Document 8
Asset Category – HV Switchgear and LV Plant
LPN

Asset Stewardship Report
2014

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Approved by Richard Wakelen / Barry Hatton

Approved Date 06/03/2014

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 costs to reflect 19th 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 Minor Minor Minor Minor Minor	Section 1.1 Section 1.1, 1.3 & Appendix 5 Throughout document Appendix 8, 9 & 10 Sec 7.7 & Appendix 2 Section 7.7
1.2	27/02/2014	Minor changes to preface and Appendix 9	Zoe Cornish	Minor	Preface & Appendix 9
1.3	27/02/2014	Minor changes to Appendix 10	Zoe Cornish	Minor	Appendix 10
1.4	28/02/2014	Minor changes to Appendix 8	Zoe Cornish	Minor	Appendix 8
1.5	04/03/2014	Minor Changes to 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 Business Plan Data Table reconciliation:** This section explains the 'line of sight' between the UKPN Network Asset Management Plan (NAMP) replacement volumes contained in the Ofgem RIGS tables. The NAMP is the UKPN ten year rolling asset management investment plan. It is used as the overarching plan to drive both direct and indirect Capex and Opex interventions volumes and costs. The volume and cost data used in this ASR to explain our investment plan is taken from the UK Power Networks NAMP. Appendix 8 explains how the NAMP outputs are translated into the Ofgem RIGS tables. The translation of costs from the NAMP to the ED1 RIGS tables is more complex and it is not possible to explain this in a simple table. This is because the costs of a project in the 'NAMP' are allocated to a wide variety of tables and rows in the RIGS. For example the costs of a typical switchgear replacement project will be allocated to a range of different Ofgem ED1 RIGs tables and rows such as CV3 (Replacement), CV5 (Refurbishment) CV6 (Civil works) and CV105 (Operational IT Technology and Telecoms). However guidance notes of the destination RIGs tables for NAMP expenditure are included in the table in the Section 1.1 of the Executive Summary of each ASR.
2. **Appendix 9 – Efficiency benchmarking with other DNO's:** This helps to inform readers how UK Power Networks is positioned from a benchmarking position with

other DNO's. It aims to show why we believe our investment plans in terms of both volume and money is the right answer when compared to the industry, and why we believe our asset replacement and refurbishment investment proposals are efficient and effective and in the best interest for our customers.

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

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

Contents

1.0 Executive Summary LPN HV Switchgear and LV Plant

1.1 Scope

This document details UK Power Network's NLRE intervention proposals for LPN 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 20,875 HV switchgear assets with an estimated Modern Equivalent Asset Valuation (MEAV) of £345m. The proposed investment is £3.1m per annum and this equates to an average annual 1.0% of the MEAV for this asset category. Furthermore, the LV switchgear population comprises of approximately 27,050 assets and 47,632 link boxes. The combined estimated MEAV of LV plant is £517m. The proposed investment is £7.3m per annum and this equates to an average annual 1.4% of the MEAV for these asset categories.

Intervention costs total £83m and are held in Ofgem's RIGs reporting plan as shown in Table 1.

<table>
<tr><th rowspan="2">Investment Type</th><th rowspan="2">NAMP Reference</th><th colspan="2">RIGs Volumes</th><th rowspan="2">RIGs Costs</th><th rowspan="2">ED1 Investment</th></tr>
<tr><th>Additions</th><th>Removals</th></tr>
<tr><td rowspan="3">Install HV CB at Secondary Sites</td><td rowspan="2">1.49.30</td><td rowspan="2">CV3 34</td><td rowspan="2">CV3 162</td><td>CV3 34</td><td rowspan="10">£24.5m Asset Replacement
£0.9m Civils
£5.3m IT&T</td></tr>
<tr><td>CV6 27/28</td></tr>
<tr><td>2.50.33*</td><td>V4b 34</td><td>V4b 34</td><td>CV15a 27</td></tr>
<tr><td rowspan="3">Install HV Switch at Secondary Sites</td><td rowspan="2">1.49.32</td><td rowspan="2">CV3 37</td><td rowspan="2">CV3 165</td><td>CV3 37</td></tr>
<tr><td>CV6 27/28</td></tr>
<tr><td>2.50.35*</td><td>V4b 37</td><td>V4b 37</td><td>CV15a 27</td></tr>
<tr><td rowspan="4">Install HV RMU at Secondary Sites</td><td rowspan="3">1.49.51</td><td rowspan="3">CV3 38</td><td rowspan="3">CV3 166</td><td>CV3 38</td></tr>
<tr><td>CV6 27/28</td></tr>
<tr><td>CV105 6</td></tr>
<tr><td>2.50.21*</td><td>V4b 38</td><td>V4b 38</td><td>CV15a 27</td></tr>
<tr><td>Replace LV Boards</td><td>1.44.08</td><td>CV3 18</td><td>CV3 146</td><td>CV3 18</td><td rowspan="2">£15.4m Asset Replacement</td></tr>
<tr><td>Replace ACB</td><td>1.44.12</td><td>CV3 15</td><td>CV3 143</td><td>CV3 15</td></tr>
<tr><td rowspan="2">Replace Link Boxes</td><td>1.44.04</td><td rowspan="2">CV3 19</td><td rowspan="2">CV3 147</td><td rowspan="2">CV3 19</td><td rowspan="4">£42.9m Asset Replacement
£1.2m I&M</td></tr>
<tr><td>2.50.17*</td></tr>
<tr><td>Replace LB Covers & Frames</td><td>1.44.07</td><td colspan="2" rowspan="2">CV13 11</td><td rowspan="2">CV13 11</td></tr>
<tr><td>Replace LB Covers & Frames (Roadway)</td><td>1.44.11</td></tr>
<tr><td colspan="6">Note: *The 2.50 NAMP lines are fault restoration costs for HV and LV plant</td></tr>
</table>

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

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 LPN (excluding civils/automation etc) is £83m. The annual expenditure profile (including 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
LPN	*Switchgear*	*HV Switchgear*	*1.49.30/ 2.50.33*	*Install HV CB at Secondary Sites*	*146*	*146*	*146*	*146*	*146*	*146*	*146*	*146*
			1.49.32/ 2.50.35	*Install HV Switch at Secondary Sites*	*82*	*82*	*82*	*82*	*82*	*82*	*82*	*82*
			1.49.51/ 2.50.21	*Install HV RMU at Secondary Sites*	*3,579*	*3,579*	*3,579*	*3,579*	*3,579*	*3,579*	*3,579*	*3,579*
		LV Switchgear	*1.44.08*	*Replace LV Boards*	*1,511*	*1,511*	*1,511*	*1,511*	*1,511*	*1,511*	*1,511*	*1,511*
			1.44.12	*Replace ACB*	*418*	*418*	*418*	*418*	*418*	*418*	*418*	*418*
		Link Boxes	*1.44.04/ 2.50.17*	*Replace Link Boxes*	*5,365*	*5,365*	*5,365*	*5,365*	*5,365*	*5,365*	*5,365*	*5,365*
			1.44.07	*Replace Covers & Frames*	*60*	*60*	*60*	*60*	*60*	*60*	*60*	*60*
			1.44.11	*Replace LB Covers & Frames - Roadway*	*89*	*89*	*89*	*89*	*89*	*89*	*89*	*85*
		TOTAL (£k)			***11,250***	***11,250***	***11,250***	***11,250***	***11,250***	***11,250***	***11,250***	***11,246***

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 <u>with</u> intervention to Y3 then <u>without</u> Y4 to Y11].

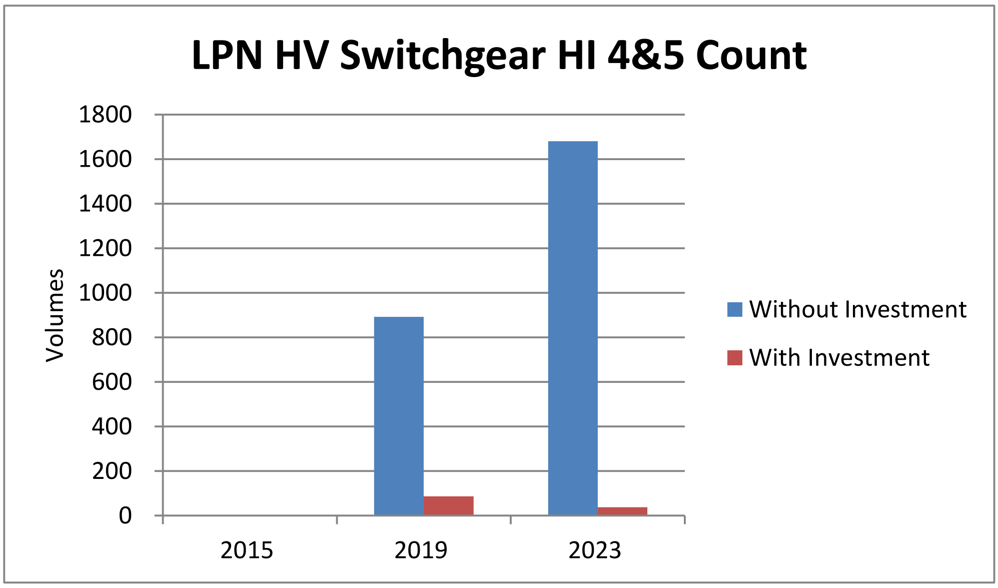


Figure 1: HV Switchgear HI 4 & 5 Count (Source: 25_07_2012 ARP Model)

Figure 1 shows the number of HI 4 and 5 assets at the end of ED1 for HV switchgear with and without investment. Approximately 1,660 assets are due to be replaced during ED1 (8% of the population) compared with 4,075 assets during DPCR5 (pro-rata'd). 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 small percentage of older oil-filled defective assets that are in poorest condition on the network. This equates to small volumes per year and is a reduction compared with DPCR5 achievements and historical volumes.

As shown in Figure 1 it is expected that (based on the current condition data) all of the HI 4 and 5 assets will be removed from the network by the start of ED1 (2015), and similarly by the end of ED1 (2023), with the aim to maintain LPNs network performance, safety and reliability.

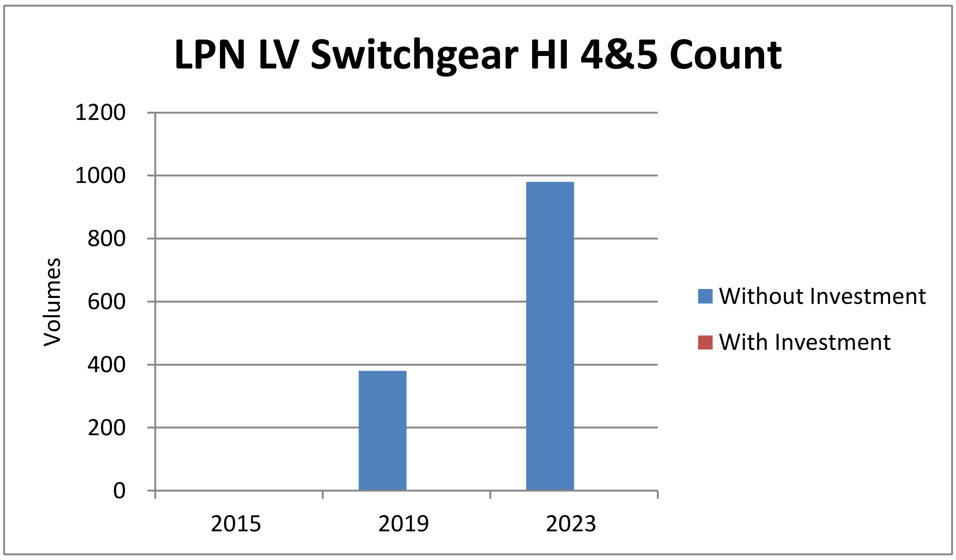


Figure 2: LV Switchgear HI 4 & 5 Count (Source: SARM v0.3 Statistical Model)

The LV switchgear HI profile (Figure 2) is based on the statistical SARM model and consideration of the number of assets that will have surpassed their nominal design life by 2023. The SARM model is used where there is not a representative sample of condition data.

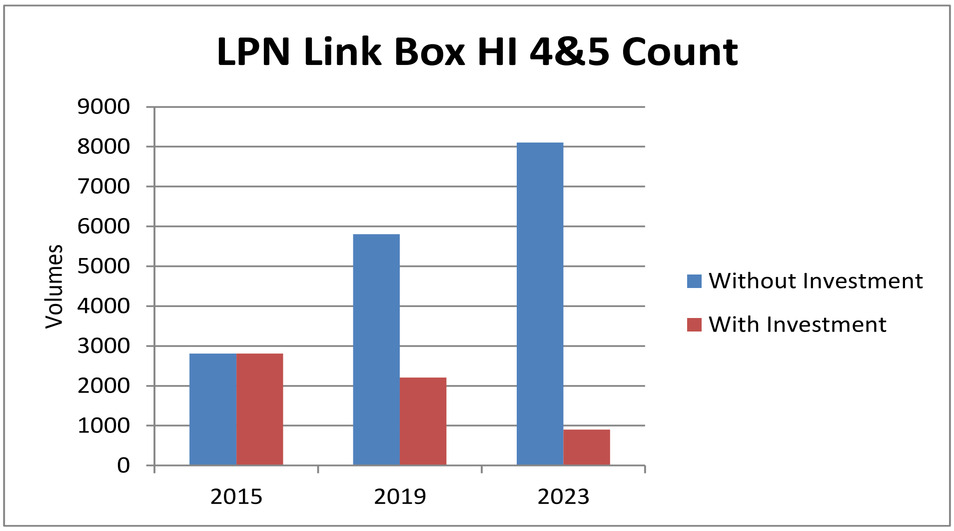


Figure 3: Link Box HI 4 & 5 Count (Source: Stocks & Flows Model V1.1)

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 **HV Plant** we are proposing to replace **7%** of our assets while other DNOs were seeking funding to replace **9%** of these assets on average. It shows that for **LV Plant** we are proposing to replace **5%** 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 sserious events relating to gas and electrical link box explosions, some with severe consequences. In order to minimize these health and safety risks, we are exploring a range of innovative mitigation options including hinged, vented and sprung covers.

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

1.5 Risks and Opportunities

	Description of similarly likely opportunities or risks arising in ED1 period	Uncertainties
Risk/ Opportunity	Exploring the provision of link box covers.	± 14% 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	Cost of 20% of LPN distribution switchgear replacements are likely to increase by 50% expenditure due to the location of some sites (particularly those in basements or on third party properties).	+ 6% of ED1 investment

Table 3: Risks and Opportunities

2.0 Description of HV Switchgear and LV Plant

2.1 HV Switchgear

HV switchgear on the LPN distribution network includes 6.6kV and 11kV units. Its function is to control, protect and isolate electrical equipment. There are approximately 20,875 HV switchgear assets operating within the LPN region of UK Power Networks, consisting of a large majority of Ring Main Units (RMUs) and smaller volumes of circuit breakers and switches. Due to the fact that this plant powers the London region, many of the installations are indoors or in the basement of buildings. As shown in Figure 4, just over three quarters of these are SF_6 filled switchgear (77%), with 18% of the population being oil-filled switchgear and 5% vacuum, distributed over more than 15,000 substation sites.

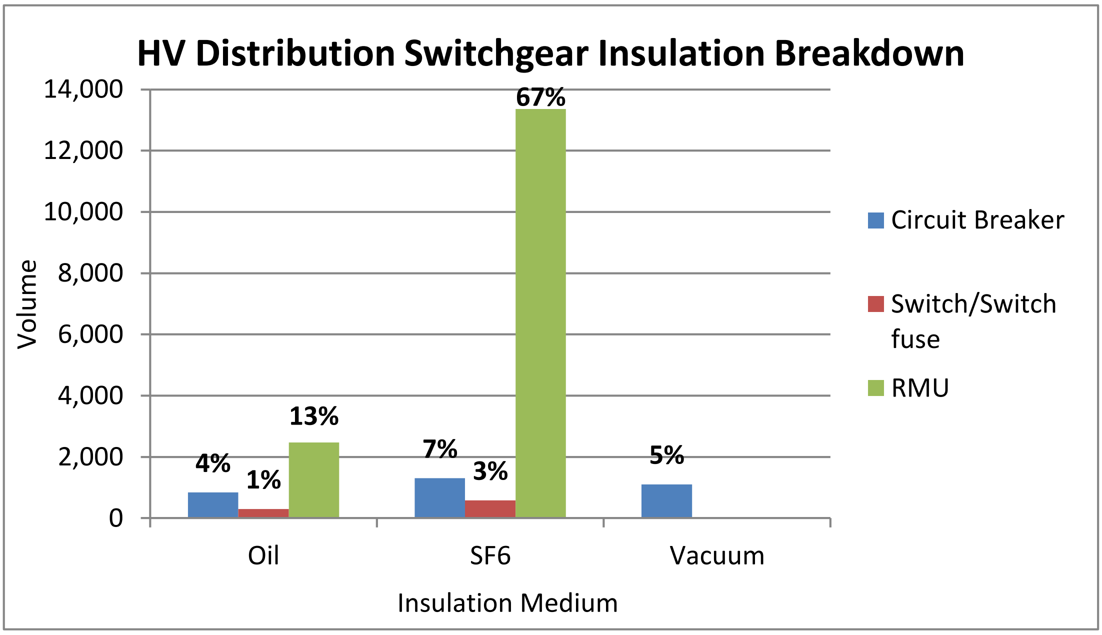


*Figure 4: HV Distribution Switchgear Insulation Breakdown (*Source: 25_07_2012 ARP Model)

As shown in Figure 5, only a small number of HV switchgear assets that were commissioned on the LPN network during the 1960s are still commissioned. This highlights the young fleet of assets covering this region. The average age of secondary switchgear in this area is approximately 18 years. The oldest 10% of assets (the 1960s peak) in this region has an average age of approximately 52 years. Furthermore, without intervention during ED1, 13% of the LPN HV switchgear population will be beyond the average asset life by 2023.

