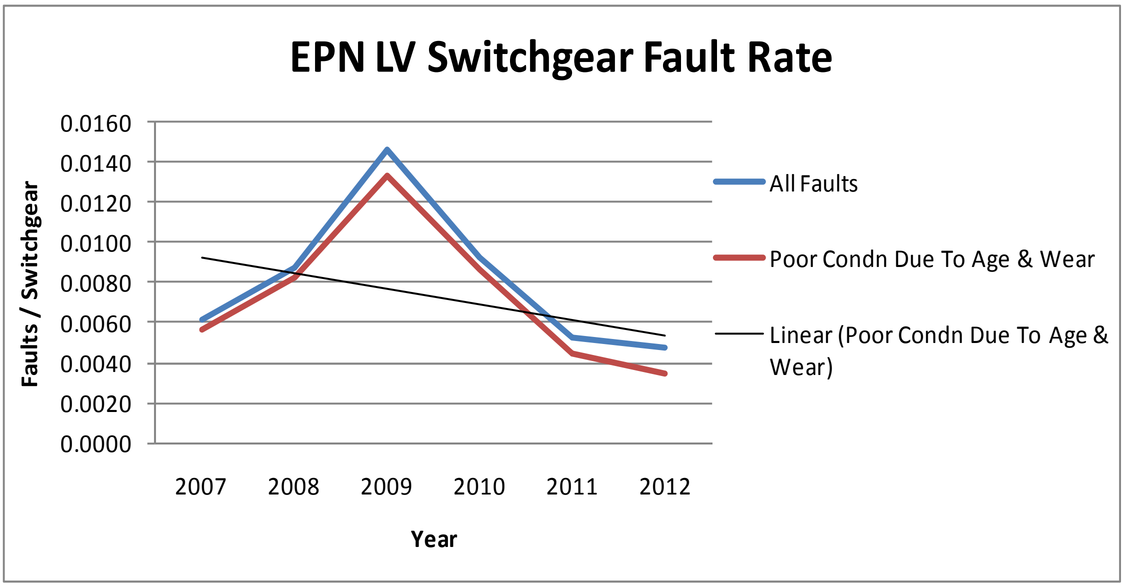


Figure 55: LV Switchgear Fault Rate (Incl Link Boxes) (Source: UKPNs Fault Analysis Cube 15_03_2013)

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
EPN	Switchgear	HV Switchgear (GM)	1.49.30/ 2.50.33	Install HV CB at Secondary Sites	226	226	225	225	225	225	225	225
			1.49.32/ 2.50.35	Install HV Switch at Secondary Sites	20	20	20	20	20	20	20	20
			1.49.51/ 2.50.21	Install HV RMU at Secondary Sites	258	258	259	259	259	259	259	259
			1.22.10	Switchgear weather cover installation	194	194	194	194	194	194	194	194
		HV Switchgear (PM)	1.19.27	Replace Pole Mounted Recloser	7	7	7	7	7	7	7	7
			1.20.34	Replace 11kV ABSD	37	37	37	37	37	37	37	37
		LV Switchgear	1.44.02	Replace LV Switchgear - Network Pillar	100	100	100	100	100	100	100	100
			1.44.03/ 2.50.25	LV Pillar - TMFC (ID)	45	45	45	45	45	45	45	45
			1.44.03/ 2.50.25	LV Feeder Pillar and TMFC (OD)	93	92	92	92	92	92	92	92
			1.44.05	Remove Service Turret	23	23	23	23	23	23	23	23
			1.44.08	Replace LV Boards	51	51	51	51	51	51	51	51
		Link Boxes	1.44.04/ 2.50.17	Replace Link Boxes	500	500	500	500	500	500	500	500
			1.44.07	Replace Covers & Frames	300	300	300	300	300	300	300	300
				TOTAL	**1,965**	**1,964**	**1,964**	**1,964**	**1,964**	**1,964**	**1,964**	**1,964**

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
EPN	Switchgear	HV Switchgear (GM)	1.49.30/ 2.50.33	Install HV CB at Secondary Sites	3,306	3,306	3,291	3,291	3,291	3,291	3,291	3,291
			1.49.32/ 2.50.35	Install HV Switch at Secondary Sites	136	136	136	136	136	136	136	136
			1.49.51/ 2.50.21	Install HV RMU at Secondary Sites	3,846	3,846	3,863	3,863	3,863	3,863	3,863	3,863
			1.22.10	Switchgear weather cover installation	103	103	103	103	103	103	103	103
		HV Switchgear (PM)	1.19.27	Replace Pole Mounted Recloser	61	61	61	61	61	61	61	61
			1.20.34	Replace 11kV ABSD	98	98	98	98	98	98	98	98
		LV Switchgear	1.44.02	Replace LV Switchgear - Network Pillar	722	722	722	722	722	722	722	722
			1.44.03/ 2.50.25	LV Pillar - TMFC (ID)	260	260	260	260	260	260	260	260
			1.44.03/ 2.50.25	LV Feeder Pillar and TMFC (OD)	534	533	533	533	533	533	533	533
			1.44.05	Remove Service Turret	97	97	97	97	97	97	97	97
			1.44.08	Replace LV Boards	543	543	543	543	543	543	543	543
		Link Boxes	1.44.04/ 2.50.17	Replace Link Boxes	2,115	2,115	2,115	2,115	2,115	2,115	2,115	2,115
			1.44.07	Replace Covers & Frames	22	22	22	22	22	22	22	22
		TOTAL (£k)			**11,844**	**11,843**	**11,844**	**11,844**	**11,844**	**11,844**	**11,844**	**11,844**

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

Appendix 6 Sensitivity Analysis

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

Introduction

This is a report of the sensitivity analysis conducted on the Asset Risk and Prioritisation (ARP) Model developed by EA Technology used to support the asset replacement & investment strategy for EPN 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 life.

Sensitivity Analysis

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

Standard average asset lives are used in the ARP model. These are from 30 to 55 years. In 2012 about 37% had a current average life of 40 years, about 34% of 45 years and about 25% of 55 years. This study covered the full population of EPN HV Secondary Switchgear.

