Document 9
Asset Category – Distribution Transformers
SPN

Asset Stewardship Report 2014

Zoe Cornish

Approved by Richard Wakelen / Barry Hatton

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Document History

Version	Date	Details	Originator	Revision Class	Section Update
1.0	19/02/2014	Original Submission	N/A	N/A	N/A
1.1	19/02/2014	New Introduction addition Fault restoration costs updated to reflect 13th February S&R NAMP figures. Updated references to align to latest NAMP Addition of Appendices 8,9 & 10 Updated HI profiles to reflect latest RIGs tables	Zoe Cornish	Minor Minor Minor Minor Minor	Section 1.1 Section 1.2, 1.4 & Appx 5 Throughout document Appx 8, 9 & 10 Sec 1.4, 4.6, 7.6 & Appx 2
1.2	24/02/2014	Updated references to reflect 19th February S&R NAMP Added preface and removed Introduction added in version 1.1 Removed cost table from Appendix 8 & updated expenditure in Appendix 10 (to Oct RIGs)	Zoe Cornish	Minor Minor Minor	Throughout document Pg 3 & 4 Appendix 8 & 10
1.3	25/02/2014	Removed HI/CI risk matrices	Zoe Cornish	Minor	Section 7.7
1.4	25/02/2014	Changes to Appendix 8 & 10 Source references	Zoe Cornish	Minor	Appendix 8 & 10
1.5	27/02/2014	Minor changes to preface and App 9 & 10	Zoe Cornish	Minor	Preface & Appendix 9 & 10
1.6	27/02/2014	Minor changes to preface and App 10	Zoe Cornish	Minor	Appendix 10
1.7	04/03/2014	Changes to Exec Summary Scott Transformer case amended to align with LRE document.	Robert Lafferty	Minor	Section 1.3 & Sections 3 and 7.3
2.0	04/03/2014	Final Approved	Ian Butler	Minor	

Preface

UK Power Networks uses Asset Stewardship Reports ('ASR') to describe the optimum asset management strategy and proposals for different groups of assets. This optimised asset management strategy and plan details the levels of investment required and the targeted interventions and outputs needed. Separate ASRs define the most efficient maintenance and inspection regimes needed and all documents detail the new forms of innovation which are required to maximise value, service and safety for all customers and staff throughout the ED1 regulatory period. Outline proposals for the ED2 period are also included.
Each DNO has a suite of approximately 20 ASR's. Although asset policy and strategy is similar for the same assets in each DNO the detailed plans and investment proposals are different for each DNO. There are also local issues which must be taken into account. Accordingly each DNO has its own complete set of ASR documents.

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

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

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

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

2. **Appendix 9 – Efficiency benchmarking with other DNO's:** This helps to inform readers how UK Power Networks is positioned from a benchmarking position with other DNO's. It aims to show why we believe our investment plans in terms of both

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

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

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

Contents

1.0 Executive Summary SPN HV Transformers

1.1 Scope

This document details SPN's NLRE (non-load related expenditure) replacement proposals for ground-mounted HV distribution Transformers for the RIIO-ED1 period. In total there are approximately 21,229 of these assets, in SPN, with an estimated MEAV of £295m.The proposed annual investment in ED1 is £3.1m and is 1.1% of the MEAV per annum.

Replacement costs for these assets are held in the Networks Asset Management Plan (NAMP) and in sections of the RIGS tables identified in Table 1.

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

INVESTMENT TYPE	ED1 COSTS	NAMP Line	RIGS REFERENCE
Asset Replacement - GM Distribution Transformers - 11kV	£10.1m	1.19.01	**Volumes - RIGS Table CV3:** Additions Row 48 - HV - 6.6/11kV Transformer (GM) Removals Row 176 - HV - 6.6/11kV Transformer (GM) **Costs - RIGS Table CV3:** Row 48 - HV - 6.6/11kV Transformer (GM) (Note: A proportion of costs map to CV6 27/28/29)
Asset Replacement - 3.5kV & 2KV Transformers	£0.3m	1.19.26	**Volumes - RIGS Table CV3:** Additions Row 48 - HV - 6.6/11kV Transformer (GM) Removals Row 176 - HV - 6.6/11kV Transformer (GM) **Costs - RIGS Table CV3:** Row 48 - HV - 6.6/11kV Transformer (GM) (Note: A proportion of costs map to CV6 27/28/29)
Asset Replacement - Capital replacement of damaged GM 11kV DTF	£0.4m	2.50.03	**Volumes - RIGS Table V4b:** Additions Row 48 – HV: 6.6/11kV Transformer (GM) Disposals Row 48 – HV: 6.6/11kV Transformer (GM) **Costs - RIGS Table CV15a:** CV15a Row 27 - HV - All Other Plant and Equipment (inc GM transformers) - Asset Repair/Replacement Required