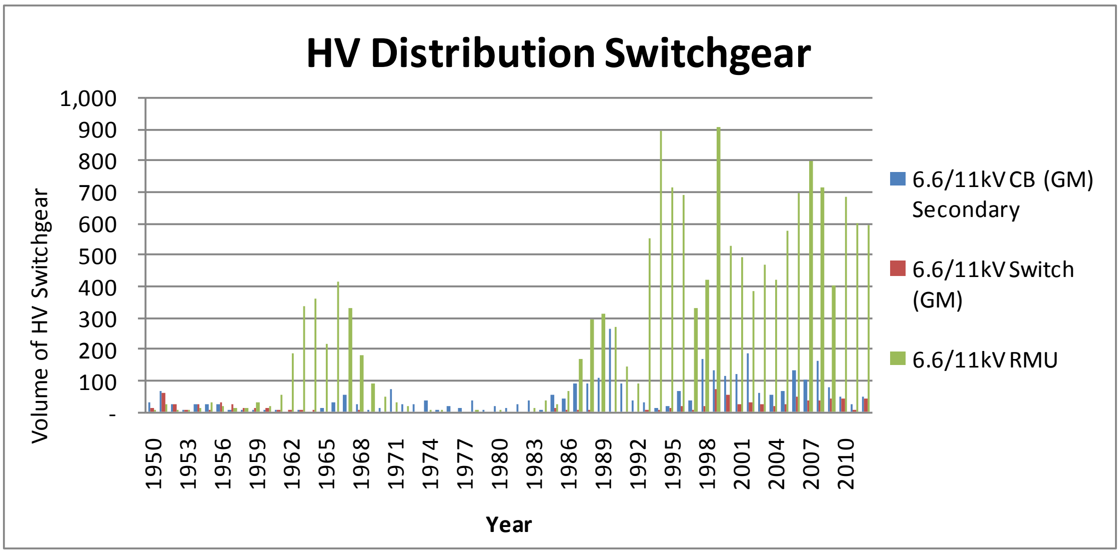


Figure 5: HV Distribution Switchgear Age Profile (Source: 2012 RIGs Table V5)

SF_6 filled switchgear dominates the LPN network and continues to grow 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 largest population of the remaining oil-filled switchgear still commissioned on the network are the Reyrolle LMI RMUs (1,154 assets) followed by the Switchgear and Cowens RA4 RMU (470 assets) and the AEI-Henley QF371H RMU (388 assets), all with an average age of 47 years.

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.

2.2 LV Switchgear

There are approximately 27,050 LV switchgear assets commissioned on the LPN network comprising of LV Air Circuit Breakers (ACBs), Transformer Mounted Fuse Cabinets (TMFC) and LV boards. The breakdown of these assets is shown in Figure 6.

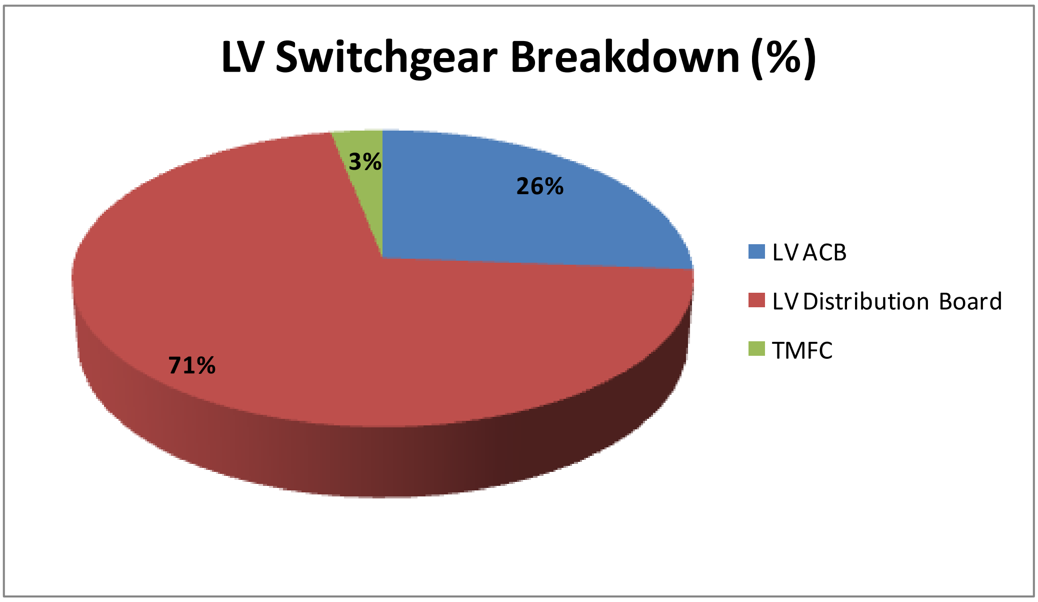


Figure 6: LV Switchgear (Source: 27_02_2013 Ellipse Extract)

Contrary to the commissioning of HV switchgear, it can be seen from the age profile in Figure 7 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 58 years. Without intervention 13% of the LV switchgear population will be beyond the average asset life by the end of ED1 in 2023.

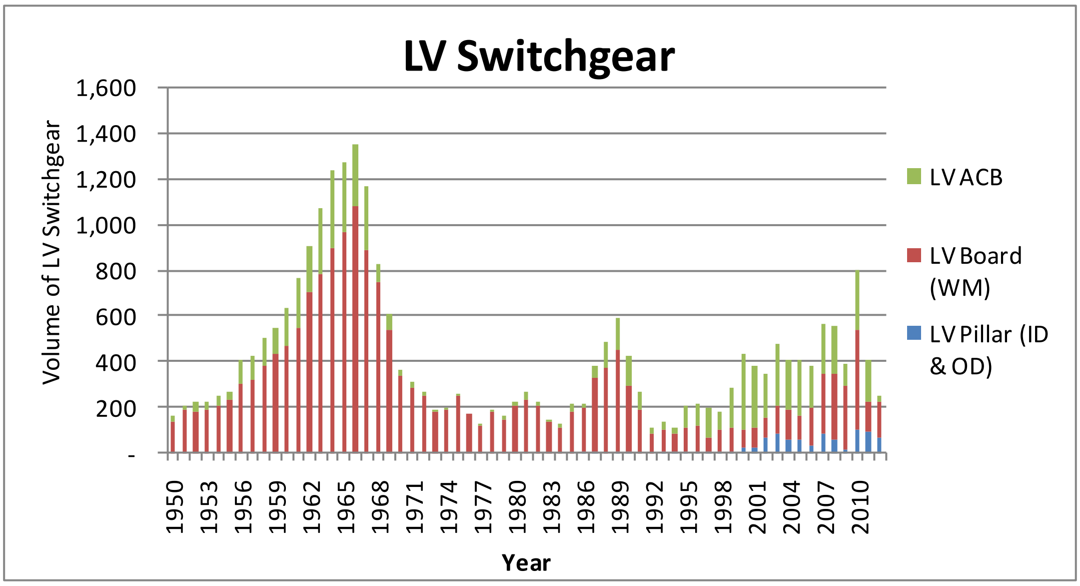


Figure 7: LV Switchgear Age Profile (Source: 2012 RIGs Table V5)

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

2.3 Link Boxes

There are approximately 47,632 link boxes currently operating within the LPN 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 processes 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 LPN 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	-

*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 driver that influences the actions and decisions involved in the management of distribution substation switchgear is 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, leading to extensive amounts of rust developing as shown in Figure 8.

Figure 8: SCO RAE4 RMU at Queenhithe Hotel, Paternoster and SCO RA71 RMU

There is no one type of LV board that stands out as more unreliable than others, however there has been a slight deterioration in the reported condition of LV boards. The areas of concern are compound leaks and the condition of phase barriers which may become dislodged, broken or missing. On top of this, a high number of LV boards will be replaced over ED1 on safety or operational grounds.

Figure 9 shows a Westminster board installed at Grosvenor Place 16. The busbars are staggered with the upper red phase bar protruding more than 200mm further than the bottom neutral bar. The board uses standard fuse carriers but there are no barriers between ways or phases. There is a strategic decision on the basis of safety to remove all Westminster Boards within the LPN region over ED1.

Figure 9: Westminster Board installed at Grosvenor Place 16 Substation

Furthermore, Figure 10 shows an English Electric type 'CJ' LV board. These are generally commissioned in the West London region and have open busbars at high level and bare risers. All are due to be replaced over ED1.

Figure 10: Cornwall Gdns 5 Substation

Virtually all LV ACBs are reported as being in good condition externally on routine inspection. However, since 2008, reports of nuisance tripping were experienced in relation to the Masterpact M ACBs fitted with STR trip units. Investigations determined that this was caused by a corroded thermistor within the trip unit. It was concluded that refurbishing the protection module in question would eliminate the nuisance tripping without having to replace the ACB.

3.2 Defects

3.2.1 Defects used as Replacement Drivers for HV Switchgear

The switchgear defects used in the ARP model to help calculate the overall Health Index 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 most 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	For withdrawable switchgear only, this is used to record defects with

mechanism	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 11. 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.

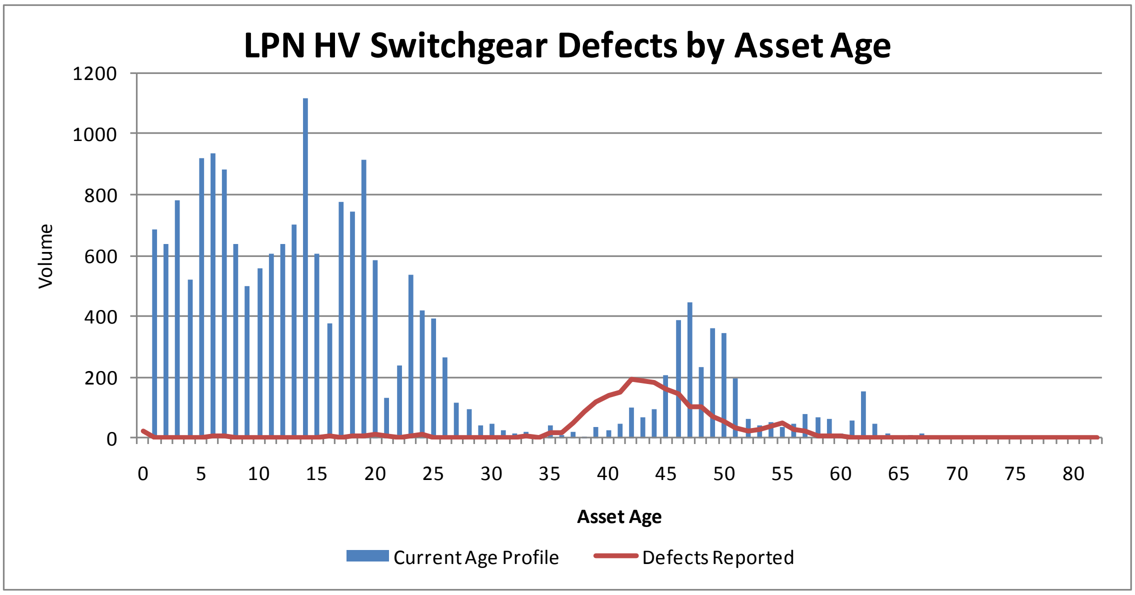


Figure 11: Defects by Age (Source: Ellipse Extract 19_02_2013 & RIGs V5)

Figure 12 shows the number of switchgear defects reported since 2007 when the Ellipse asset register was introduced and shows a declining trend of reported defects for LPN HV switchgear, highlighting the large proportion of young SF_6 assets operating on the network.

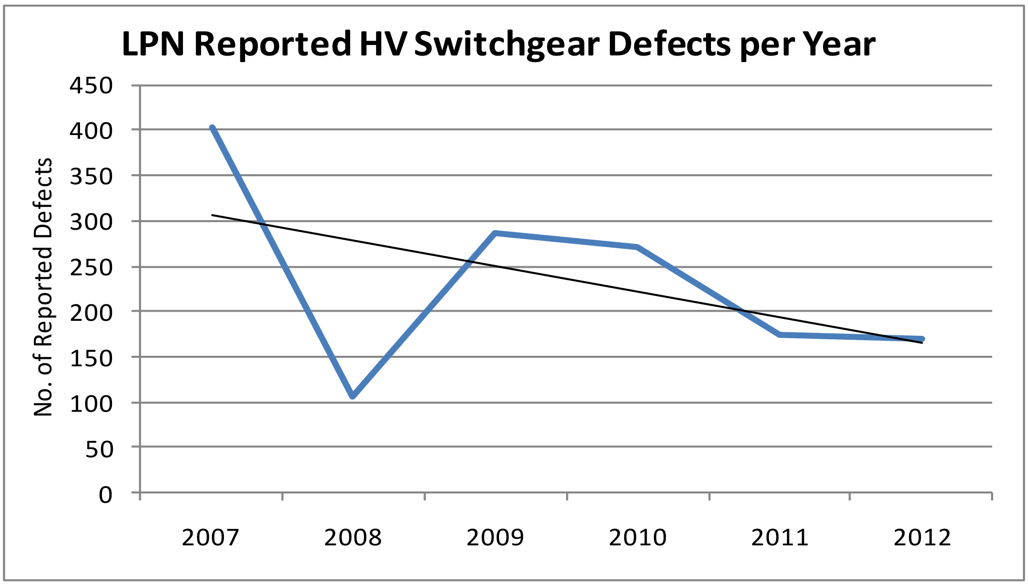


Figure 12: Defects per Year (Source: Ellipse Extract 19_02_2013)

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 13 shows a severe oil leak of a Switchgear and Cowens RMU, inevitably increasing the likelihood of asset failure.

Figure 13: Severe RMU Oil Leak

Similarly, Figure 14 highlights a serious compound leak where the only option is to replace the item of switchgear.

Figure 14: Serious Compound Leal (39 Maddox St, London)

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 15: White Deposits on Yellow Phase Bushing Bolts

Figure 16 shows the results of a GEC VMX circuit breaker that failed disruptively at Southwark Street 65 substation in LPN 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 16: 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 LPN area that are the targeted interventions over ED1 are shown in Figure 17. Asset replacement will continue to reduce this ever decreasing oil-filled population in favour of gas insulated switchgear.

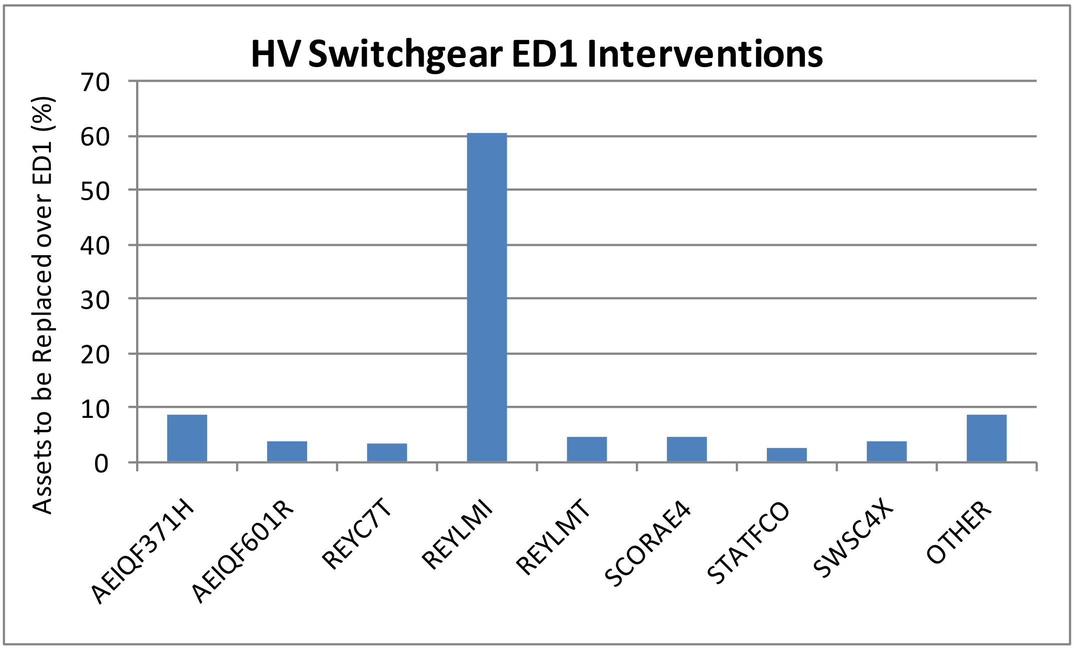


Figure 17: HV Switchgear Intervention Breakdown (Source: 25_07_2012 ARP Model)

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

The high number of Reyrolle RMUs to be replaced is due to significant compound leaks this plant seems to suffer from. Furthermore, the LMI associated LMT OCB suffer from lack of lubrication or hardening of grease more than other units.

GEC VMX gear has proven to be flawed, particularly the earlier 'form B.' In a dry clean environment it performs satisfactorily, but if installed in damp or polluted conditions discharge activity soon becomes a problem. Cast resin mouldings are used throughout and once discharge activity has started, the only cure is replacement of the defective components. These sites will be monitored and scheduled for replacement during ED1 based on analysis of partial discharge.