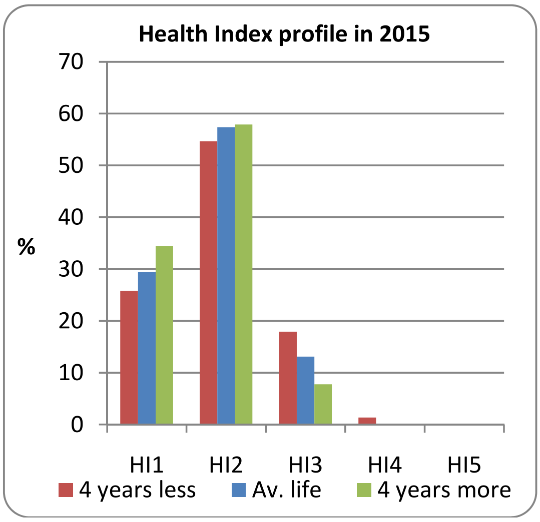
Using 2012 asset data and the replacement plans up to 2023, the ARP model was used to predict the Health Index of each asset at the beginning and end of ED1. This was then repeated varying each current average asset life by ±1, 2 & 4 years.

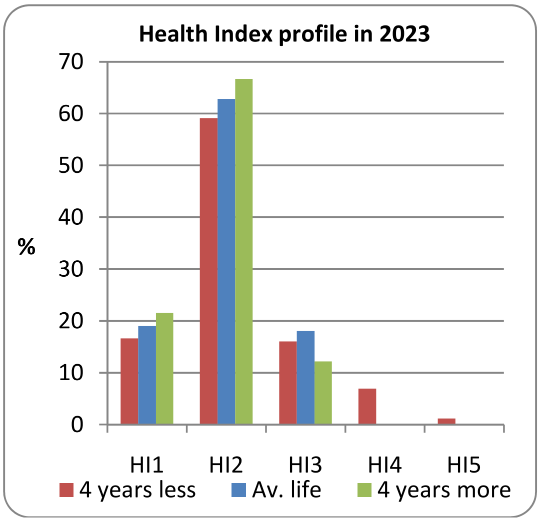
All results are shown below as the percentages of the population.

Average life change	**2015** percentage HI profile				
	HI1	HI2	HI3	HI4	HI5
-4	25.8	54.6	18.0	1.4	0.2
-2	28.0	55.5	15.7	0.7	0.0
-1	29.1	56.1	14.4	0.4	0.0
0	29.4	57.3	13.2	0.1	0.0
1	31.3	57.4	11.2	0.1	0.0
2	32.6	57.2	10.1	0.1	0.0
4	34.5	57.9	7.7	0.0	0.0

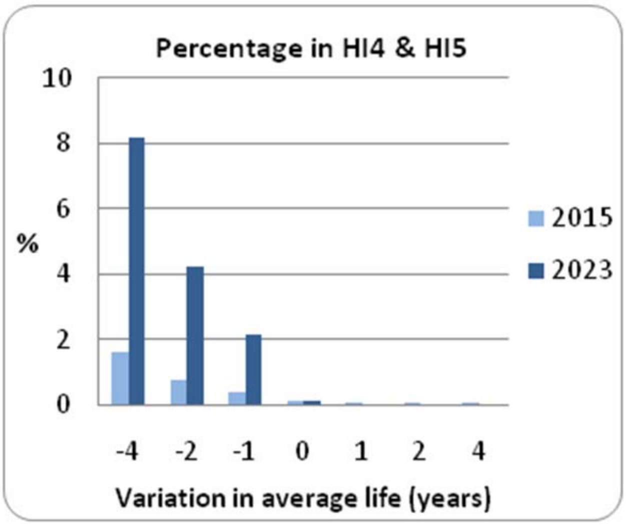
Average life change	**2023** percentage HI profile				
	HI1	HI2	HI3	HI4	HI5
-4	16.6	59.1	16.0	7.0	1.2
-2	17.3	61.4	17.0	4.1	0.1
-1	18.8	61.6	17.5	2.1	0.0
0	19.0	62.8	18.1	0.1	0.0
1	19.3	64.2	16.5	0.0	0.0
2	20.6	64.3	15.3	0.0	0.0
4	21.5	66.7	12.1	0.0	0.0

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





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



The results show

- A variation in asset life will affect the proportions of HI4 & HI5 assets in 2015 and 2023.
- In 2015 if average life is 4 years longer, the proportion of HI4 & HI5 will reduce from 0.1% to 0.0% but if 4 years shorter it will increase to 1.6%.
- In 2023 if average life is 4 years longer, the proportion of HI4 & HI5 will reduce from 0.1% to 0.0% but if 4 years shorter it will increase to 8.2%.

Conclusion

The ED1 replacement plan for EPN HV Secondary Switchgear is mildly sensitive to a variation in average asset life of up to 4 years.

Sensitivity Analysis for EPN 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 2 standard deviations either side of the mean). The initial population and age of assets is not consistent for all regions and means that sensitivity analysis must be conducted on a region by region basis.

EPN Base Case

- The ED1 plan for the EPN region is 2488 replacements (8.0% 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 84 to 2993 by 2023. This represents a rise from 0.3% to 9.6% of the population.
- With investment, the number of high risk assets is 0.4%, which is close to the 2015 figure of 0.3%
- **The ED1 investment programme manages 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 18.6% of the population will be high risk assets.
- Applying the ED1 plan to ED2 (2488 replacements between 2024 and 2031) means that by 2031 the number of high risk assets is 10.6% 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 ED1.
- By the end of the ED1 investment plan 42% of the population is between 45 and 63 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.

EPN Sensitivity to 'End of Life'

- Sensitivity to end of life was tested by varying the average asset life by +/- 1, 2 and 4 years.
- If the expected asset life was one year lower than the base case, with the current ED1 investment plan the number of high risk assets rises from 113 to 651 (from 0.4% to 2.1% 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 113 to 1247 (from 0.4% to 4.0% 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 113 to 2594 (from 0% to 8.3% of the LV Switchgear population).

- The number of high risk assets (Category H4 and H5) is sensitive to mean asset life. If the mean asset life is anywhere between 61 years and 65 years then the number of high risk assets can range between 113 and 2594(0 to 8.3% of the entire population).

The Base Case (EPN Region)

Model inputs

Mean = 65 years

Standard Deviation = 5 years

Investment plan for ED1 = 2488 asset replacements between 2015 and 2023 (2880 asset replacements when including 2012 to 2015).