Table 1 – Investment areas (Source: 21st February 2014 ED1 Business Plan Data Tables)

1.2 Investment strategy

The long-term investment proposal for the replacement of ground-mounted distribution transformers has been set based on statistical model forecasts. The investment proposals have been validated by comparing the forecasts to historical fault rates and observed trends in condition data for the ageing distribution transformer population in SPN. Specific transformers identified for replacement each year will be based on:

- Overall condition of the transformer (determined from condition assessments and defects identified and reported from routine inspections and maintenance activities) and
- PCB levels greater than 500ppm and or in poor condition.

Investment levels have been set such that we maintain the level of risk on the broadly constant network, i.e. the number of assets with a poor health index (HI 4 and HI 5) at the start and end of RIIO-ED1.

1.3 ED1 Proposals

The proposed investment level for the replacement of distribution transformers in SPN is £10.8m. The yearly expenditure profile is shown in Table 2.

NAMP lines	Description	15/16	16/17	17/18	18/19	19/20	20/21	21/22	22/23	ED1 Total
1.19.01.6653	Replace GM Distribution Transformers - 11kV	1,268	1,268	1,268	1,268	1,268	1,268	1,268	1,268	10,144
1.19.26.6658	Replace 3.5 & 2KV Transformers	33	33	33	33	33	33	33	33	264
2.50.03	Capital replacement of damaged GM 11kV DTF	50	50	50	50	50	50	50	50	400
Total		1351	1351	1351	1351	1351	1351	1351	1351	10811

Table 2 – Summary Table of ED1 investment (Source – 19th February 2014 NAMP Table J Less Indirect)

Figure 1 shows the HI profile at the start and end of ED1, with and without investment. The chart shows that there will be a similar number of HI4 and HI5 assets at the end of the ED1 than at the start, if the proposed investment levels are carried out. This is to ensure that we maintain the level of network risk broadly constant.