Most of the defects found are familiar, 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 most older switchgear. If any compound leaks out, the impulse rating is reduced with the risk of a disruptive failure if the equipment is subject to an overvoltage.
	Defect phase barriers	Existing phase barriers broken/missing – water transfer between phases causing electrical breakdown.
	Defective cable box	Oil/compound leaks can occur around cable boxes where there is a flange or gasket. Defective cable boxes may also show large amounts of rust increasing the likelihood of failure.
Link Box	Defect cover and frame	Cracked/broken - Allows water, sand, soil and wildlife to enter the pit in which the link box is installed. It could also create a tripping hazard to members of the public and operational inspectors.
	Bell Cover cracked/water ingress	Allows water, sand, soil or vermin to enter the link box – can potentially lead to failure
	Defect stalks 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

Figure 18 shows a typical leaking top entry cable box at a central basement site near Park Lane. The high ambient temperature in many substations contributes to the compound leak problems. The non-standard fuse carriers on the Lucy LV board in

Figure 19 are secured by spring pressures rather than clamps and are difficult to purchase.

Figure 18: Leaking Top Entry Box at Park Lane

Figure 19: Non-Standard Fuse Carriers on Lucy LV Board

Figure 20 shows water inside a resin-filled link box caused by condensation, increasing the likelihood of failure.

Figure 20: Water Ingress caused by Condensation

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 21: 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 21 and 22.

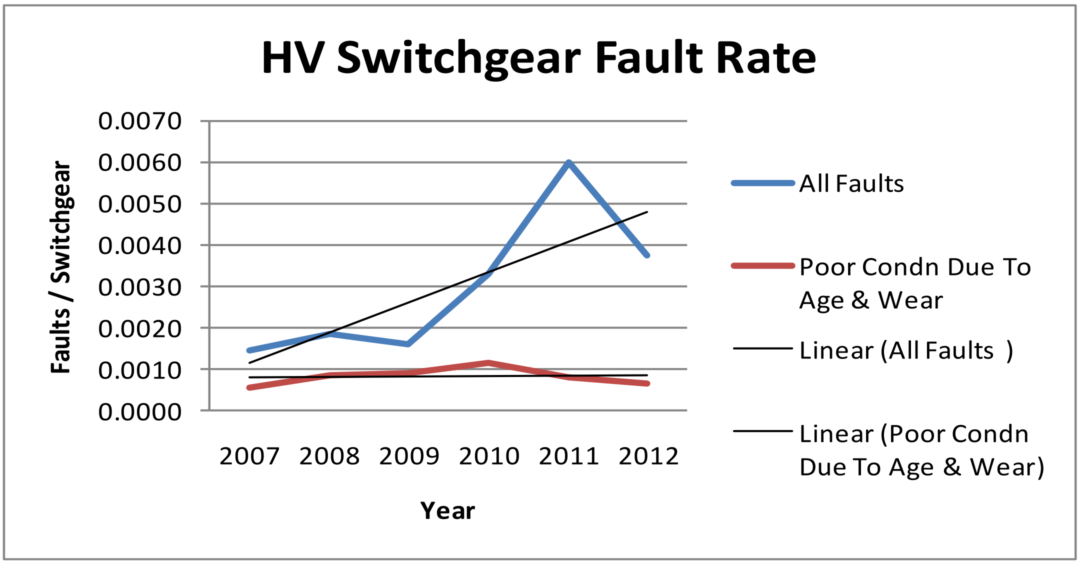


Figure 22: HV Switchgear Fault Rate (Source: UKPNs Fault Analysis Cube 15_03_2013)

The fault trend has been increasing over the past five years for HV switchgear. There is an uncharacteristic increase shown in 2011 and this is due to changes in the reporting system which increased reported electrical open or closing faults for that year only. If this is replaced with the previous five year average the five and ten year trend aligns better with the forecast. A further breakdown of fault causes shows a steady trend in the fault rate due to poor condition (age or wear) over the five year period.

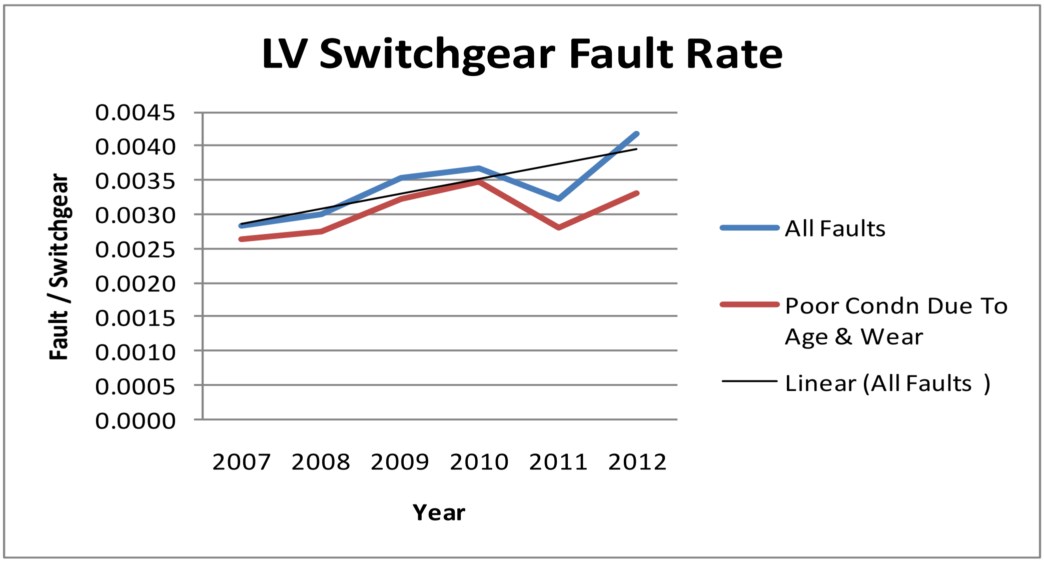


Figure 23: LV Plant Fault Rate (Incl. Link Boxes) (Source: UKPNs Fault Analysis Cube 15_03_2013)

As shown in Figure 23, the fault trend is showing an overall increase over the last five years for LV switchgear, mainly due to the abnormally high volumes in 2011/12. If these are smoothed, there is a slightly flatter trend which aligns better with the forecast. From a further breakdown of fault causes, it is evident that approximately 90% of condition-based faults are due to poor condition (age or wear).

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.

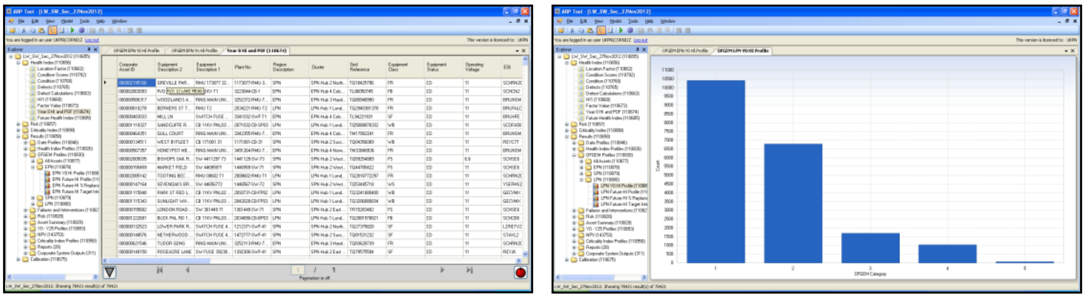


Figure 24: ARP Model

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.

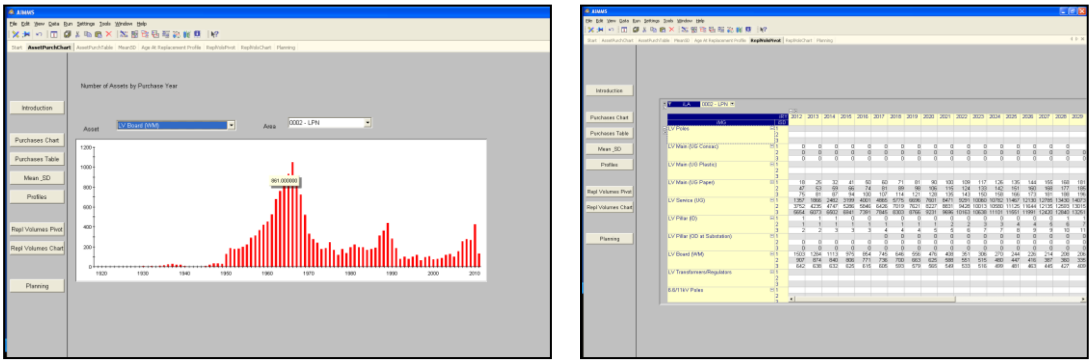


Figure 25: Statistical Model

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 LPN network of 70 years (with a standard deviation of 5 years). An average asset life of 70 years implies that most LV switchgear will be replaced between 55 and 85 years. The oldest 10% of LV switchgear is 58 years (rising to 68 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.

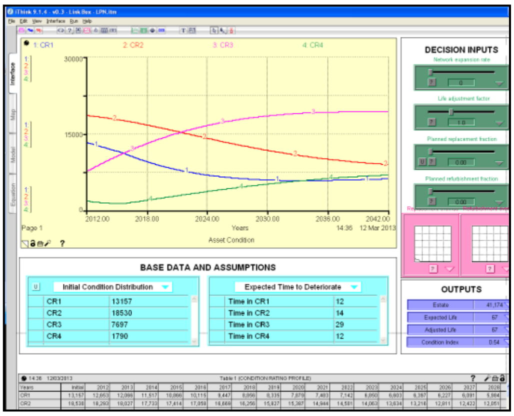


Figure 26: Stocks and Flows Model

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 had undergone rigorous testing to ensure it met 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	57%	89%	96%
LV switchgear	96%	*	*
Link Boxes	73%	*	76%

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 57% 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 96% 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 and LV switchgear is shown in Figure 27:

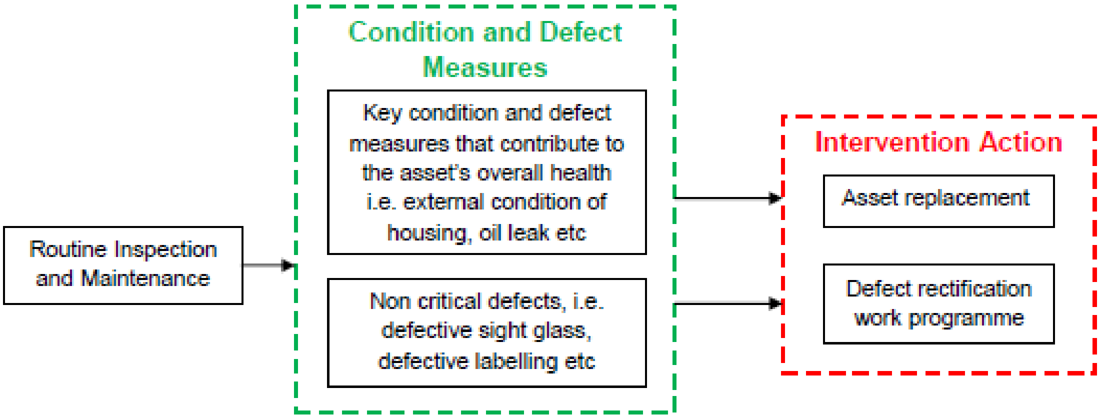


Figure 27: Intervention Decision Flow Chart

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 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 28, 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.

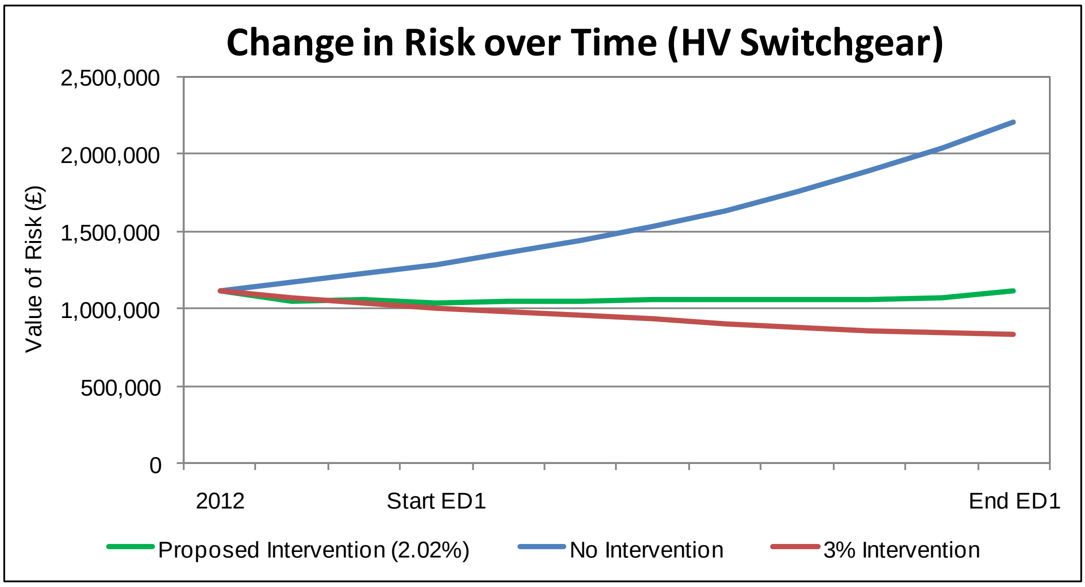


Figure 28: Change in Risk over Time (Source: 25_07_2012 ARP Model)

6.2 LV Remote Control and Automation

The IFI team within UK Power Networks 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 28) and RTUs (Remote Terminal Units) that provides remote control of the LV devices.


Figure 29: Before and After: 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 30 and allows paralleled networks to be sectionalised during a fault. Furthermore, local control of switches (which is fitted under the link box lid) will be provided by a control panel.


Figure 30: Before and After: Switches Installed to a LB in place of Standard Links

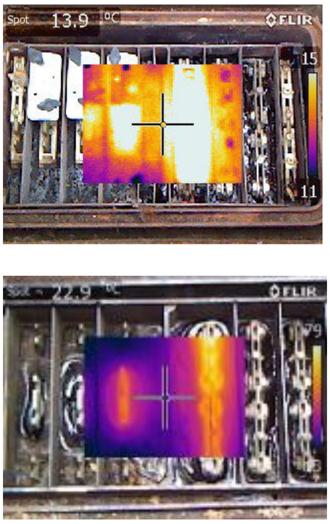
This will enable UK Power Networks to improve network performance and gain higher granular visibility to improve our understanding and management of the LV network.

6.3 Link Boxes

UK Power Networks has experienced serious events relating to gas and electrical link box explosions, some with serious consequences. In order to minimize these health and safety risks, we are exploring a range of innovative mitigation options including hinged, vented and sprung covers, as shown in Figure 31.

Figure 31: 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 32: 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 5s the same at the start and end of the period (as shown in section 1.3).

7.2 Intervention Techniques

7.2.1 Intervention Technique for HV Switchgear

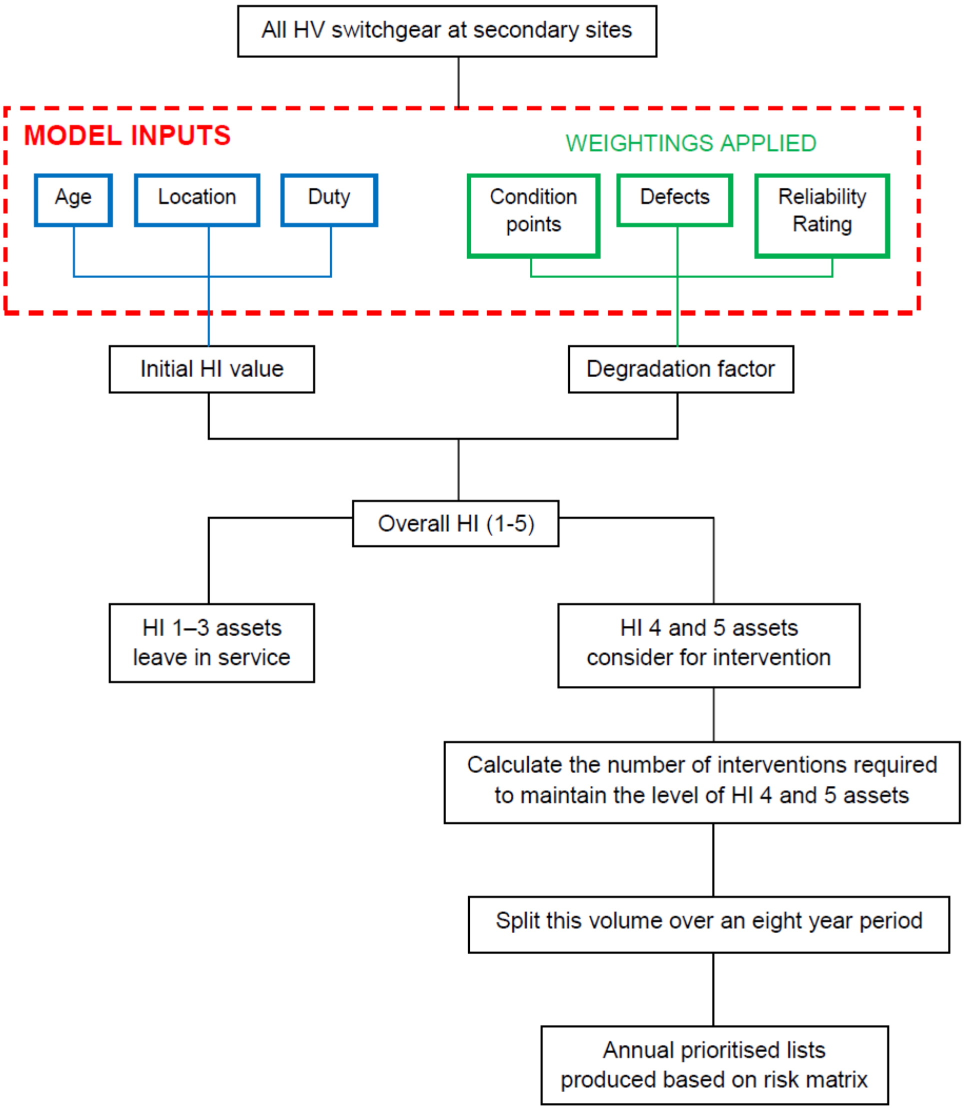


Figure 33: HV Switchgear Intervention Flowchart

It is important to note that the methodology above does not take into account 'consequential' changes. The LPN region will be replacing small numbers of switch/switch fuse combinations with RMUs, 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 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