These inputs results in the age profile of the LV Switchgear shown in:

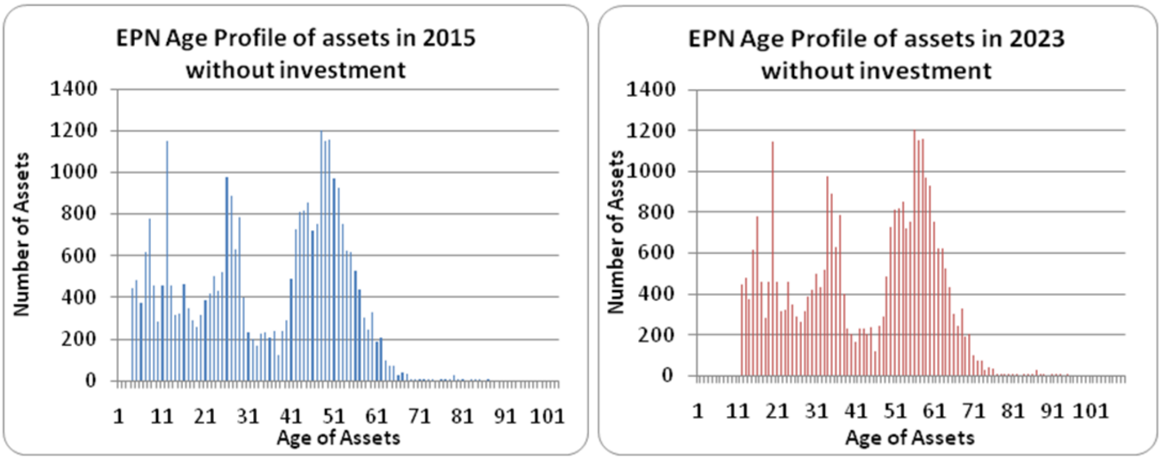


Figure 1. Comparison of age profiles for 2012 to 2023

The 47% of the asset population is between the ages of 40 and 60 years old in 2015. By the end of ED1, without investment, this large proportion of the population will be approaching its average asset life.

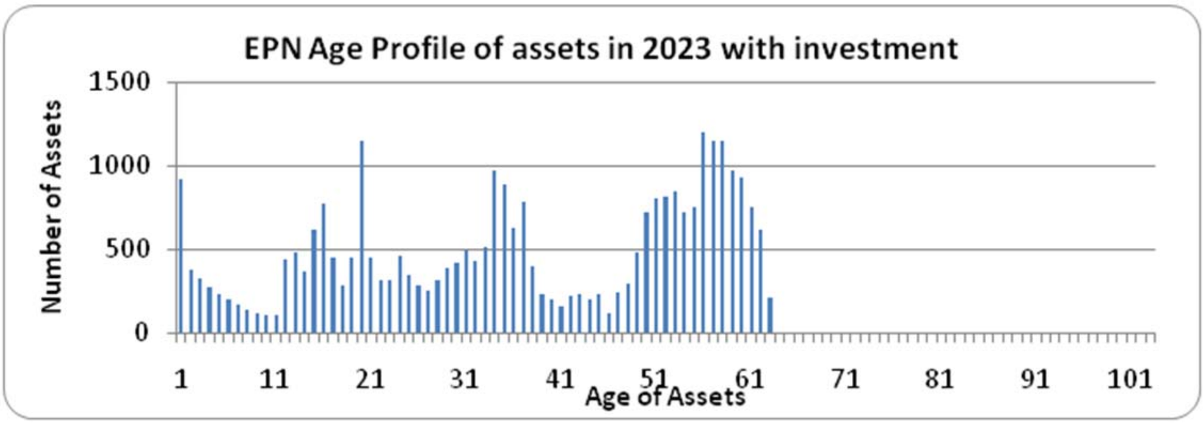


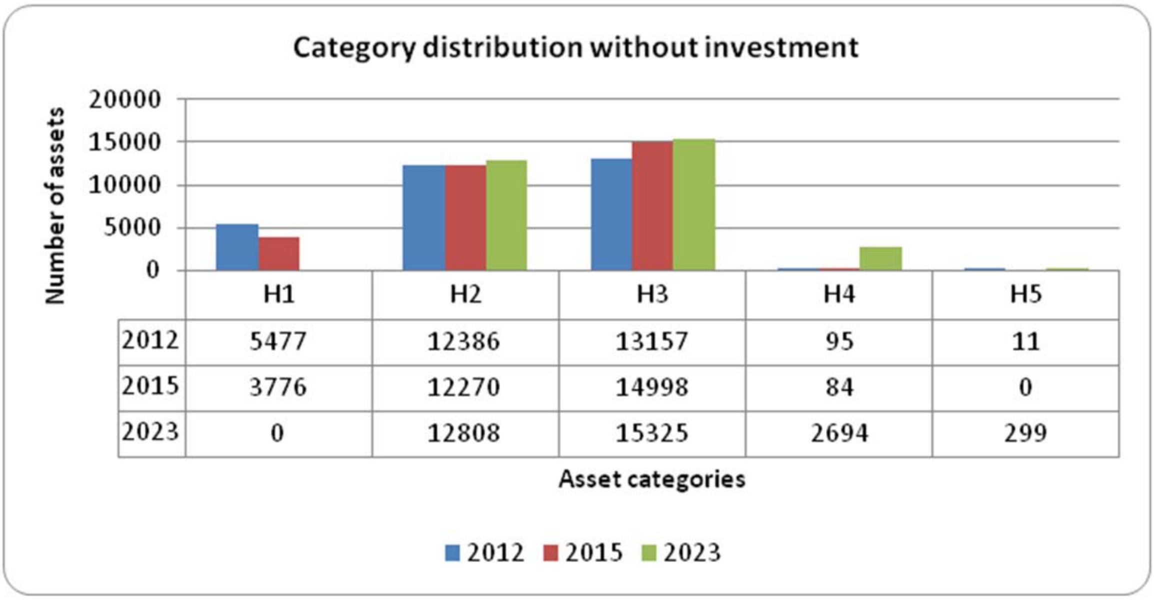
Figure 2. Age profile of the assets in 2023 with investment

Figure 2 shows that by the end of the ED1 investment plan that 42% of the population is between 45 and 63 years old. This is a very high proportion to be close to the average asset life.