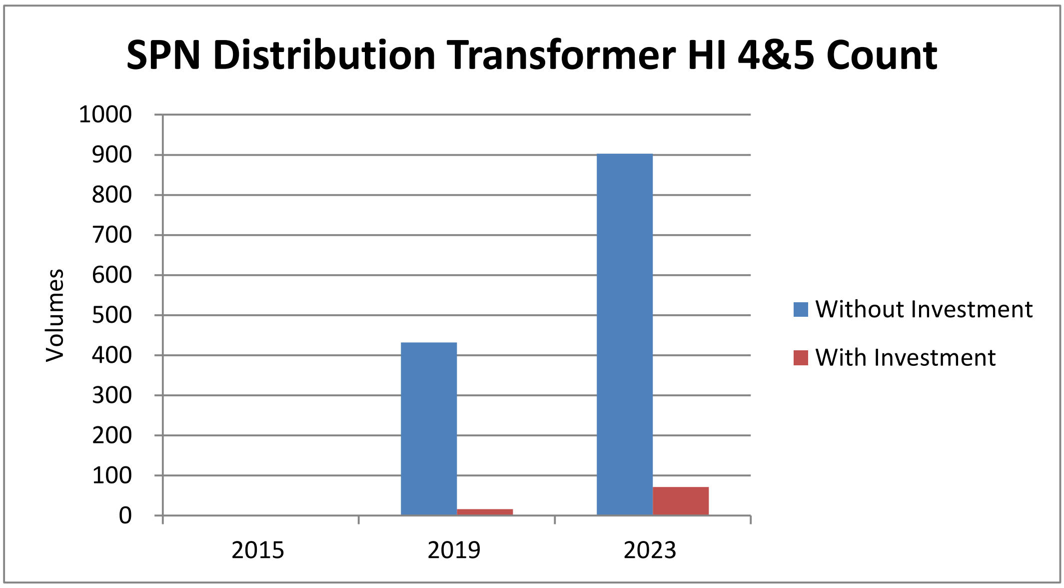

Figure 1 - HI profile (with and without investment) for ED1; Source – SARM v0.3

Appendix 9 benchmarks our ED1 proposals with reference to other DNOs July 2013 submissions. It shows that for Distribution Transformers we are proposing to replace **4%** of our assets while other DNOs were seeking funding to replace **6%** 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 HV plug-in bushing ("Mekufa") bushing has been approved for use in the three licence areas operated by UK Power networks (LPN, SPN and EPN). The new bushing will reduce oil handling requirements and make it easier to connect ring main units to the transformer. It will also reduce installation times (typically by a few hours).

1.5 Risks and opportunities

Table 3 highlights the risks associated with the ED1 investment proposals for distribution transformers in SPN.

	Description of similarly likely opportunities or risks arising in ED1 period	**Uncertainties**
Risk	New EU regulation with regards to reducing losses will have an impact on prices for new transformers.	Up to +20% of ED1 investment
Risk	We may not be able to source new distribution transformers with a primary winding voltage of 2kV and 3.5kV to replace ageing ones in poor condition.	Up to +5% of ED1 investment

Table 3 – Risks and opportunities

2.0 Description of HV Transformer Population

2.1 HV Transformers

2.1.1 Types

There are 21,229 ground-mounted HV transformers currently commissioned within the SPN region, with a primary winding voltage of between 2kV and 11kV and ratings ranging from 50kVA-1000kVA.

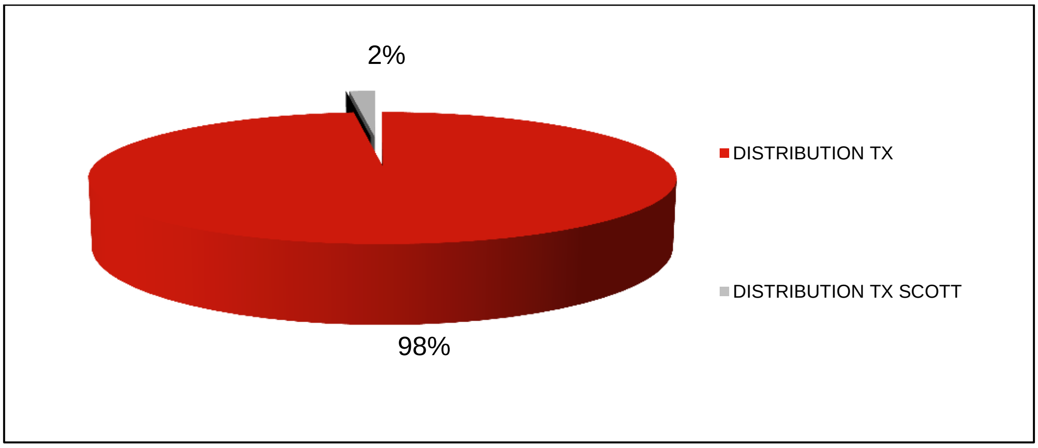

Figure 2 – Distribution transformer breakdown by voltage

The asset population includes 379 *Scott Transformers*. Scott transformers are used to derive two-phase output from a three-phase source and were introduced to cater for the use of triple concentric cables used almost exclusively in parts of Croydon and surrounding areas. The strategy in ED1 is to carry out like-for-like replacements of Scott transformers in poor condition. UK Power networks has approached and received quotes from one manufacturer for the manufacture of new units. A "type approval" process will be followed to approve new units. However, due to the relatively low volume, manufacturing costs for new Scott transformers will be twice those of conventional 3-phase transformers (estimate is £25k per transformer). This is still the preferred option as uprating the Scott Network will involve replacements of large lengths of LV cable which would be less cost effective. The typical cost for converting a Scott substation is £320k which is significantly more than the unit cost of a new Scott transformer.