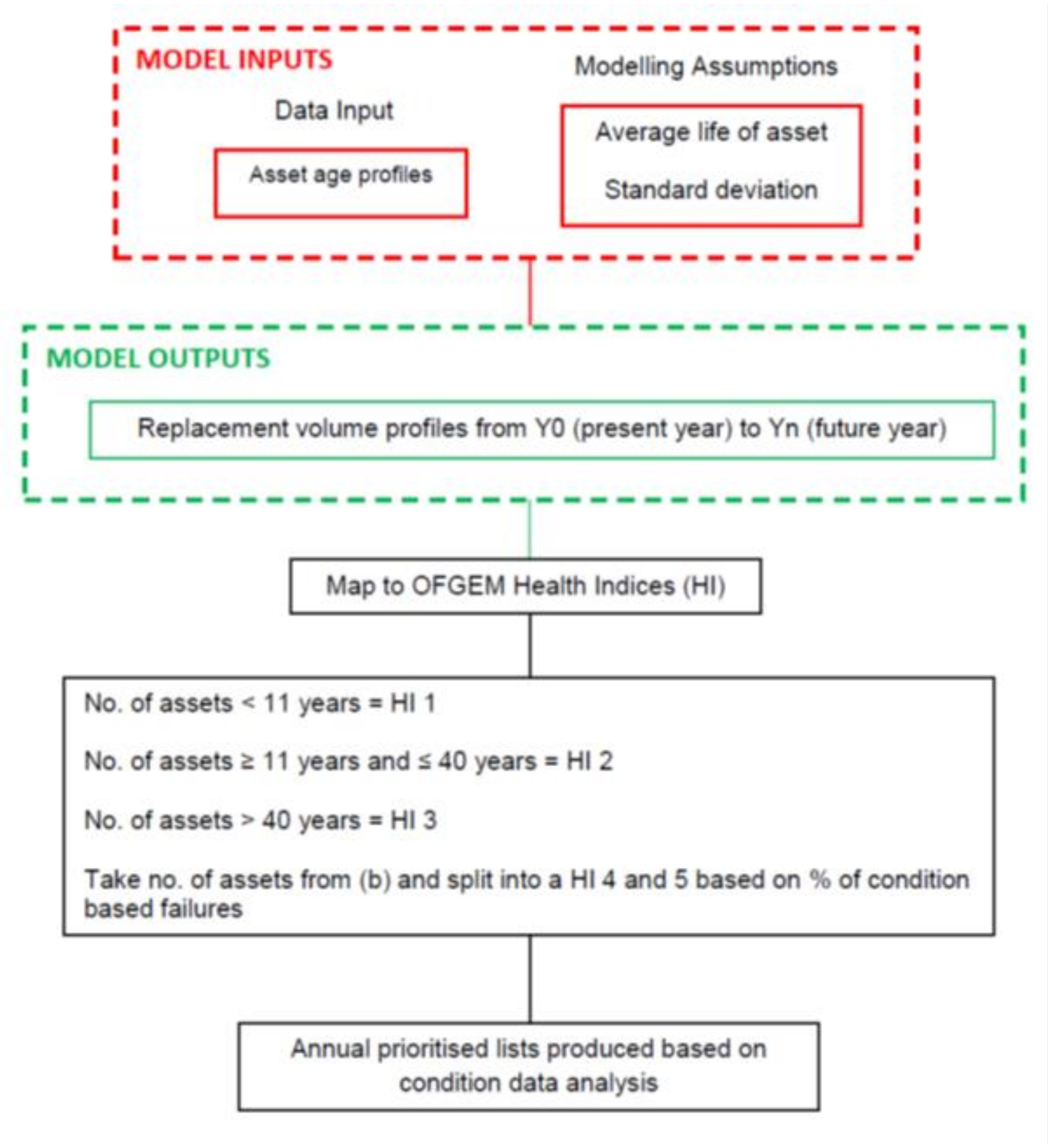


Figure 34: LV Switchgear Intervention Flowchart

7.2.3 Intervention Technique for Link Boxes

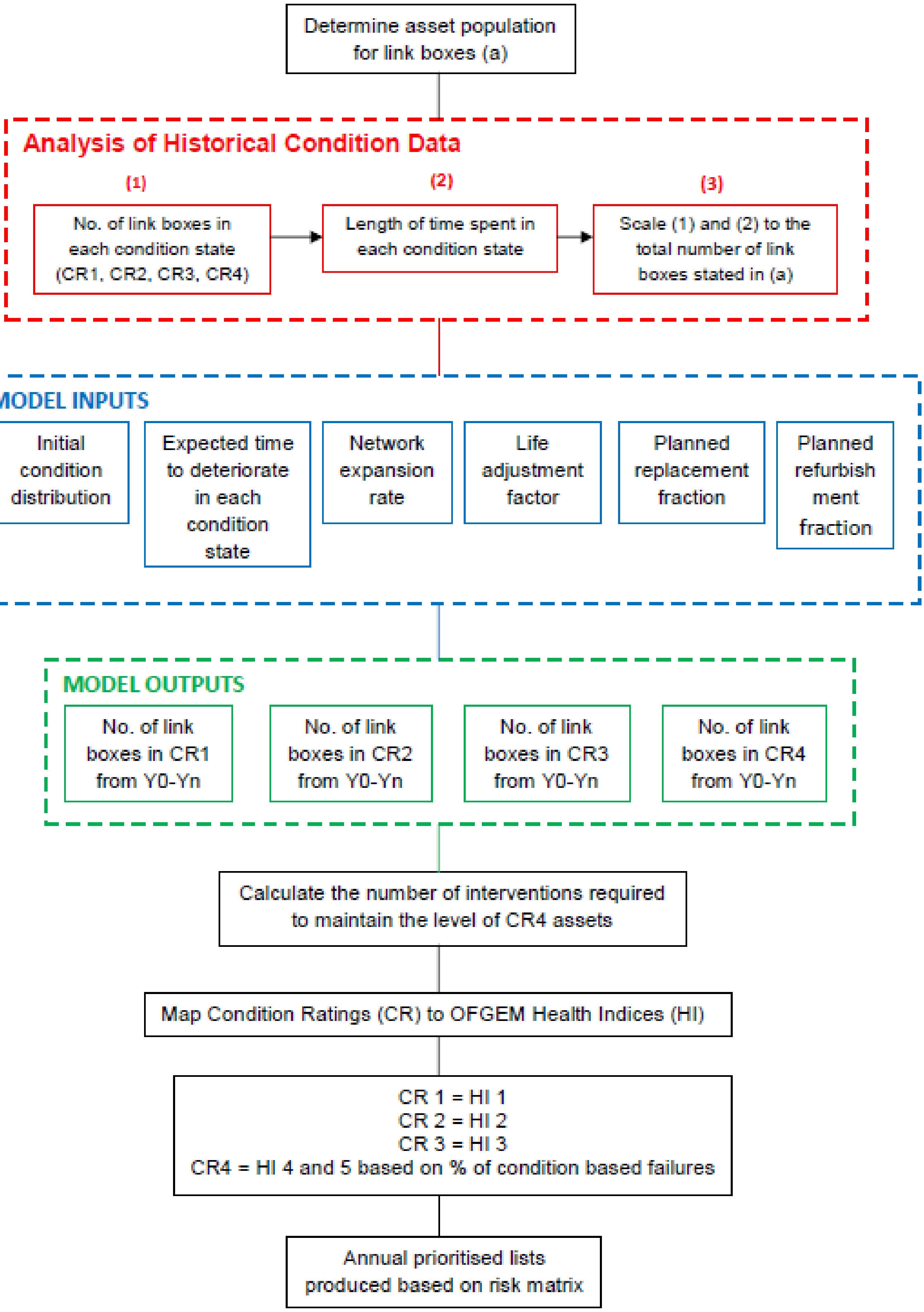


Figure 35: Link Box Intervention Flowchart

7.3 Additional Considerations

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 Charts

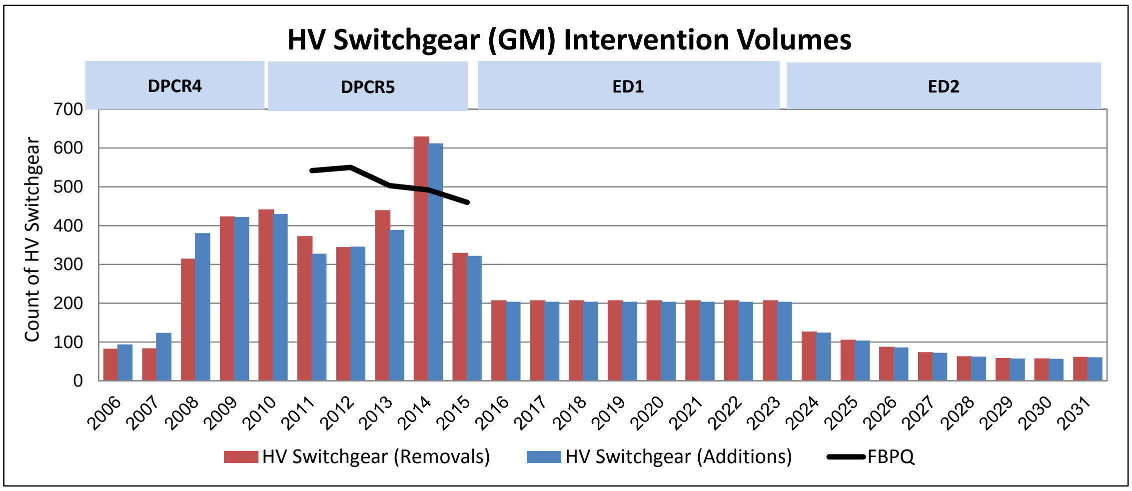


Figure 36: HV Switchgear Intervention Volumes

[Note: removals and additions are not always consistent due to a small number of sites where a mixture of switches are decommissioned and replaced with one RMU].

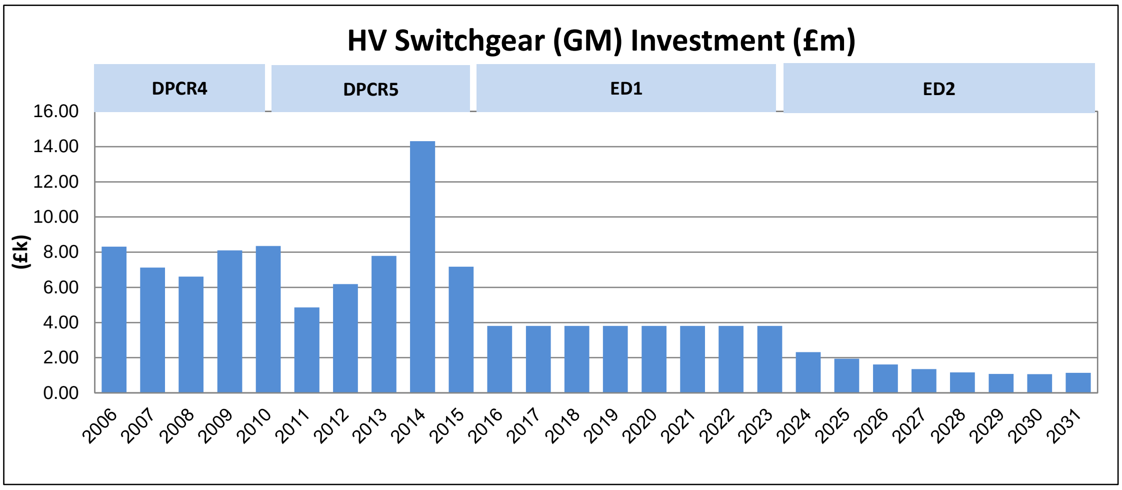


Figure 37: HV Switchgear Investment

7.4.2 HV Switchgear 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;
- 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. SCO FA/ID) will be replaced with a RMU (75%) or an extensible RMU and a circuit breaker (25%).

Referring to Figure 36, we fell short of our HV distribution switchgear FBPQ target in year two of DPCR5, however we are currently on target for achieving these replacements by the end of March 2015. Resource issues in year 2 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.

Furthermore, we are reducing our level of replacements throughout ED1 compared with DPCR4-5. The strategic view to maintain network risk over the ED1 period means approximately 208 assets per year will need replacing over the eight year period, and this is reflected in the age profile (Figure 5) which shows a young LPN network with an average age of 18 years. The small peak of defective oil-filled assets commissioned in the 1960s (with an average age of 52 years) are the interventions proposed during ED1. The volumes align to the fault rate which, for HV switchgear due to age or wear (shown in Figure 22 of section 3) is steady-state over the five year period, confirming an increase is not necessary.

As shown in Figure 37, the expenditure levels for HV switchgear reflect the volumes over DPCR5 and ED1. The ED2 figures have been created using the age-based statistical asset replacement model (SARM1) and the reduction in volumes highlights the fact that by the start of this period (2023), over 90% of our LPN HV distribution network will be newer SF_6 switchgear.

7.4.3 LV Switchgear Charts

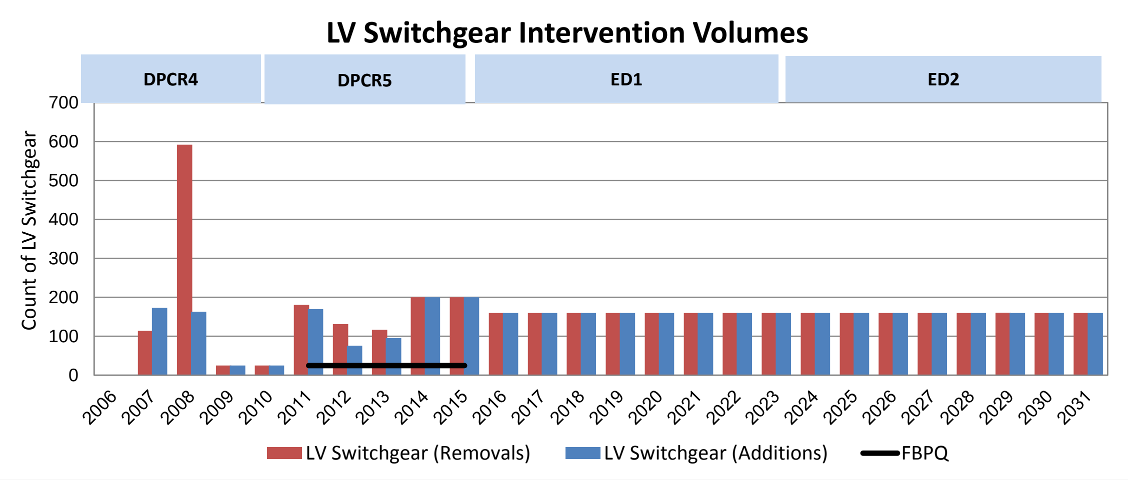


Figure 38: LV Switchgear Intervention Volumes

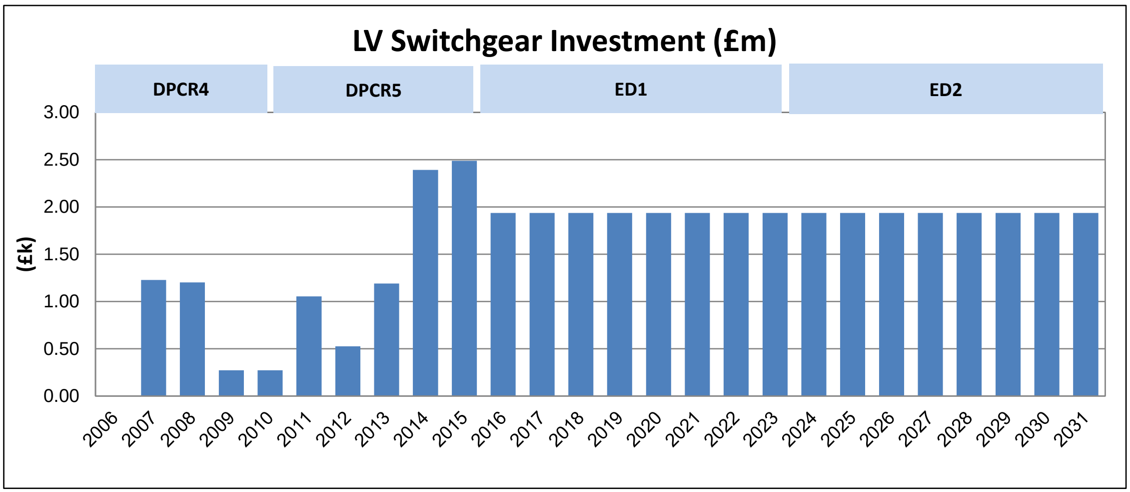


Figure 39: LV Switchgear Investment

7.4.4 LV Switchgear Commentary

Figure 38 shows an increase in DPCR5 achievements and projections compared with the FBPQ target. This is due to a risk review combined with poor condition assets reported for this asset class. There are large removal/addition discrepancies in 2008 and 2011 due to reporting issues. A review of reporting processes has already improved reporting this year and is set to continue over the forthcoming years.