HI Scoring

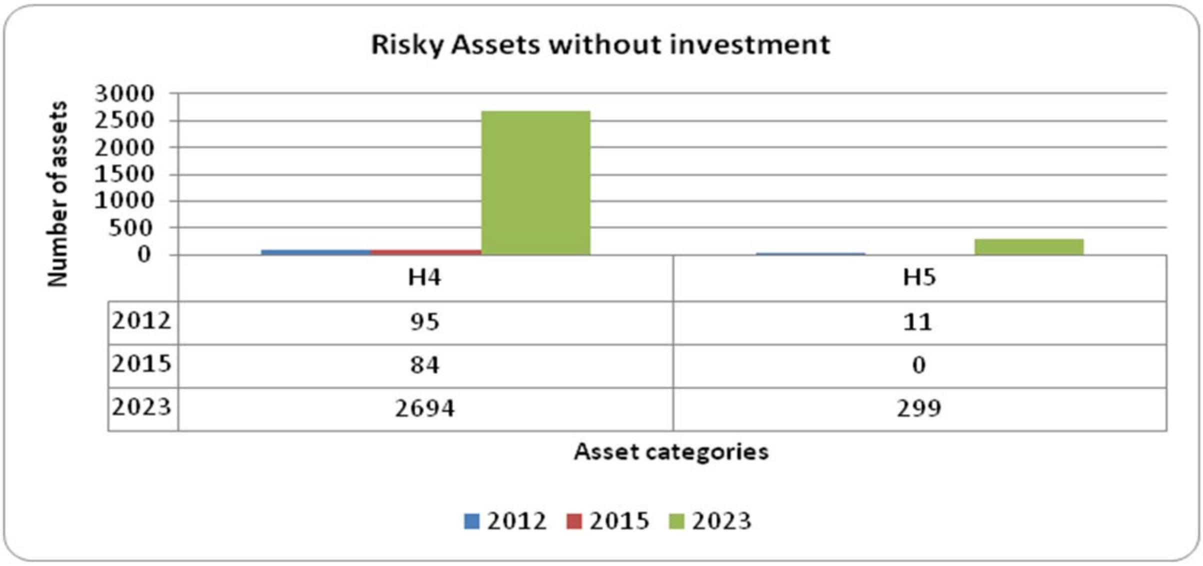
The volume of new HI4 and HI5 each year is calculated by taking the number of replacements indicated by SARM 1, and then splitting at a 9:1 ratio between HI4 and HI5. This method was developed by UKPN and not subjected to SA.

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



	H1	H2	H3	H4	H5
2012	5477	12386	13157	95	11
2015	3776	12270	14998	84	0
2023	0	12808	15325	2694	299

Figure 3. HI split without investment

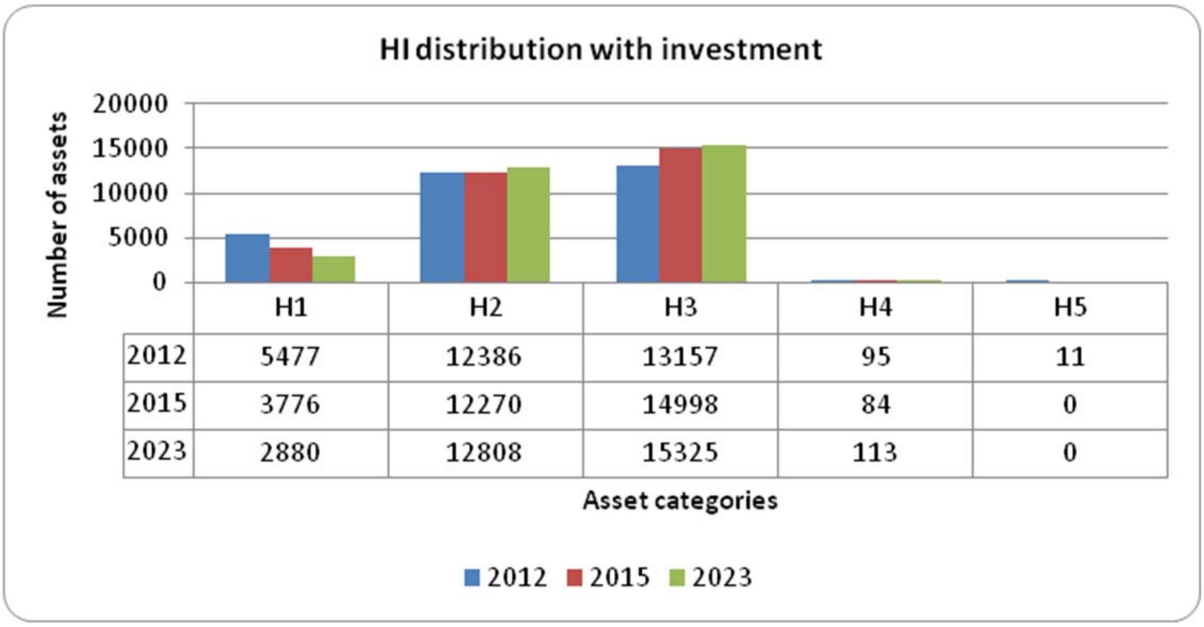


	H4	H5
2012	95	11
2015	84	0
2023	2694	299

Figure 4. High risk asset volumes without investment

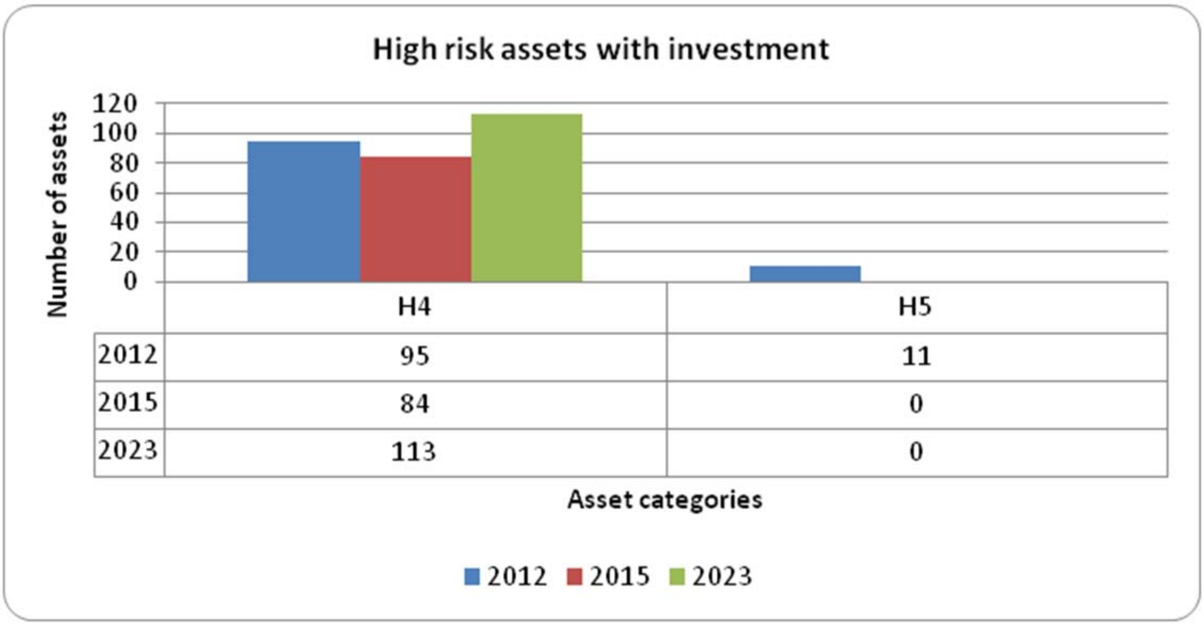
Clearly there is a significant rise in the number of LV Switchgear in the high risk categories (HI4 and HI5) from 2012 to 2023. In the period from 2015 to 2023 the number of high risk assets rises from 84 to 2993 (From 0.3% to 9.6% of the whole population). The risk has risen and investment needs to happen in order to reduce the number of high risk assets.