Due to the nature of some isolated areas within the Scott Transformer network exhibiting poor Quality of Supply and expected high CI/CML, schemes may be raised outside the preferred option of replacing like-for-like. (See Section 7.3 for schemes)

Figure 3 – Example of a Scott Transformer at Groombridge substation

The asset population also includes transformers with a primary winding voltage between of 2kV and 3.5kV. The 2kV and 3.5kV system is a legacy from the 1920s that was installed in the geographical region between Tonbridge, Kent and Oxted in Surrey, and between Ripley and Send near Woking in Surrey. The network supplies sparsely populated rural areas and historically the cost of uprating has been found to be uneconomical. The 2kV and 3.5kV is mainly fed through underground cables that supply small transformers (typically less than 100kVA) sited very close to the load. The 2kV transformers are single-phase transformers whilst the 3.5kV transformers are three-phase. The strategy in ED1 is to carry out like-for-like replacements of these transformers or replace them with 2kV or 3.5kV compact substations (see figure 4) where feasible.

	
Figure 4: ***Typical 2kV s/s in a brick "lean-to" on customer's house. LV fuse is on the left out of view. The porcelain caps on the air cooled transformer cover the tapping connections***	**Figure 5:** ***Replacement compact 2-3kV substation***

2.1.2 Age Profile

As shown in Figure 6, large amounts of electrical infrastructure were commissioned during the 1960's. The oldest 10% of distribution transformers in SPN have an average age of approximately 58 years. This will rise to 69 years at the end of ED1 if there are no replacements.

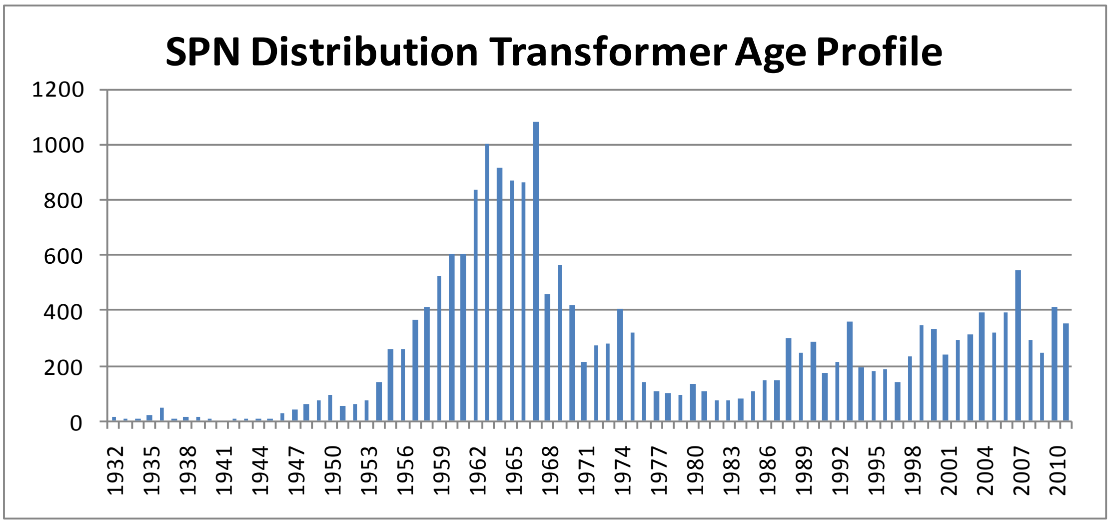

Figure 6: SPN Distribution Transformer Age Profile (Source – RIGS 2012 CV3 Table V5)

All ground-mounted distribution transformer replacement provisions for ED1 are listed under NAMP Lines:

- 1.19.01 Asset Replacement - GM Distribution Transformers - 11kV
- 1.19.26 Asset Replacement - 2KV & 3.5KV Transformers
- 2.50.03 Asset Replacement - Capital replacement of damaged GM 11kV DTF

The corresponding RIGS lines are shown in Table 4.

RIGs Table	RIGs Row	Description	
CV3	48	6.6/11kV Transformer (GM)	Additions
CV3	162	6.6/11kV Transformer (GM)	Removals

Table 4 – RIGS categories

3.0 Investment Drivers

3.1 Overview

The high level investment drivers for replacement of distribution transformers are detailed in EDP 00-0013 Asset Lifecycle Strategy Distribution Substations.

The long-term forecasts for distribution transformer replacements have been set based on statistical model forecasts. The investment proposals have been validated by comparing the forecasts to historical fault rates and observed trends in condition data for the ageing distribution transformer population. Statistical model forecasts are not asset-specific. Specific assets required for replacement each year are determined by key replacement drivers. The main investment drivers for replacing distribution transformers are:

- Overall condition and

- The amount of Polychlorinated Biphenyls (PCB) it contains.