As shown in Figure 23 of section 3 condition-based faults (due to age and wear) are increasing and a strategic decision has been made by UK Power Networks to remove all Westminster and English Electric type 'CJ' LV boards over ED1 on safety and operational grounds. The strategic view to maintain network risk over the ED1 period means approximately 160 assets per year will need replacing over the eight year period.

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.

7.4.5 Link Box Charts

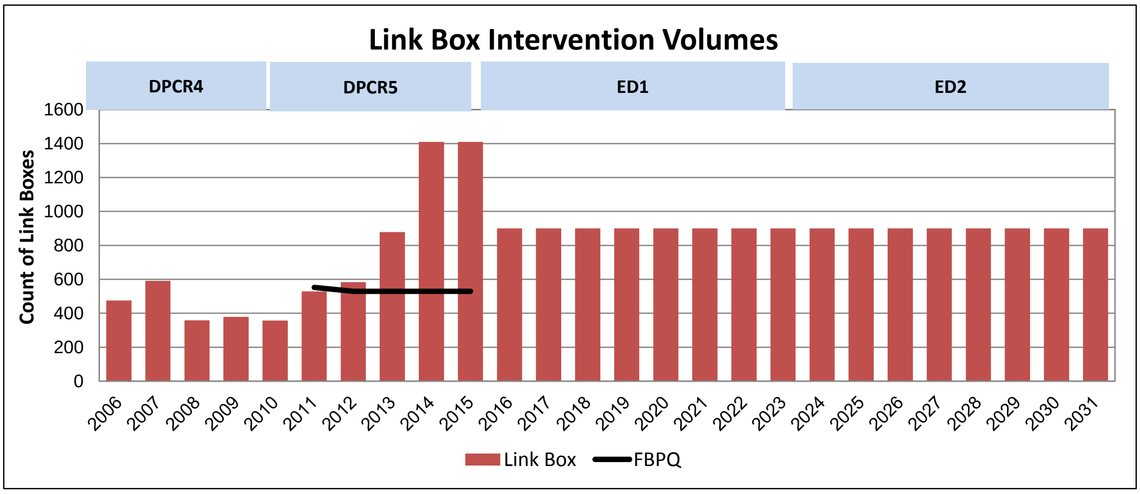


Figure 40: Link Box Intervention Volumes

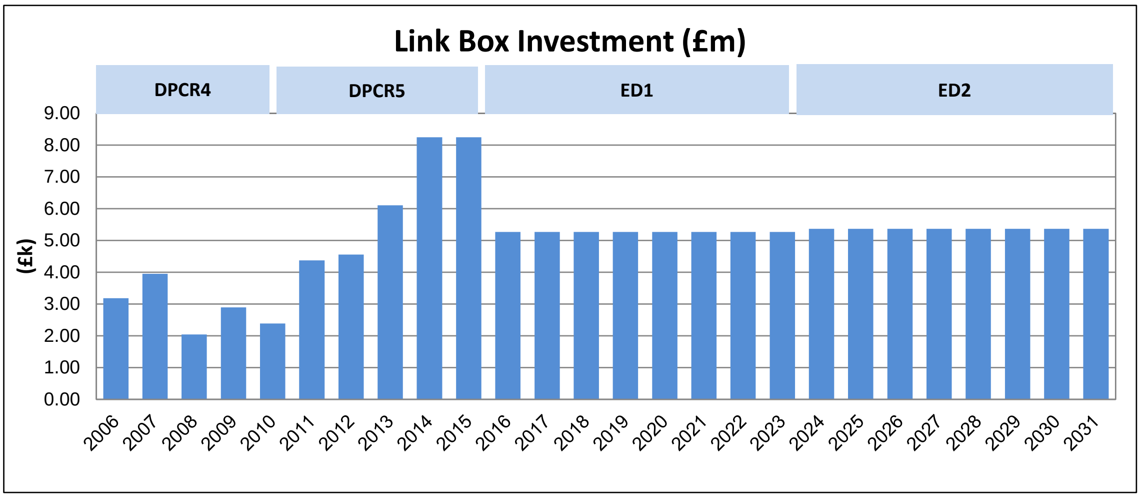


Figure 41: Link Box Investment

7.4.6 Link Box Commentary

As shown in Figure 40, 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 maintain a high number of replacements during ED1. To maximise public safety, intervention volumes are set at 900 link boxes per year over ED1. This will target all of the 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 878 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 41) reflect the increase in volumes over DPCR5 and ED1. 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.

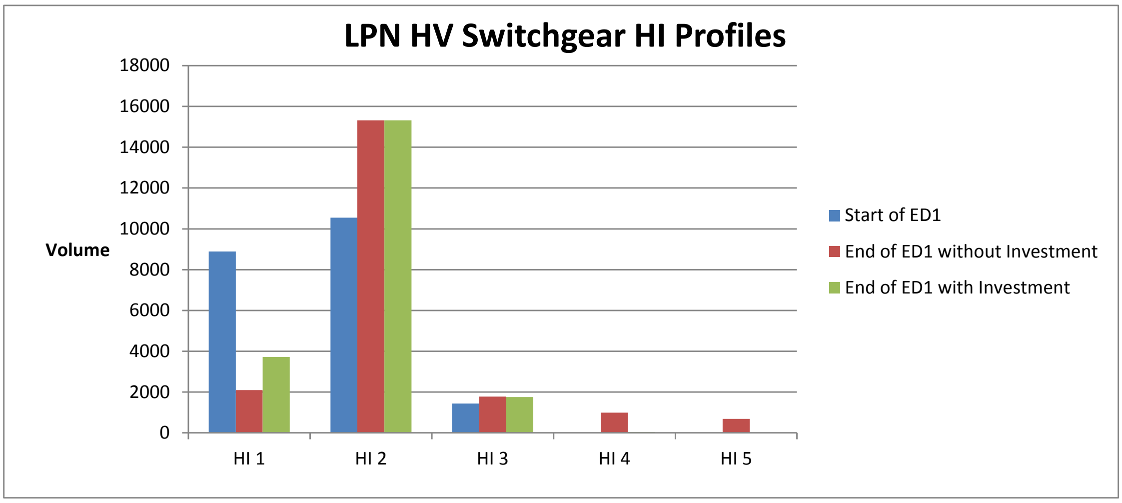


Figure 42: HV Switchgear HI (Source: 25_07_2012 ARP Model)

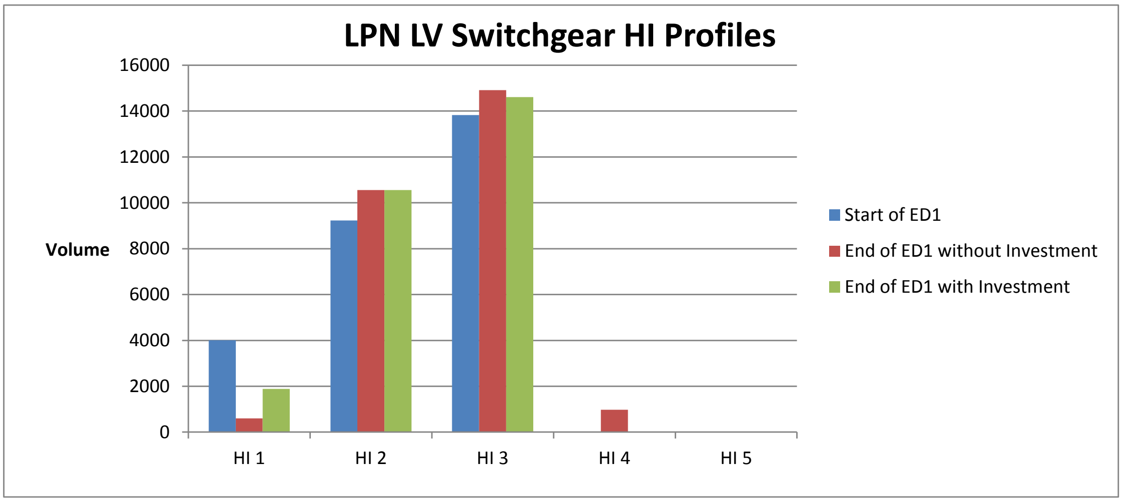


Figure 43: LV Switchgear HI Profiles (Source: SARM v0.3 Statistical Model)

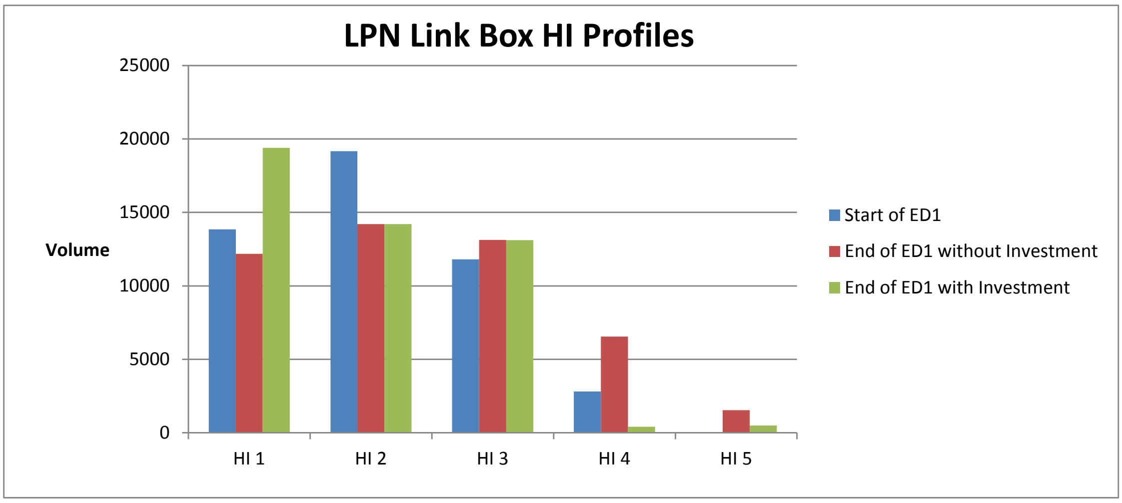


Figure 44: Link Box HI Profiles (Source: Stocks & Flows Model V1.1)

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

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	40.5	51.4	5.0	3.2	0.0
-2	42.8	49.6	7.0	0.6	0.0
-1	44.1	48.4	7.5	0.0	0.0
0	45.1	47.6	7.3	0.0	0.0
1	47.2	45.8	6.9	0.0	0.0
2	50.6	43.8	5.7	0.0	0.0
4	53.2	43.2	3.6	0.0	0.0

Average asset life change	**2023** percentage HI profile				
	HI1	HI2	HI3	HI4	HI5
-4	17.5	74.3	6.3	1.6	0.4
-2	18.3	74.6	6.0	1.1	0.0
-1	21.3	72.7	5.4	0.6	0.0
0	21.8	73.3	4.9	0.0	0.0
1	22.0	74.2	3.9	0.0	0.0
2	24.9	71.7	3.5	0.0	0.0
4	25.6	71.9	2.6	0.0	0.0

Table 11: Average Asset Life Percentage Movements

Figure 44 represents summed HI 4 and 5 assets as a percentage of the population showing the change at each average asset life iteration comparing 2015 and 2023.

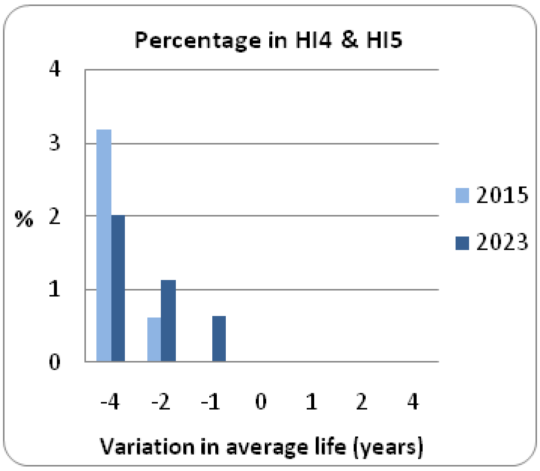


Figure 45: Percentage in HI 4 & 5 (HV Switchgear)

The results confirm that the ED1 replacement plan for LPN 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 asset life change of years ±1, 2 and 4 as shown in Figures 46 and 47 (note base case life = 70 years).

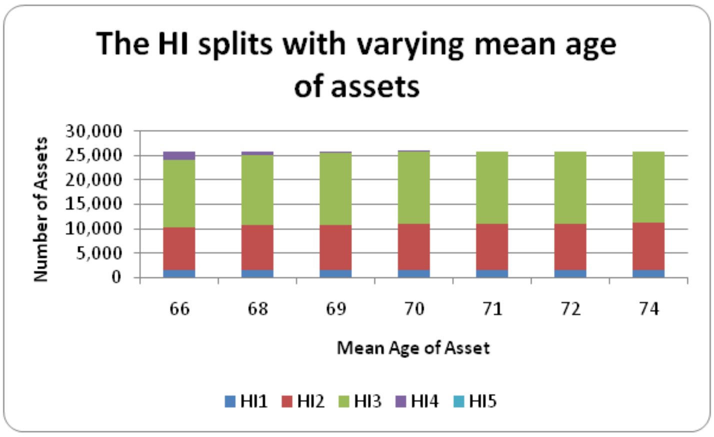


Figure 46: HI Splits for Various Average Asset Lives, with Investment

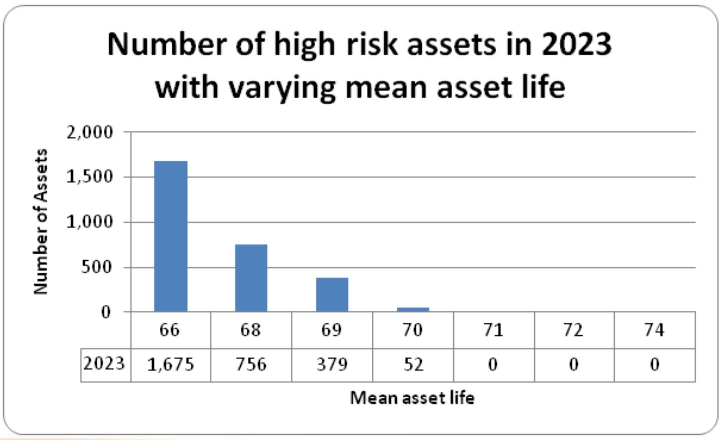


Figure 47: High Risk Asset Volumes for Various Average Asset Lives, with Investment

It is concluded that a 4 year reduction in the mean age of LV Switchgear could cause the number of high risk assets to rise to 6.5% 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
48	1.2	2081	-908	-1810	-201%
44	1.1	2410	-79	-981	-109%
40	1	2811	902	0	0
36	0.9	3312	2075	+1173	130%
32	0.8	3950	3491	+2589	287%

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

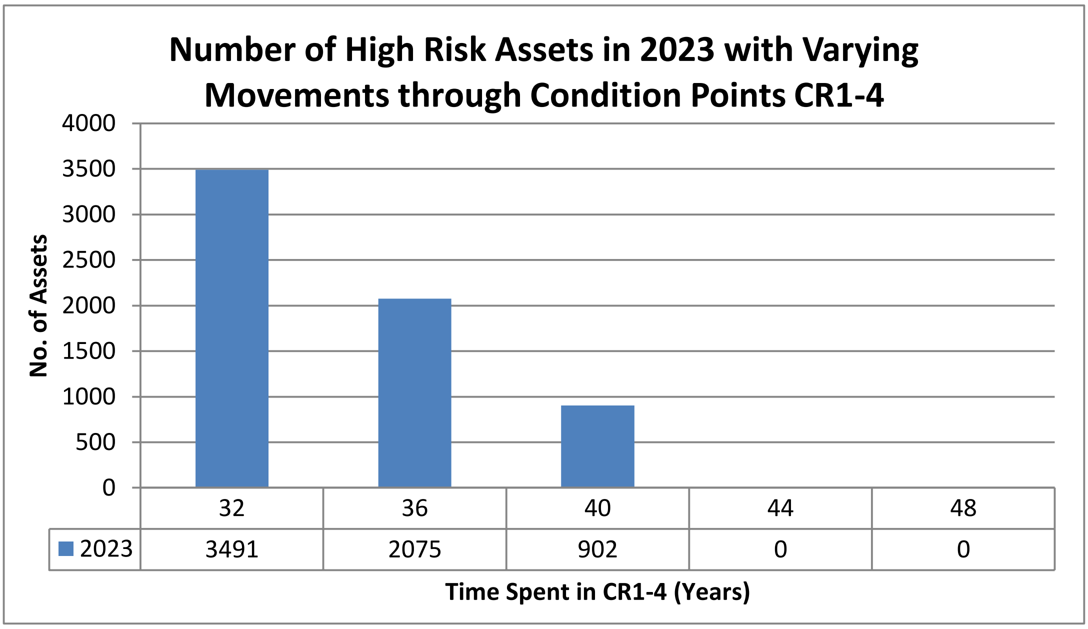


Figure 48: *High Risk Volumes for Various Movements through CR1-4, with Investment*