When the ED1 investment plan is introduced by comparing figure 6 with figure 4 it can clearly be seen that the volume of high risk assets is greatly reduced:



	H1	H2	H3	H4	H5
2012	5477	12386	13157	95	11
2015	3776	12270	14998	84	0
2023	2880	12808	15325	113	0

Figure 5. HI split with investment



	H4	H5
2012	95	11
2015	84	0
2023	113	0

Figure 6. High risk assets volumes with investment

By 2015, there are 84 high risk assets. Figure 6 above shows that the investment plan ensures that over the period from 2015 to 2023 the number of high risk asset is maintained, high risk assets rise from 84 to 113 (0.3% to 0.4%). The investment program in ED1 of 311 replacements per year has a positive effect.

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)?

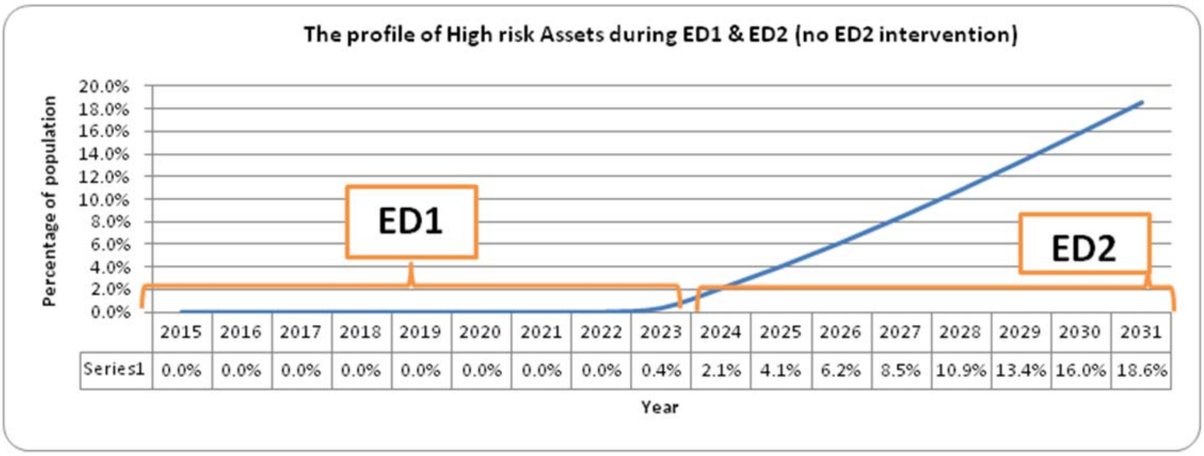


Figure 7. Proportion of high risk assets with investment in ED1

In the plan to replace 2880 assets between the years 2012 and 2023 means that by 2023 0.4% of the entire population will be high risk assets (HI4s and HI5s). If there is no ED2 plan (no replacements between 2024 and 2031) then by 2031 18.6% 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 (2488 replacements between the years 2024 and 2031)

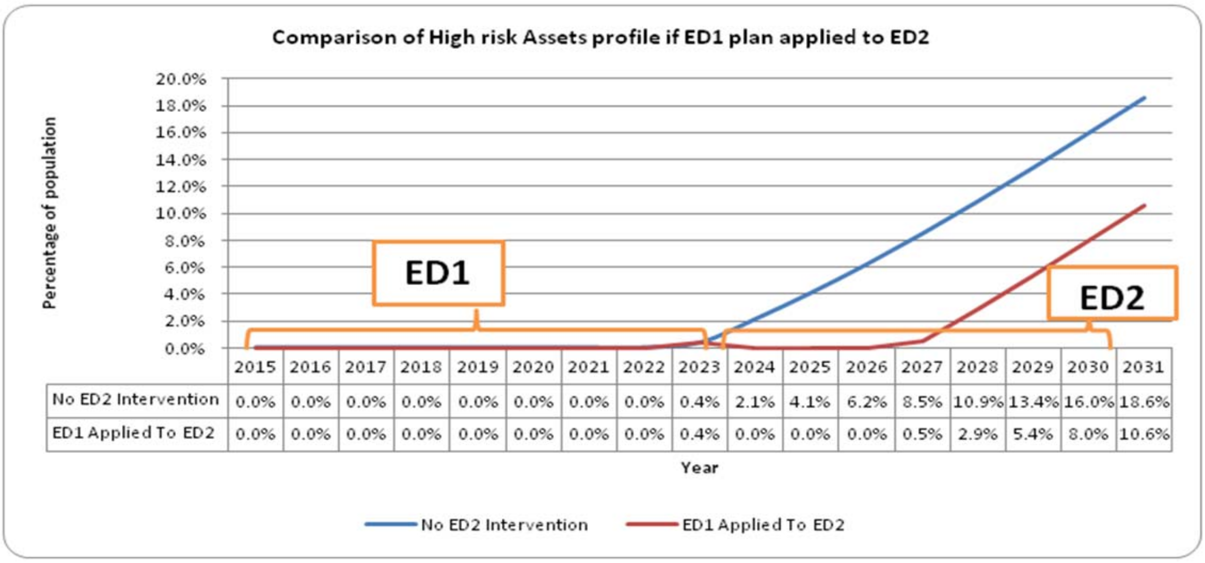


Figure 8. Proportion of high risk assets with investment in ED1 and ED2

By applying the ED1 plan to ED2 (2488 replacements between 2024 and 2031) means that by 2031 the number of high risk assets is 10.6% 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 mean asset life varies by +/- 1, 2, 3 and 4 years?