HSS 01 015 - Management of Oil Filled Equipment containing PCBs outlines the procedure within UKPN to manage oil-filled equipment containing PCBs. Other drivers that influence the decisions involved in the management of ground-mounted distribution transformers are:

- Public and operator safety
- Asset and network performance
- Major defects in some asset types
- Non-availability of spares

These drivers are supported by:

- Asset condition reports.
- Asset and network performance records.
- ESQCR risk assessments.
- Historic, current and emerging equipment and diagnostic technologies.
- Statistical modelling
- Stakeholder options

Replacements will generally be co-ordinated with other planned works on the same site in line with the asset lifecycle strategy.

3.2 Condition and Defects

The overall condition of a transformer is determined based on a combination of condition ratings for key *condition assessment measures* and defect measures. The defects and condition measures are shown below.

Principal condition assessment measures and defects:
- External condition of housing (including severe corrosion),
- Overall internal condition
- Oil containment (including defect oil level, Defect Transformer Oil Leak)
- Oil test results (e.g. Acidity levels)
- Amount of PCB in transformer oil

Other defects used to assess the condition of the transformer include:
- Defective MDI
- Plant Subsidence
- Defect Fluid Sight Glass
- Compound Leak
- Electrical Discharge Recorded
- Defective Cable Box
- Earthing defective
- Defective Gaskets
- Defect Protective Finish

Figure 7 shows two distribution transformers in poor condition with evidence of oil leaks and rust.

Figure 7 - Transformers in poor condition

PCBs were historically used to improve the insulating properties of mineral oil in transformers. However, due to PCBs' environmental toxicity and classification as a persistent organic pollutant, PCB’s were withdrawn from use in 1980 and it has been illegal to sell equipment that contains PCB’s since 1985.

HSS 01 015 - Management of Oil Filled Equipment containing PCBs outlines the procedure within UKPN to manage oil-filled equipment containing PCBs:

- For all equipment with PCB results less than 50ppm a label indicating PCB Test Passed shall be attached
- All equipment found to contain between 50ppm to 500ppm PCBs may remain in service until removed. The equipment must have an approved label indicating PCB contamination and registered with the Environment Agency within 28 days of the test.
- If the PCB level is identified as more than 500ppm, the Environment Agency shall be notified by the Environment Team immediately and arrangements made for the decontamination or disposal of the equipment by the Company’s approved Scrap Contractor.

3.2.1 Correlation between Age and Defects

Figure 8 shows the comparison between:

- Current age profile of the population
- Number of defects reported historically (including the age of the transformer when the defect was reported)

Two observations can be made from the chart - Firstly, the number of defects increases with age and secondly that majority of defects generally occur between 40 and 55 years of age.