The closest correlation to the number of failures in the last year is when the total time spent in CR1-4 is 40 (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. The health and criticality matrices with investment highlight the proportion of HI 4 and 5 assets set to be removed from the network 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	Low	No. Assets	0	0	0	0	0	**0**
	Average	No. Assets	3425	3002	0	0	0	**6,427**
	High	No. Assets	4586	6177	923	0	0	**11,686**
	Very high	No. Assets	874	1370	518	0	0	**2,762**
LV Switchgear	Low	No. Assets	0	0	0	0	0	**0**
	Average	No. Assets	2824	6847	9748	0	0	**19,419**
	High	No. Assets	1166	2349	4025	0	0	**7,540**
	Very high	No. Assets	14	28	49	0	0	**91**
Link Box	Low	No. LBs	4730	6407	4031	960	0	**16,128**
	Average	No. LBs	3892	5671	3316	790	0	**13,669**
	High	No. LBs	5230	7083	4457	1061	0	**17,831**
	Very high	No. LBs	1	2	1	0	0	**4**

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	Low	No. Assets	0	0	0	0	0	**0**
	Average	No. Assets	648	5767	24	0	0	**6,439**
	High	No. Assets	2197	8089	1355	13	0	**11,654**
	Very high	No. Assets	879	1466	373	25	0	**2,743**
LV Switchgear	Low	No. Assets	0	0	0	0	0	**0**
	Average	No. Assets	1342	7657	10420	0	0	**19,419**
	High	No. Assets	532	2868	4140	0	0	**7,540**
	Very high	No. Assets	6	35	50	0	0	**91**
Link Box	Low	No. LBs	6943	4714	4471	0	0	**16,128**
	Average	No. LBs	5517	4279	3690	0	183	**13,669**
	High	No. LBs	6930	5212	4958	418	313	**17,831**
	Very high	No. LBs	1	1	1	1	0	**4**

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 slightly 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

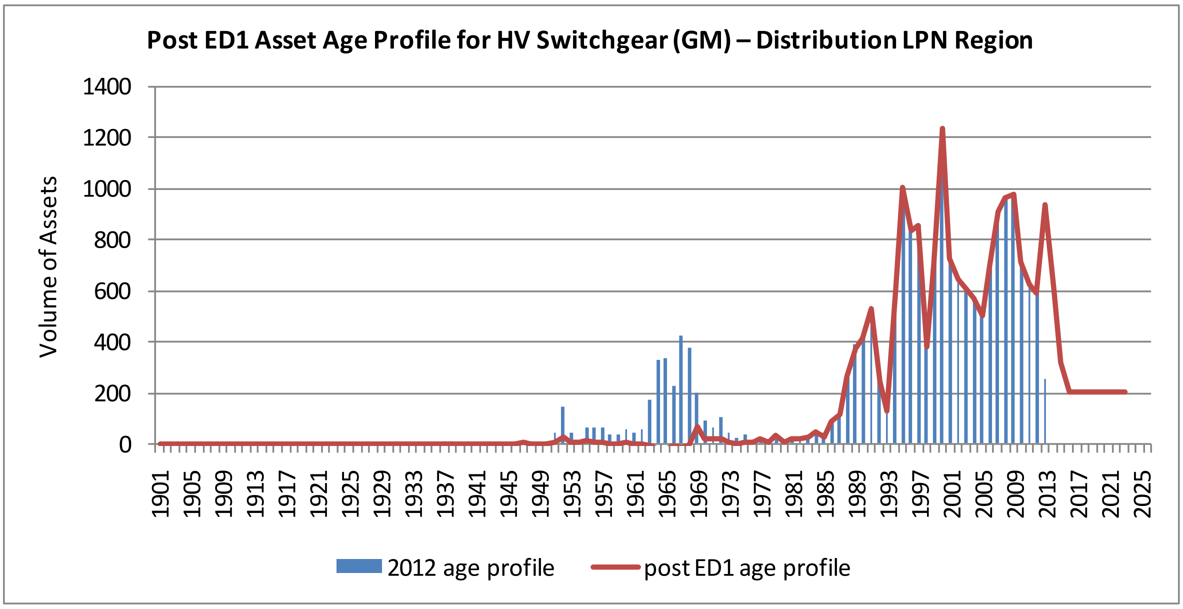


Figure 49: Post ED1 Asset Age Profile (Source: DecisionLab Ltd Analysis 2013)

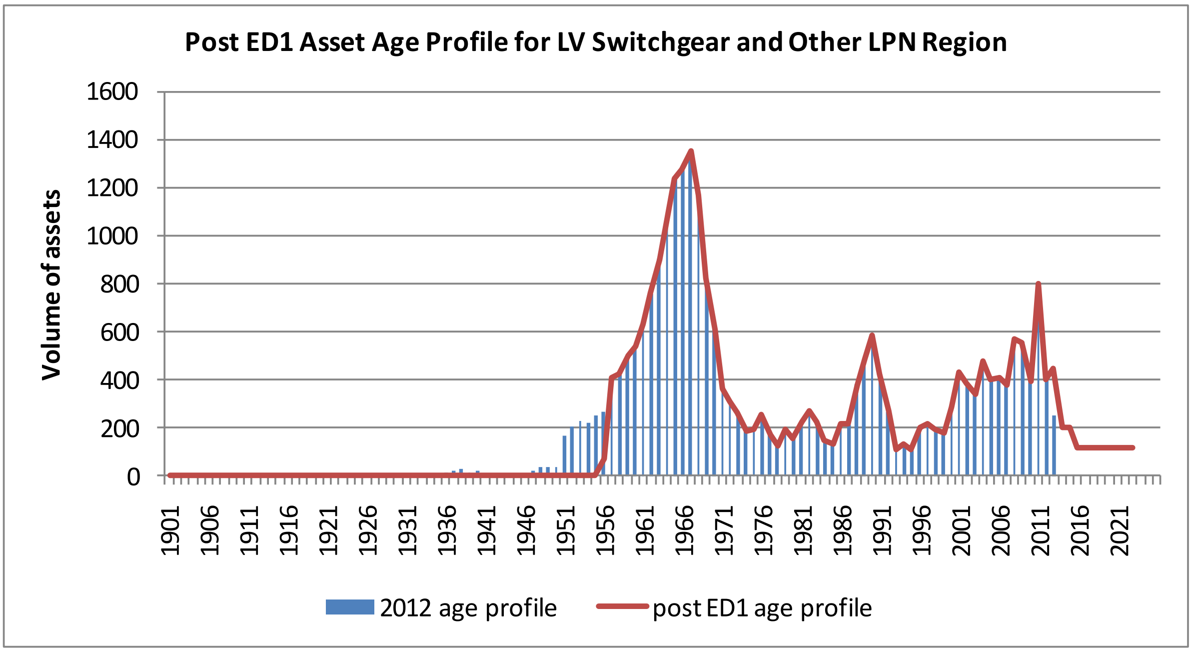


Figure 50: Post ED1 Asset Age Profile (Source: DecisionLab Ltd Analysis 2013)

[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	Low	No. Assets	0	0	0	0	0	**0**
	Average	No. Assets	3425	3002	0	0	0	**6,427**
	High	No. Assets	4586	6177	923	0	0	**11,686**
	Very high	No. Assets	874	1370	518	0	0	**2,762**
LV Switchgear	Low	No. Assets	0	0	0	0	0	**0**
	Average	No. Assets	2824	6847	9748	0	0	**19,419**
	High	No. Assets	1166	2349	4025	0	0	**7,540**
	Very high	No. Assets	14	28	49	0	0	**91**
Link Box	Low	No. LBs	4730	6407	4031	960	0	**16,128**
	Average	No. LBs	3892	5671	3316	790	0	**13,669**
	High	No. LBs	5230	7083	4457	1061	0	**17,831**
	Very high	No. LBs	1	2	1	0	0	**4**

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	Low	No. Assets	0	0	0	0	0	**0**
	Average	No. Assets	648	5767	24	0	0	**6,439**
	High	No. Assets	2197	8089	1355	13	0	**11,654**
	Very high	No. Assets	879	1466	373	25	0	**2,743**
LV Switchgear	Low	No. Assets	0	0	0	0	0	**0**
	Average	No. Assets	1342	7657	10420	0	0	**19,419**
	High	No. Assets	532	2868	4140	0	0	**7,540**
	Very high	No. Assets	6	35	50	0	0	**91**
Link Box	Low	No. LBs	6943	4714	4471	0	0	**16,128**
	Average	No. LBs	5517	4279	3690	0	183	**13,669**
	High	No. LBs	6930	5212	4958	418	313	**17,831**
	Very high	No. LBs	1	1	1	1	0	**4**

Table 16: Asset Health and Criticality 2023

Appendix 3 Fault Data

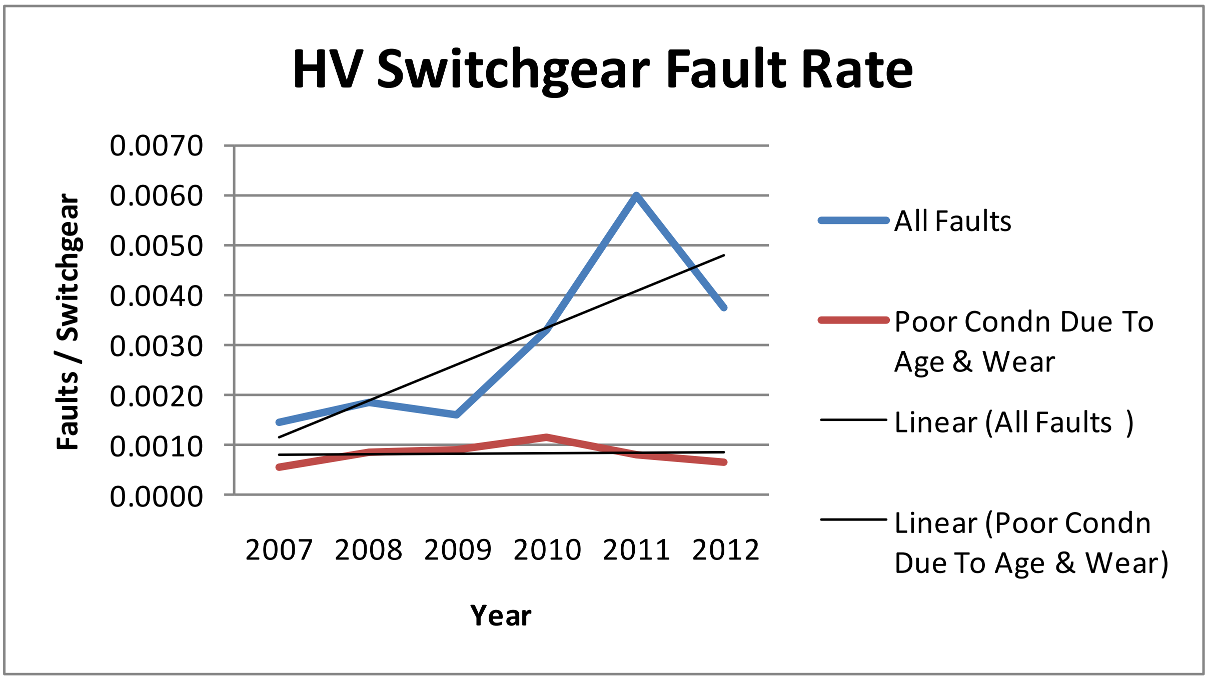


Figure 51: HV Switchgear Fault Rate (Source: UKPNs Fault Analysis Cube 15_03_2013)

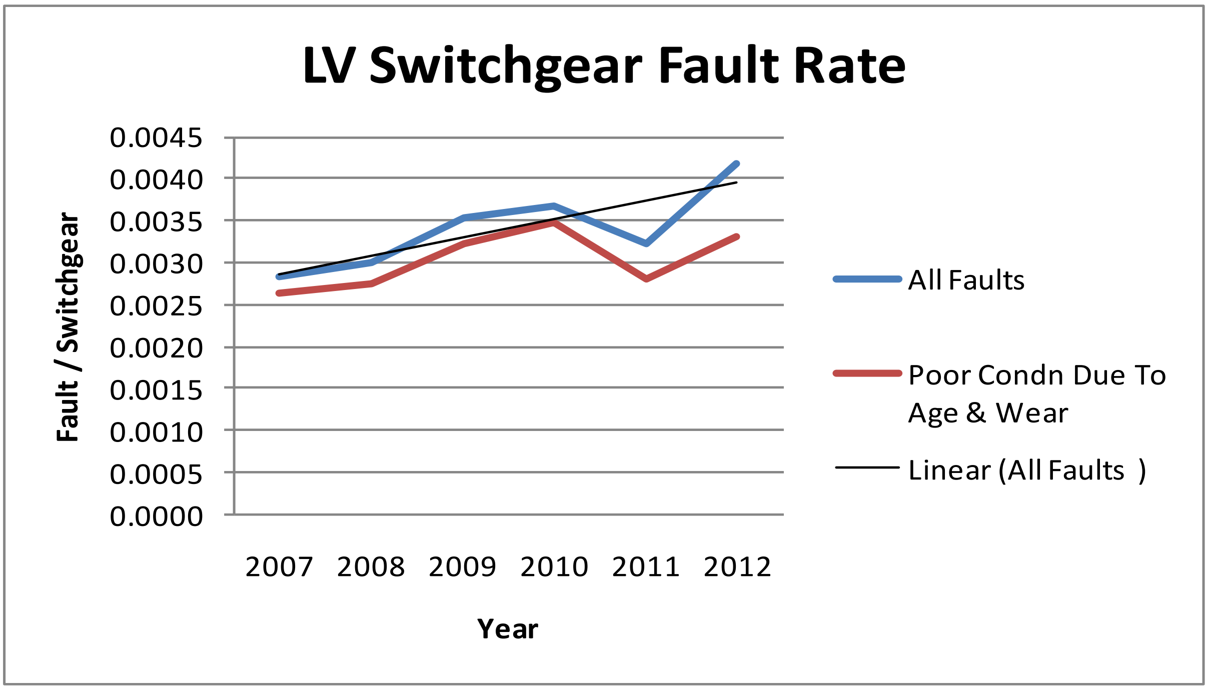


Figure 52: LV Switchgear Fault Rate (Source: UKPNs Fault Analysis Cube 15_03_2013)

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

Not relevant for distribution assets: Intentionally left blank

Appendix 5 NLRE Expenditure Plan

Volumes

		Sub-Category	NAMP line(s)	NAMP Description	2015/ 2016	2016/ 2017	2017/ 2018	2018/ 2019	2019/ 2020	2020/ 2021	2021/ 2022	2022/ 2023
LPN	Switchgear	HV Switchgear	1.49.30/ 2.50.33	Install HV CB at Secondary Sites	12	12	12	12	12	12	12	12
			1.49.32/ 2.50.35	Install HV Switch at Secondary Sites	10	10	10	10	10	10	10	10
			1.49.51/ 2.50.21	Install HV RMU at Secondary Sites	182	182	182	182	182	182	182	182
		LV Switchgear	1.44.08	Replace LV Boards	98	98	98	98	98	98	98	98
			1.44.12	Replace ACB	62	62	62	62	62	62	62	62
		Link Boxes	1.44.04/ 2.50.17	Replace Link Boxes	900	900	900	900	900	900	900	900
			1.44.07	Replace Covers & Frames	570	570	570	570	570	570	570	540
			1.44.11	Replace LB Covers & Frames - Roadway	69	69	69	69	69	69	69	66
		TOTAL VOLUME			**1,903**	**1,903**	**1,903**	**1,903**	**1,903**	**1,903**	**1,903**	**1,870**

Table 17: Summary Table of ED1 Volumes (Source: 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
LPN	Switchgear	HV Switchgear	1.49.30/ 2.50.33	Install HV CB at Secondary Sites	146	146	146	146	146	146	146	146
			1.49.32/ 2.50.35	Install HV Switch at Secondary Sites	82	82	82	82	82	82	82	82
			1.49.51/ 2.50.21	Install HV RMU at Secondary Sites	3,579	3,579	3,579	3,579	3,579	3,579	3,579	3,579
		LV Switchgear	1.44.08	Replace LV Boards	1,511	1,511	1,511	1,511	1,511	1,511	1,511	1,511
			1.44.12	Replace ACB	418	418	418	418	418	418	418	418
		Link Boxes	1.44.04/ 2.50.17	Replace Link Boxes	5,365	5,365	5,365	5,365	5,365	5,365	5,365	5,365
			1.44.07	Replace Covers & Frames	60	60	60	60	60	60	60	60
			1.44.11	Replace LB Covers & Frames - Roadway	89	89	89	89	89	89	89	85
		TOTAL (£k)			**11,250**	**11,250**	**11,250**	**11,250**	**11,250**	**11,250**	**11,250**	**11,246**

Table 18: Summary Table of ED1 Investment (£k) (Source: 19_02_2014 NAMP Table JLI)

Appendix 6 Sensitivity Analysis

Sensitivity Analysis for LPN 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 LPN 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 35 to 55 years. In 2012 about 46% had a current average asset life of 40 years, about 39% of 45 years and about 10% of 50 years. This study covered the full population of LPN HV Secondary Switchgear.