Under the current base case inputs, the number of high risk assets is manageable. How sensitive is the mean asset life value to the number of high risk assets at the end of the ED1 planning period:

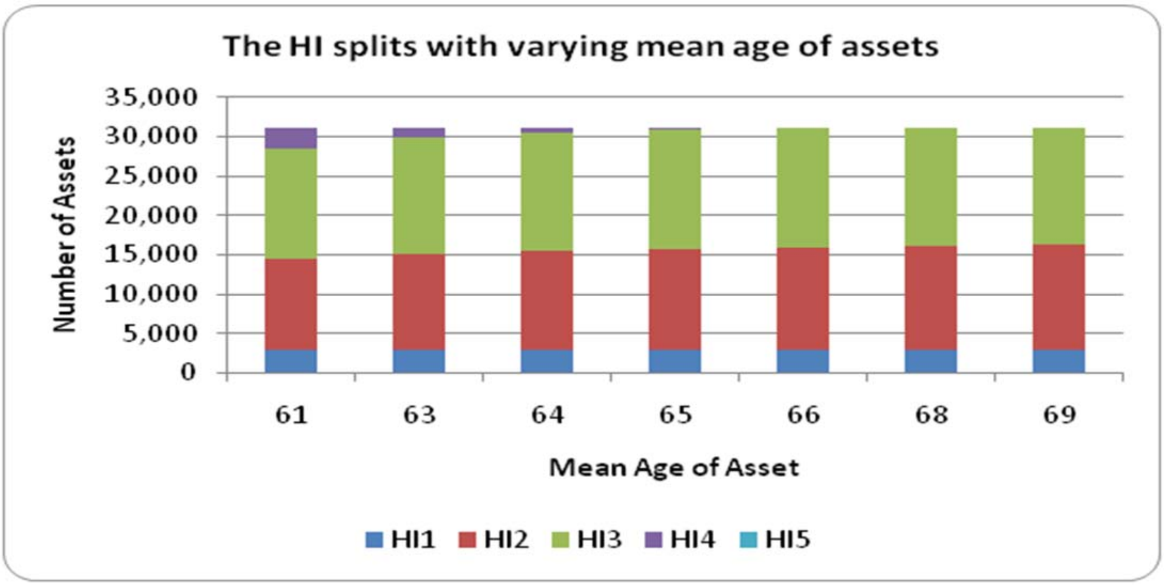


Figure 9. HI splits for various average asset lives with investment (base case life = 70 years)

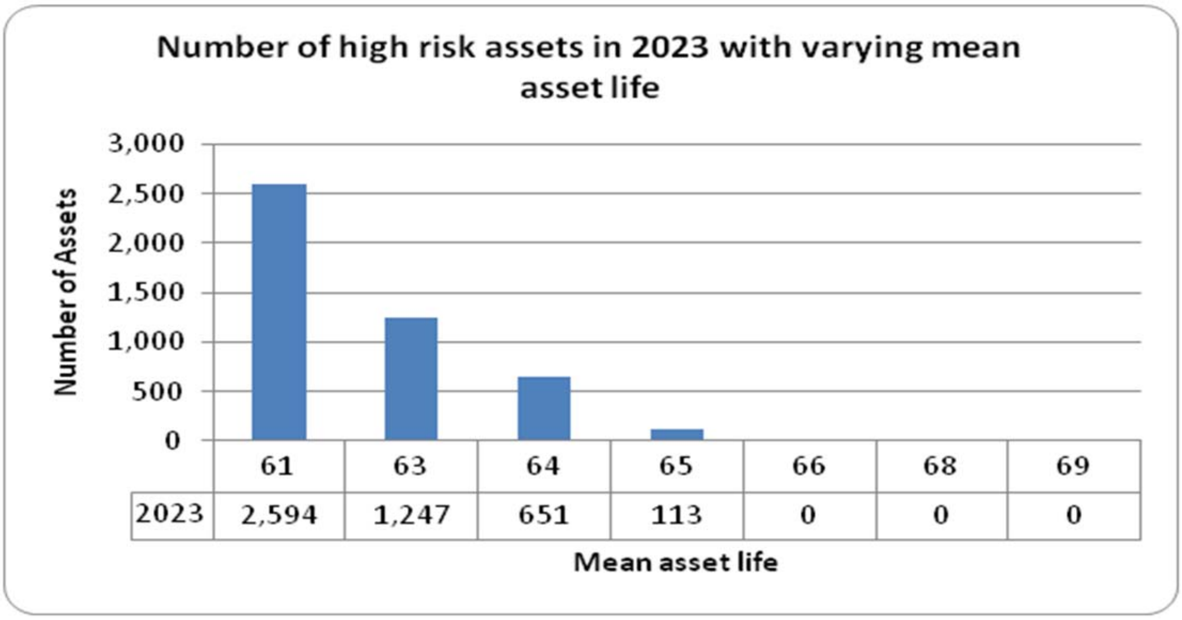


Figure 10. High risk asset volumes for various average asset lives, with investment (base case life = 70 years)

From figure 10 it can be seen that the number of high risk assets (Category H4 and H5) is sensitive to mean asset life with the current ED1 investment plan. If the mean asset life is anywhere between 61 years and 65 years then the number of high risk assets can range between 113 and 2594 (0.4% to 8.3% of the entire population).

If the mean asset life were one year lower than the base case then the number of high risk assets rises from 113 to 651 (0.4% to 2.1% of the LV Switchgear population) with the current ED1 investment plan.

If the mean asset life were two years lower than the base case then the number of high risk assets rises from 113 to 1247 (0.4% to 4.0% of the LV Switchgear population) with the current ED1 investment plan.

If the mean asset life were four years lower than the base case then the number of high risk assets rises from 113 to 2594 (0.4% to 8.3% of the LV Switchgear population) with the current ED1 investment plan.