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

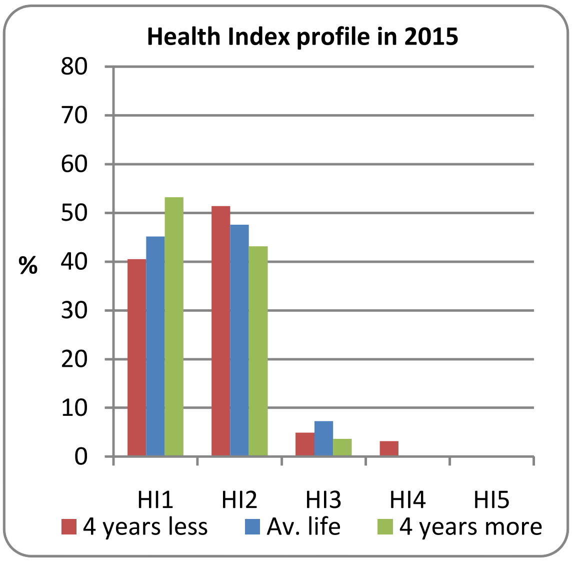
All results are shown below as the percentages of the population.

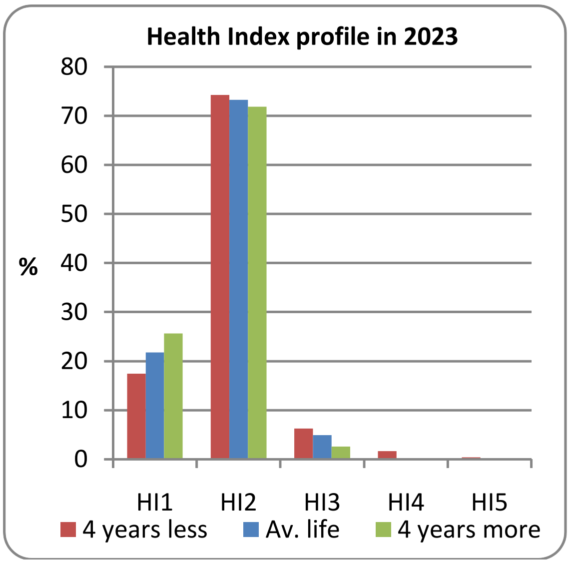
Average asset life change	2015 percentage HI profile				
	HI1	HI2	HI3	HI4	HI5
-4	40.5	51.4	5.0	3.2	0.0
-2	42.8	49.6	7.0	0.6	0.0
-1	44.1	48.4	7.5	0.0	0.0
0	45.1	47.6	7.3	0.0	0.0
1	47.2	45.8	6.9	0.0	0.0
2	50.6	43.8	5.7	0.0	0.0
4	53.2	43.2	3.6	0.0	0.0

Average asset life change	2023 percentage HI profile				
	HI1	HI2	HI3	HI4	HI5
-4	17.5	74.3	6.3	1.6	0.4
-2	18.3	74.6	6.0	1.1	0.0
-1	21.3	72.7	5.4	0.6	0.0
0	21.8	73.3	4.9	0.0	0.0
1	22.0	74.2	3.9	0.0	0.0
2	24.9	71.7	3.5	0.0	0.0
4	25.6	71.9	2.6	0.0	0.0

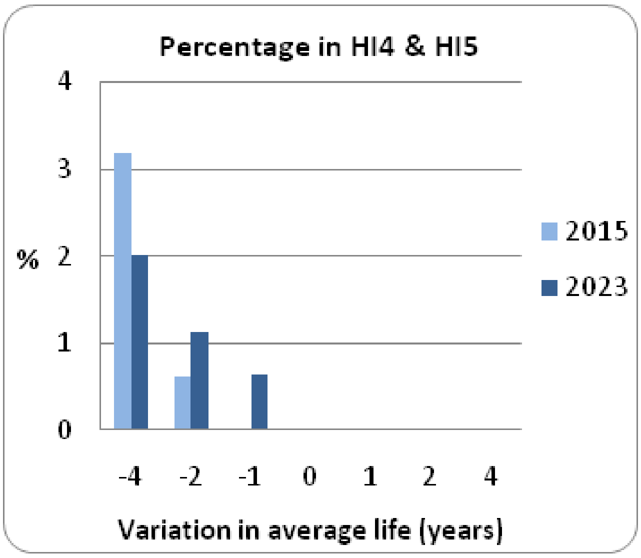
As the percentages above are rounded, the sum of a row may not be exactly 100%.

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





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



The results show

- The proportions of HI4 & HI5 assets in 2015 and 2023 will be affected by a decrease in average asset life.
- In 2015 if average asset life is 4 years shorter, the proportion of HI4 & HI5 will increase from 0.0% to 3.2%.
- In 2023 if average asset life is 4 years shorter, the proportion of HI4 & HI5 will increase from 0.0% to 2.0%.

Conclusion

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

Sensitivity Analysis for LPN 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.

LPN Base Case

- The ED1 plan is for the LPN region is 928 replacements (3.6% 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 0 to 1580 by 2023. By 2023, this would represent 6.1% of the population.
- With investment the number of high risk assets is 0.2%, which is close to the 2015 figure of 0%.
- 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 16.3% of the population will be high risk assets.
- Applying the ED1 plan to ED2 (928 replacements between 2024 and 2031) means that by 2031 the number of high risk assets is 12.8% of the population. This is an increase on today’s figure, and the expected figure by 2023. This suggests that higher investment will be needed in ED2 than ED1.
- By the end of the ED1 investment plan 49% of the population is between 50 and 70 years old. This is a very high proportion to be close to the expected average asset life and explains why the ED2 plan will not work when the ED1 plan is applied to the ED2 plan.

LPN 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 average asset life was one year lower than the base case, with the current ED1 investment plan the number of high risk assets rises from 52 to 379 (from 0.2% to 1.5% 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 52 to 756 (from 0.2% to 2.9% 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 52 to 1675 (from 0.2% to 6.5% of the LV Switchgear population).
- The number of high risk assets (Category HI4 and HI5) is sensitive to average asset life.

- If the average asset life is anywhere between 66 years and 70 years then the number of high risk assets can range between 52 and 1675 (0.2% to 6.5% of the entire population).

The Base Case (LPN Region)

<u>Model inputs</u>

Mean = 70 years

Standard Deviation = 5 years

Investment plan for ED1 = 928 asset replacements between 2015 and 2023 (1528 asset replacements when including 2012 to 2015).

Given the above input this is the age profile of the LV Switchgear

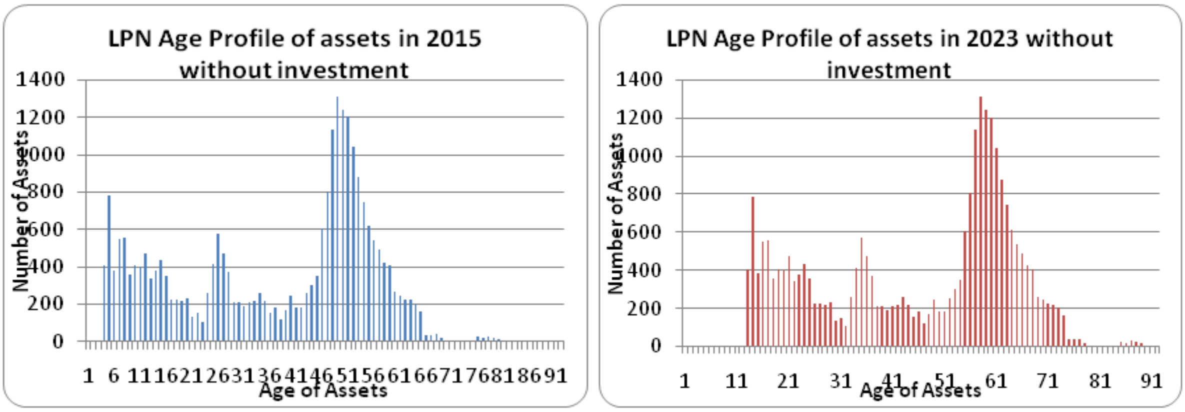


Figure 1. Comparison of age profiles for 2015 to 2023

The 51% 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.

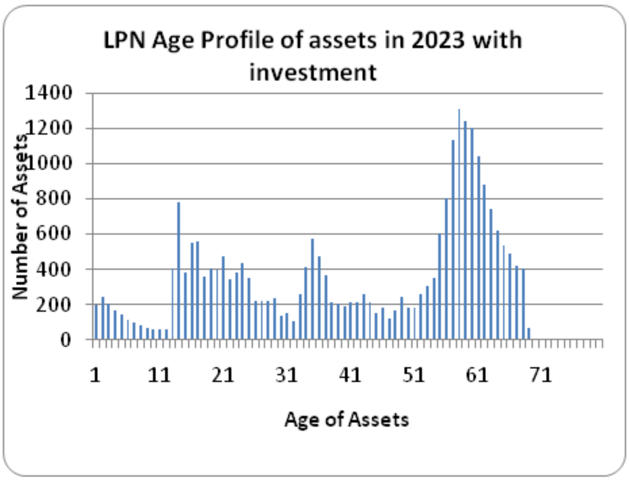


Figure 2. Age profile of the assets in 2023 with investment

Figure 2 shows that by the end of the ED1 investment plan that 49% of the population is between 50 and 70 years old. This is a very high proportion 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?

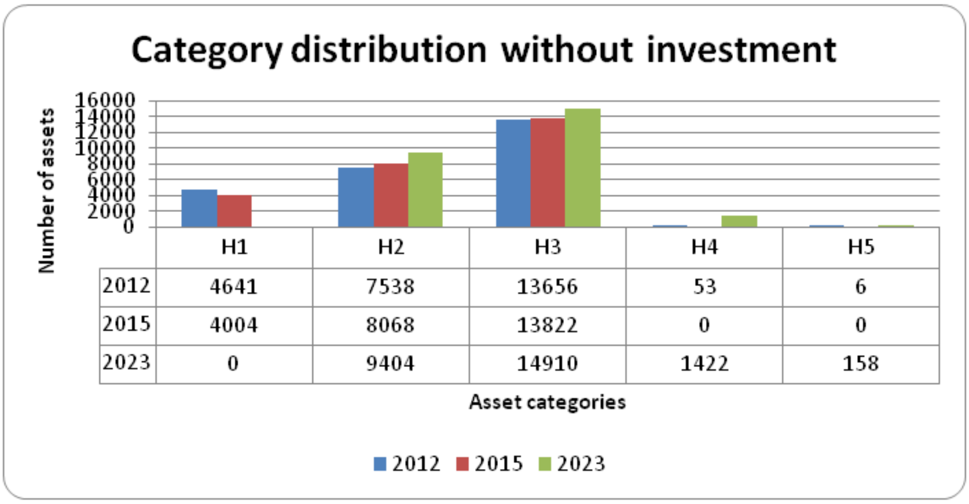


Figure 3. HI split without investment.

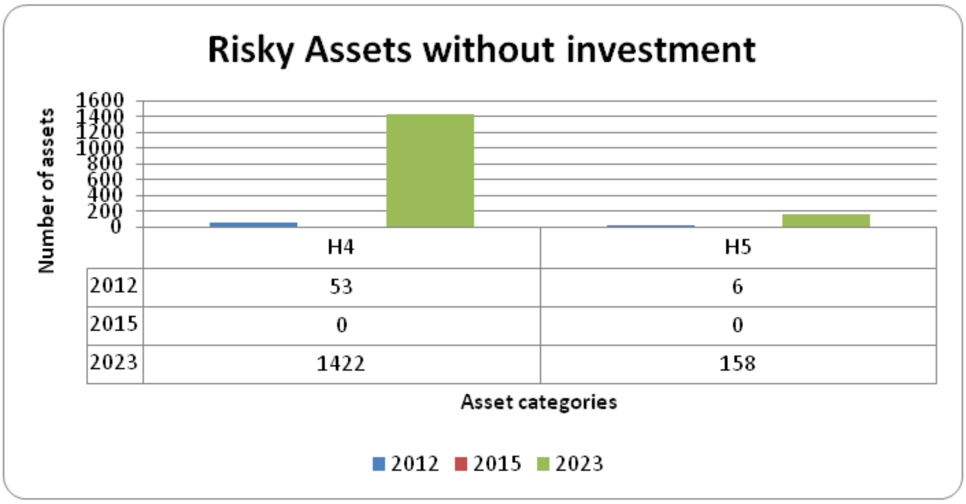


Figure 4. High Risk asset volumes without investment.

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 0 to 1580 (6.1% of the whole population). The risk has risen and investment is needed to reduce the number of high risk assets.

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

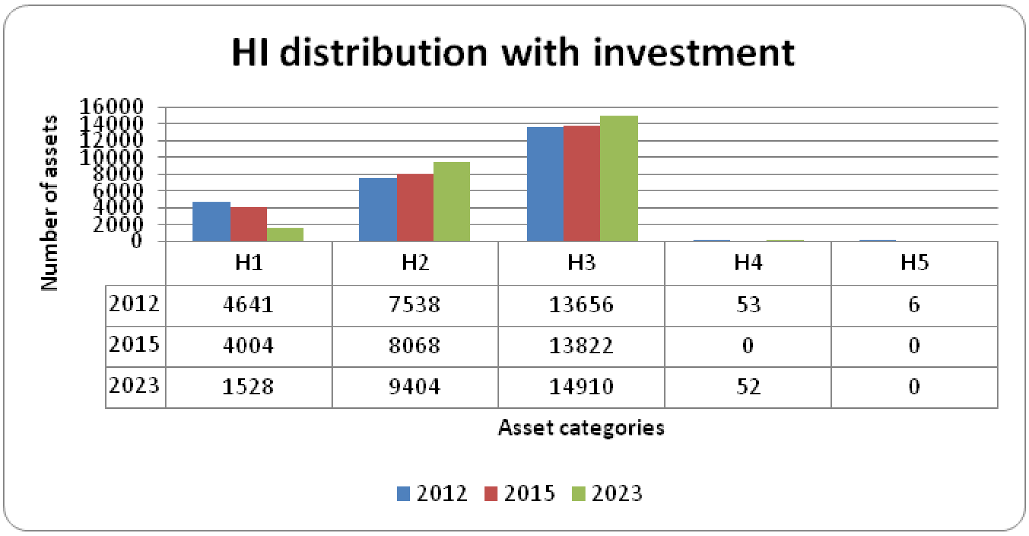


Figure 5. HI Split with Investment

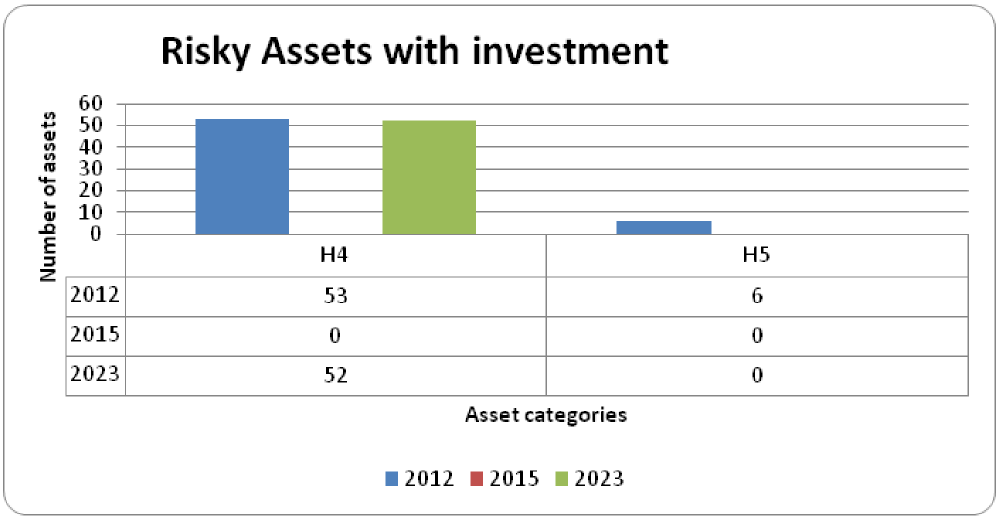


Figure 6. High Risk Asset Volumes with Investment.

By 2015, there are no 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 0 to 52 (0.2%). The investment program in ED1 of 116 replacements per year maintains the level of risk at a level close to 2015.

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)?

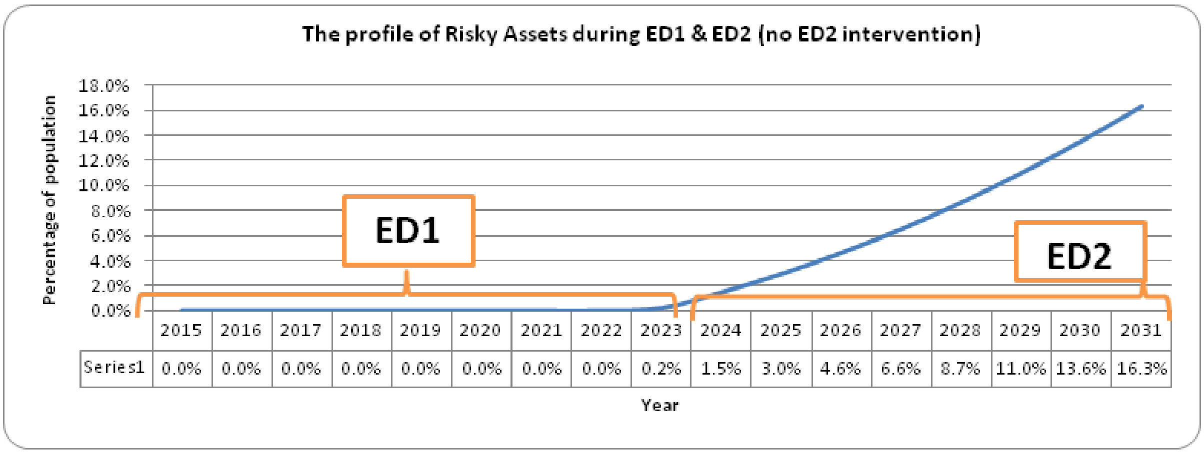


Figure 7. Proportion of high risk assets with investment in ED1.

In the plan to replace 2880 assets between the years 2012 and 2023 means that by 2023 0.2% 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 16.3% 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 (928 replacements between the years 2024 and 2031).

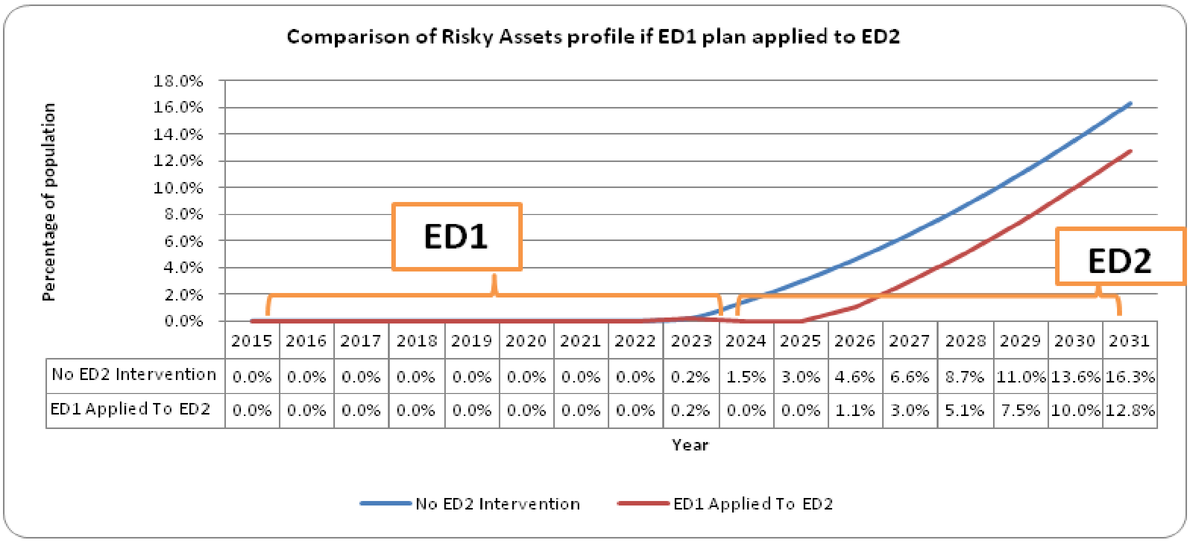


Figure 8. Proportion of high risk assets with investment in ED1 and ED2.

By applying the ED1 plan to ED2 (928 replacements between 2024 and 2031) means that by 2031 the number of high risk assets is 12.8% of the population. This is the result of an ageing population of assets.

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

Sensitivity Analysis

What happens to the investment plan in 2023 if the average asset life varies by +/- 1, 2, 3 and 4 years?

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

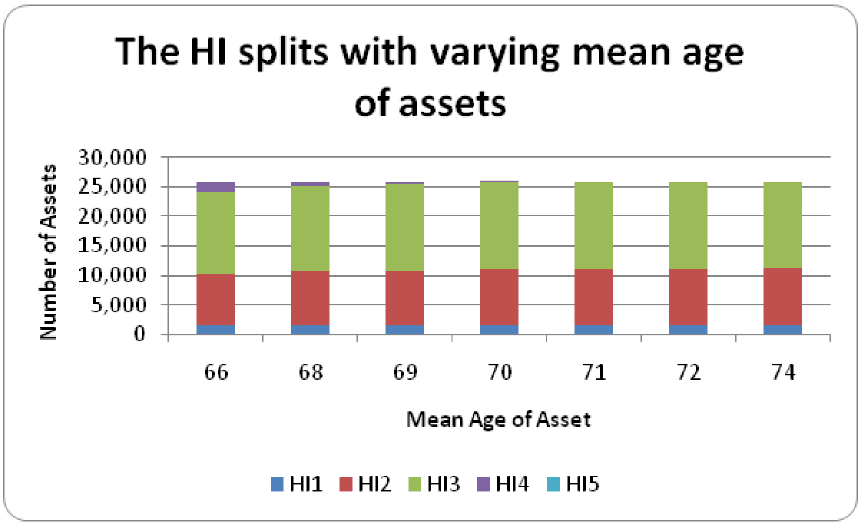


Figure 9. HI splits for various average asset lives with investment (base case life = 70 years)

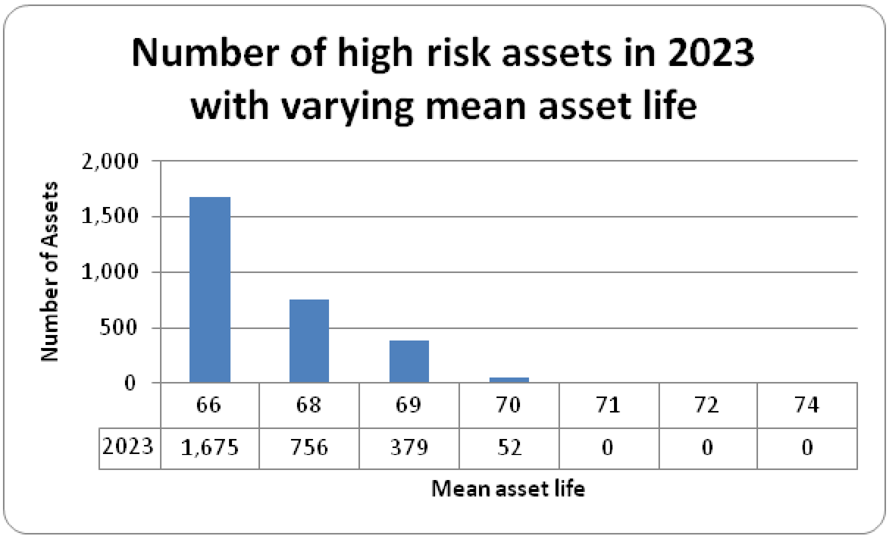


Figure 10. High risk asset volumes for various average asset lives, with investment (base case life = 70 years)

From figure 10 it can be seen that the number of high risk assets (Category H4 and H5) is sensitive to average asset life with the current ED1 investment plan. If the average asset life is anywhere between 66 years and 70 years then the number of high risk assets can range between 52 and 1675 (0.2% to 6.5% of the entire population).

If the average asset life were one year lower than the base case then the number of high risk assets rises from 52 to 379 (0.2% to 1.5% of the LV Switchgear population) with the current ED1 investment plan.

If the average asset life were two years lower than the base case then the number of high risk assets rises from 52 to 756 (0.2% to 2.9% of the LV Switchgear population) with the current investment plan.

If the average asset life were four years lower than the base case then the number of high risk assets rises from 52 to 1675 (0.2% to 6.5% of the LV Switchgear population) with the current investment plan.

These are important points to take notice of because a -4 reduction in the mean age of LV Switchgear could cause the number of high risk assets to rise to 6.5% 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																				
Asset Type	Outputs	Asset Stewardship Reports										Business Plan Data Tables										
	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	11	11	11	11	11	11	11	11	**88**	CV3	*34	11	11	11	11	11	11	11	11	**88**
	Install HV Switch at Secondary Sites	1.49.32	10	10	10	10	10	10	10	10	**80**	CV3	*37	10	10	10	10	10	10	10	10	**80**
	Install HV RMU at Secondary Sites	1.49.51	163	163	163	163	163	163	163	163	**1,304**	CV3	*38	163	163	163	163	163	163	163	163	**1,304**
	Install HV CB at Secondary Sites (Faults)	2.50.33	1	1	1	1	1	1	1	1	**8**	V4B	*34	1	1	1	1	1	1	1	1	**8**
	Install HV RMU at Secondary Sites (Faults)	2.50.21	19	19	19	19	19	19	19	19	**152**	V4B	*38	19	19	19	19	19	19	19	19	**152**
LV Switchgear	Replace LV ACB	1.44.12	62	62	62	62	62	62	62	62	**496**	CV3	143	62	62	62	62	62	62	62	62	**496**
	Replace LV Boards	1.44.08	98	98	98	98	98	98	98	98	**784**	CV3	146	98	98	98	98	98	98	98	98	**784**
Link Boxes	Replace Link Boxes	1.44.04	800	800	800	800	800	800	800	800	**6,400**	CV3	147	900	900	900	900	900	900	900	900	**7200**
	Replace Link Boxes (Fault)	2.50.17	100	100	100	100	100	100	100	100	**800**											
	Replace Covers & Frames	1.44.07	570	570	570	570	570	570	570	540	**4,530**	CV13	11	639	639	639	639	639	639	639	606	**5,079**
	Replace Covers & Frames (Roadway)	1.44.11	69	69	69	69	69	69	69	66	**549**			4,023	4,023	4,023	4,023	4,023	4,023	4,023	3,812	**31,973**
	Total		**1,903**	**1,903**	**1,903**	**1,903**	**1,903**	**1,903**	**1,903**	**1,870**	**15,191**	**Total**		**1,903**	**1,903**	**1,903**	**1,903**	**1,903**	**1,903**	**1,903**	**1,870**	**15,191**

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 row has volumes from other projects unrelated to this document mapping to it. The volume differences are described below:

- A further 31,973 assets map to CV13 11. The total volumes mapping to this line is 37,052.

Appendix 9 Efficiency Benchmarking with other DNOs

HV Switchgear

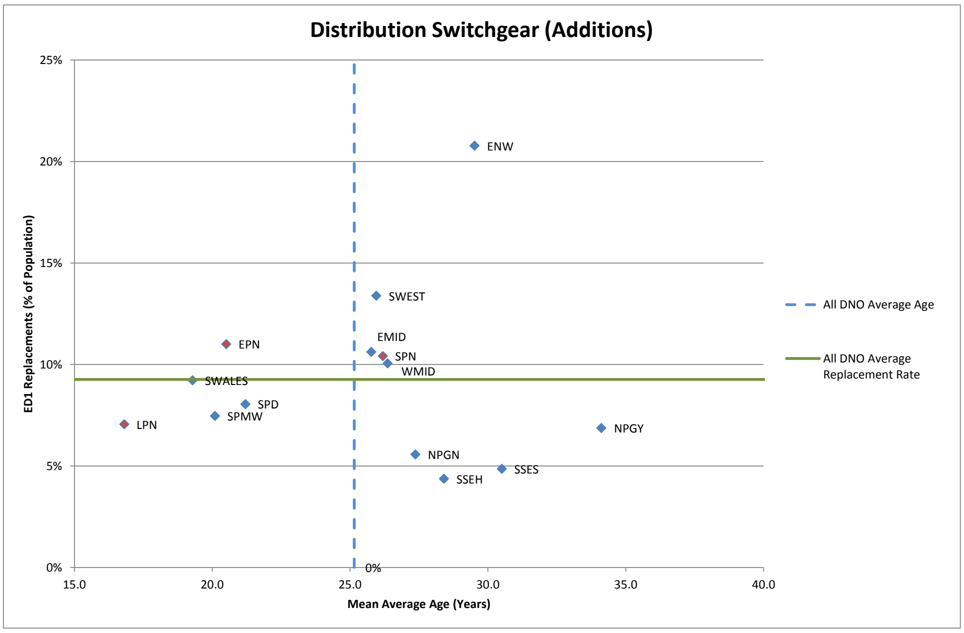


Figure 53: Efficiency Benchmarking *(Source: DNO Datashare 2013)*

Figure 53 shows that LPN has a lower 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 LPN is due to the large activity of work (i.e. asset replacement, load-related and connections) since 1999 resulting in just over 77% of the LPN distribution switchgear network being SF_6-filled switchgear.

LV Switchgear

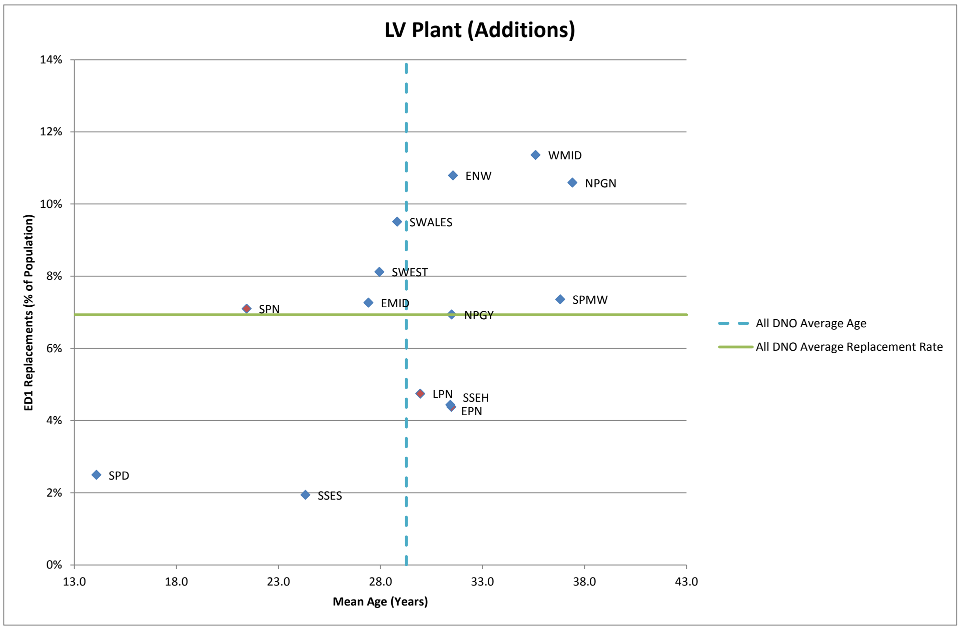


Figure 54: Efficiency Benchmarking *(Source: DNO Datashare 2013)*

Figure 54 shows that LPN 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

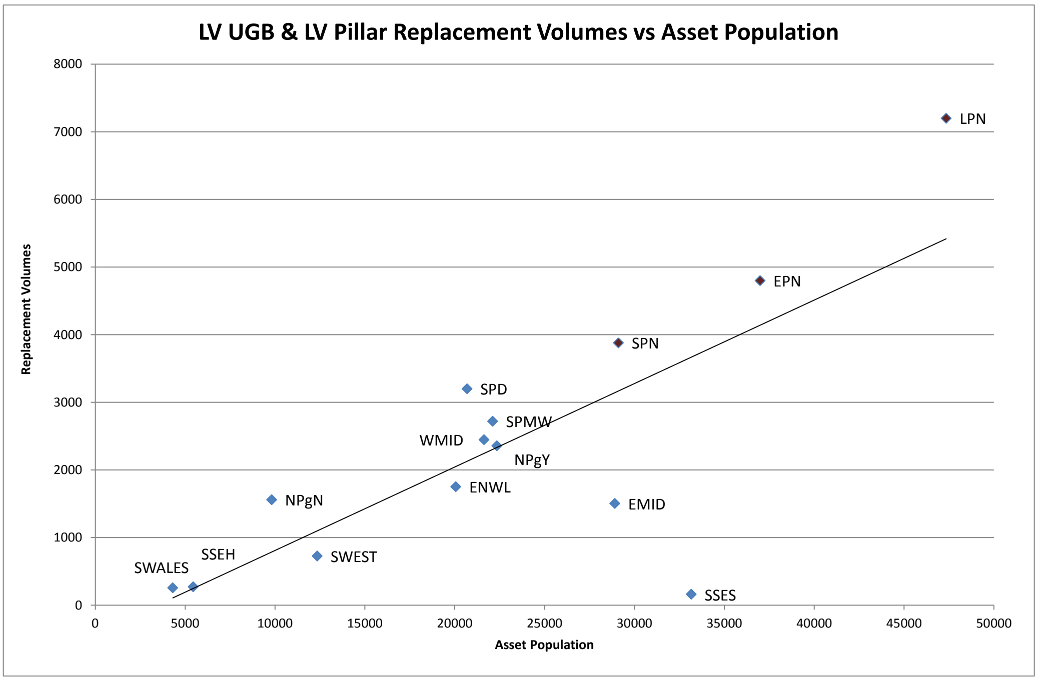


Figure 60: Efficiency Benchmarking *(Source: DNO Datashare 2013)*

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

Figure 60 shows that LPN 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)	1,472	1,472	0
		Volume (Removals)	1,496	1,496	0
		Investment (£m)	27.93	24.50	(3.43)
		UCI (£k)	18.67	16.38	(2.29)
LV Switchgear	Replace	Volume (Additions)	1,280	1,280	0
		Volume (Removals)	1,280	1,280	0
		Investment (£m)	15.43	15.43	0
		UCI (£k)	12.05	12.05	0
Link Boxes	Replace	Volume (Additions)	7,200	7,200	0
		Volume (Removals)	7,200	7,200	0
		Investment (£m)	42.92	42.92	0
		UCI (£k)	5.96	5.96	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 £3.43m based on a RMU UCI change. Compatible unit analysis and industry comparisons show our submitted UCI in LPN is considerably higher than the industry average. Site locations and underground installations make delivery more difficult in LPN (and therefore more expensive) and this has been taken into consideration when proposing the new UCI. UKPN propose to reduce the LPN RMU UCI by approximately £2k compared to the July 2013 submission, reducing the overall expenditure by £3.43m.

Faults (V4b/CV15a)

Asset Type	Action	Change Type	2013 Submission	2014 Submission	Difference
HV Switchgear (GM)	Replace	Volume (Additions)	160	160	0
		Volume (Removals)	175	175	0
		Investment (£m)	Changes to capitalised fault restoration expenditure can be found in Document 14: LPN I&M & Faults		
		UCI (£k)			
Link Boxes	Replace	Volume	Included in CV3		

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

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