These are important points to take notice of because a small error in mean age of a LV Switchgear (-4 years) could cause the number of high risk assets to rise to 8.3% 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	216	216	215	215	215	215	215	215	1,722	CV3	*34	216	216	215	215	215	215	215	215	1,722
	Install HV Switch at Secondary Sites	1.49.32	15	15	15	15	15	15	15	15	120	CV3	*37	15	15	15	15	15	15	15	15	120
	Install HV RMU at Secondary Sites	1.49.51	218	218	219	219	219	219	219	219	1,750	CV3	*38	218	218	219	219	219	219	219	219	1,750
	Install HV CB at Secondary Sites (Faults)	2.50.33	10	10	10	10	10	10	10	10	80	V4B	*34	10	10	10	10	10	10	10	10	80
	Install HV Switch at Secondary Sites (Faults)	2.50.35	5	5	5	5	5	5	5	5	40	V4B	*37	5	5	5	5	5	5	5	5	40
	Install HV RMU at Secondary Sites (Faults)	2.50.21	40	40	40	40	40	40	40	40	320	V4B	*38	40	40	40	40	40	40	40	40	320
	EPN Weather Cover Installation	1.22.10	194	194	194	194	194	194	194	194	1,552	CV6	11	194	194	194	194	194	194	194	194	1,552
														350	350	350	350	350	350	350	350	2,800
HV Switchgear (PM)	Replace Pole Mounted Recloser	1.19.27	7	7	7	7	7	7	7	7	56	CV3	160	7	7	7	7	7	7	7	7	56
	Replace 11kV ABSD	1.20.34	37	37	37	37	37	37	37	37	296	CV3	164	37	37	37	37	37	37	37	37	296
LV Switchgear	LV Pillar - TMFC (ID)	1.44.03	37	37	37	37	37	37	37	37	296	CV3	144	37	37	37	37	37	37	37	37	296
	Capital Replacement of LV Pillar - TMFC (ID)	2.50.25	8	8	8	8	8	8	8	8	64	V4B	16	8	8	8	8	8	8	8	8	64
	LV Feeder Pillar and TMFC (OD)	1.44.03	76	76	76	76	76	76	76	76	608	CV3	145	76	76	76	76	76	76	76	76	608
	Capital Replacement LV Feeder Pillar & TMFC (OD)	2.50.25	17	16	16	16	16	16	16	16	129	V4B	17	17	16	16	16	16	16	16	16	129
	Remove Service Turret	1.44.05	23	23	23	23	23	23	23	23	184	V4A	19 (Removals)	23	23	23	23	23	23	23	23	184
	Replace LV Boards	1.44.08	51	51	51	51	51	51	51	51	408	CV3	146	51	51	51	51	51	51	51	51	408
	Replace LV Switchgear - Network Pillar	1.44.02	100	100	100	100	100	100	100	100	800											
Link Boxes	Replace Link Boxes	1.44.04	429	429	429	429	429	429	429	429	3,432	CV3	147	600	600	600	600	600	600	600	600	4,800
	Replace Link Boxes (Fault)	2.50.17	71	71	71	71	71	71	71	71	568											
	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
														824	1,246	1,119	670	677	1,323	1,741	1,465	9,065
	Total		1,854	1,853	1,853	1,853	1,853	1,853	1,853	1,853	14,825	Total		1,854	1,853	1,853	1,853	1,853	1,853	1,853	1,853	14,825

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 2,800 assets map to CV6 11. The total volumes mapping to this line is 4,352.
- A further 9,065 assets map to CV13 11. The total volumes mapping to this line is 11,465.

Appendix 9 Efficiency Benchmarking with other DNOs

HV Switchgear

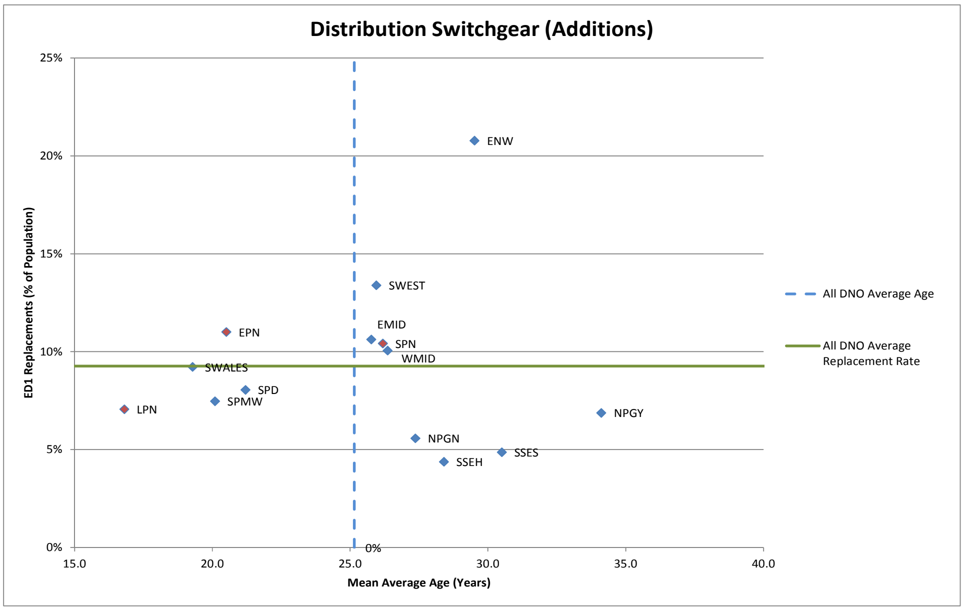


Figure 56: Efficiency Benchmarking *(Source: DNO Datashare 2013)*

Figure 56 shows that EPN has a higher replacement rate than the industry average per percentage of population and a lower average age. As discussed in Section 4.1, the ED1 plan is based on output from the ARP model where no asset is replaced purely on age.

The low average age in EPN is due to the large activity of work (i.e. asset replacement, load-related and connections) since 1997 resulting in just over 50% of the EPN distribution switchgear network being SF_6-filled switchgear.

LV Switchgear

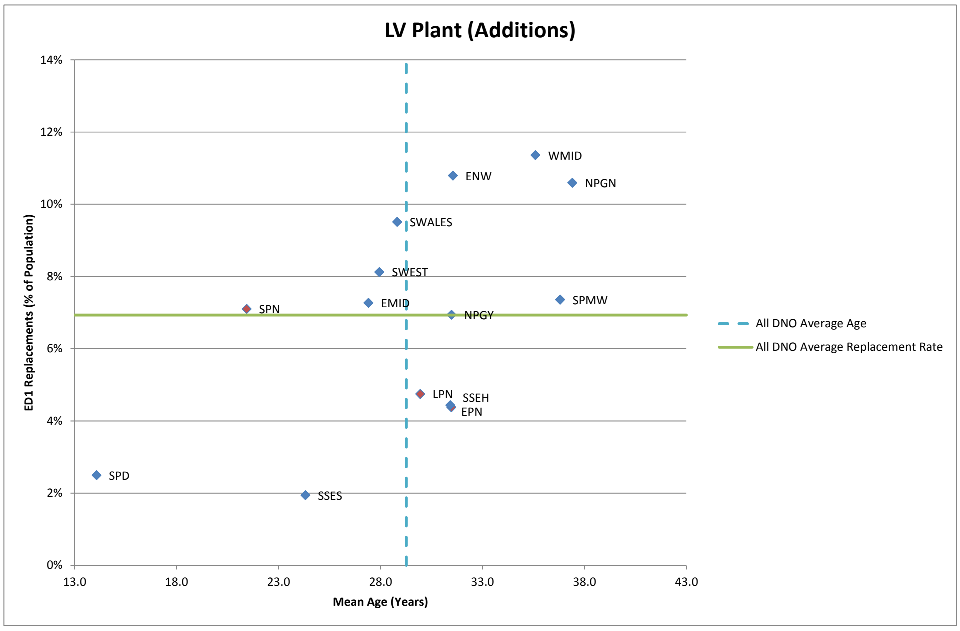


Figure 57: Efficiency Benchmarking *(Source: DNO Datashare 2013)*

Figure 57 shows that EPN has a lower replacement rate than the industry average per percentage of population and a higher average age. The plan for ED1 has been based on the output from the age based statistical model, historical replacement rates, fault rates and the condition of the oldest 10% of the population to determine the right outputs to use for investment forecasts.

Link Boxes

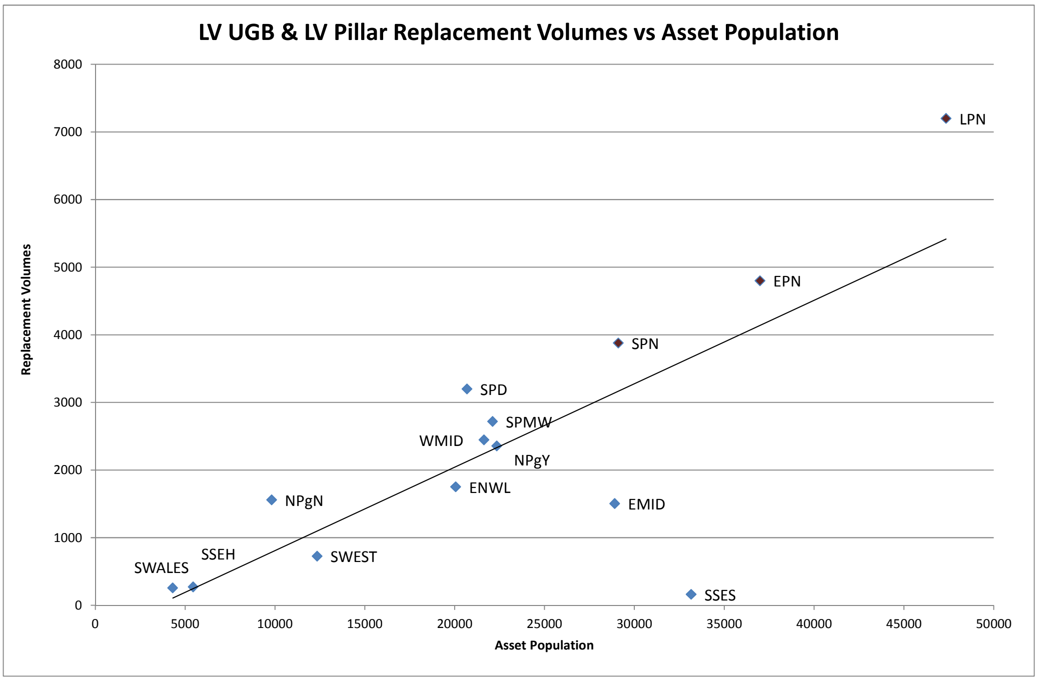


Figure 58: Efficiency Benchmarking *(Source: DNO Datashare 2013)*

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

Figure 58 shows that EPN 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 (particularly in the Central London Network area where there is a high population density). 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)	4,480	3,592	(888)
		Volume (Removals)	4,871	3,672	(1,199)
		Investment (£m)	58.11	*48.68	(9.43)
		UCI (£k)	12.97	13.55	0.58
HV Switchgear (PM)	Replace	Volume (Additions)	352	352	0
		Volume (Removals)	352	352	0
		Investment (£m)	1.27	1.27	0
		UCI (£k)	3.61	3.61	0
LV Switchgear	Replace	Volume (Additions)	1,312	1,312	0
		Volume (Removals)	1,312	1,312	0
		Investment (£m)	10.46	10.46	0
		UCI (£k)	7.97	7.97	0
Link Boxes	Replace	Volume (Additions)	4,800	4,800	0
		Volume (Removals)	4,800	4,800	0
		Investment (£m)	22.70	22.70	0
		UCI (£k)	4.73	4.73	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 reduce the original submission by £9.43m based on a reduction in EPN secondary switchgear replacements. The submitted replacement volumes were produced from the ARP model and these have been reviewed against the asset age profiles and fault trends (see Figure 54). Fault trends have reduced over the five year period for HV switchgear and the average age of this asset type is significantly less when compared to the industry average. Based on a risk and criticality review, UKPN are proposing to reduce their replacements by appoximately 20%. [Note: the overall UCI increase is due to analysis of the circuit breaker replacement cost which was too low in the original submission].

Faults (V4b/CV15a)

<table>
<tr><th>Asset Type</th><th>Action</th><th>Change Type</th><th>2013 Submission</th><th>2014 Submission</th><th>Difference</th></tr>
<tr><td rowspan="4">HV Switchgear (GM)</td><td rowspan="4">Replace</td><td>Volume (Additions)</td><td>440</td><td>440</td><td>0</td></tr>
<tr><td>Volume (Removals)</td><td>554</td><td>554</td><td>0</td></tr>
<tr><td>Investment (£m)</td><td colspan="3" rowspan="2">Changes to capitalised fault restoration expenditure can be found in Document 14: EPN I&M & Faults</td></tr>
<tr><td>UCI (£k)</td></tr>
<tr><td rowspan="4">LV Switchgear</td><td rowspan="4">Replace</td><td>Volume (Additions)</td><td>193</td><td>193</td><td>0</td></tr>
<tr><td>Volume (Removals)</td><td>193</td><td>193</td><td>0</td></tr>
<tr><td>Investment (£m)</td><td colspan="3" rowspan="2">Changes to capitalised fault restoration expenditure can be found in Document 14: EPN I&M & Faults</td></tr>
<tr><td>UCI (£k)</td></tr>
<tr><td>Link Boxes</td><td>Replace</td><td>Volume</td><td colspan="3">Included in CV3</td></tr>
</table>

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)