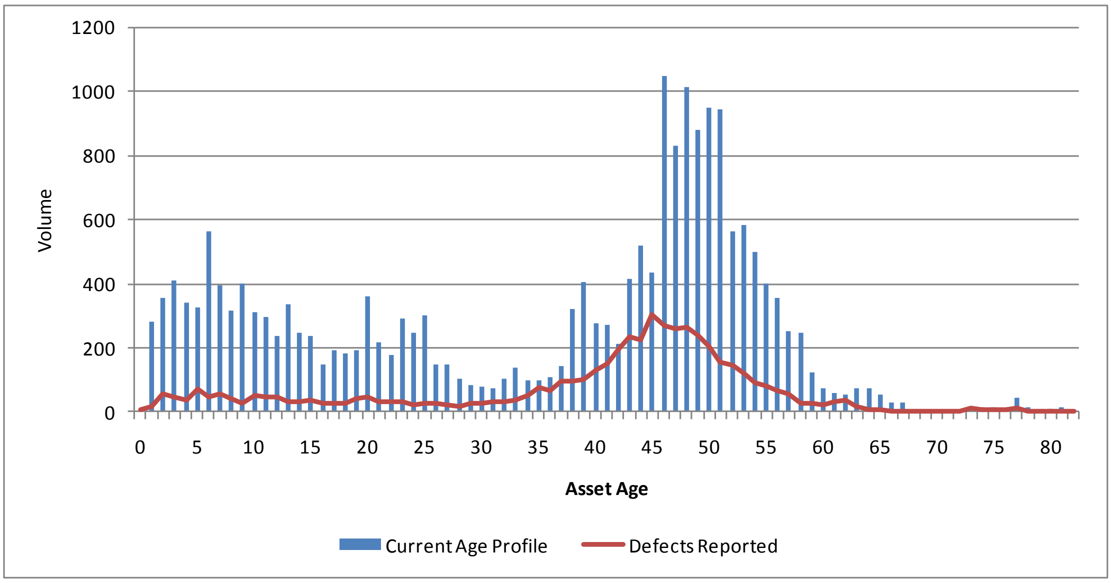

Figure 8 – Correlation between defects and asset age

3.2.2 Fault Rate

Review of historical fault rates show that there has been an overall decrease in fault rates over the four-year period 2008-2012. However fault rates due to ageing and wear (including corrosion), showed an increase over the same four-year period. Figure 9 shows the fault rate trends over the last six years. Replacement of distribution transformers, in poor condition, in ED1, will reduce the number of transformer failures. This will result in a reduction the number of CIs and CMLs associated with distribution transformer failures.

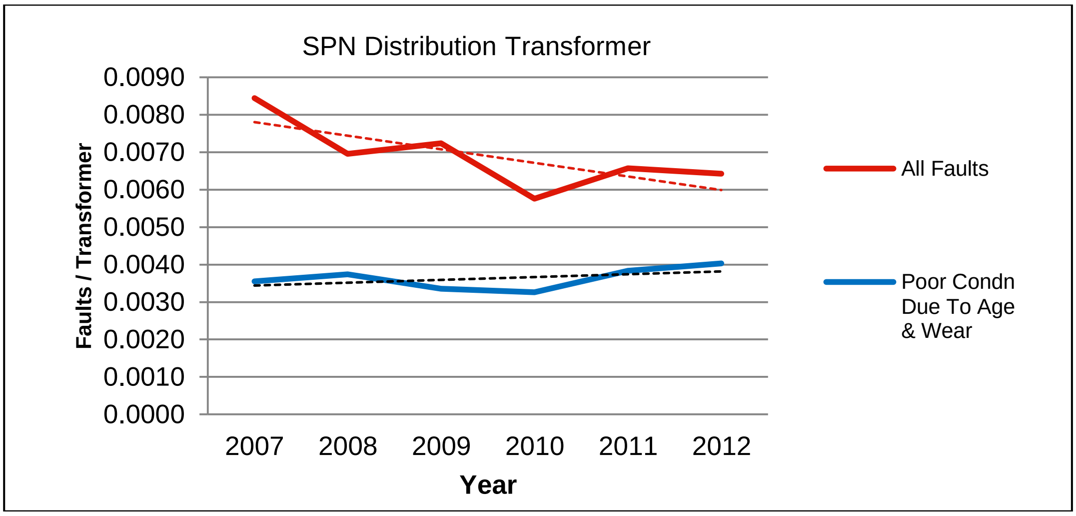

Figure 9 - Fault rate - distribution transformers in SPN (Source - UKPN Fault Cube)

3.3 Condition Measurements

3.3.1 Substation Inspection

The main source of condition data for our distribution transformers is from Substation Inspectors. Inspections are carried out every three years in line with the inspection and maintenance policy (EMS 10-0002 Inspection and Maintenance Frequency Schedule). As part of the inspections process, inspectors complete scripts on hand held devices (HHD) or submit the relevant paper forms with key condition information. Figure 10 shows the handheld device and paper forms used by substation inspectors.

Figure 10 – Handheld device (HHD) and paper form

3.3.2 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.'

Ellipse 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 replacement of distribution assets in poor condition will contribute to a reduction in operating costs by reducing the number of asset failures. Typically an asset failure will result in loss of supply to customers. This will result in operating costs for restoration of supplies through switching and or use of generation.

4 Asset Assessment

4.1 Asset Health (Statistical Asset Replacement Models)

A statistical asset replacement model (SARM) has been used to determine the long-term investment requirements for distribution transformers in RIIO-ED1. SARM uses the age profile of an asset and key inputs such as average asset life and standard deviation to determine projections.

The average asset life in the SARM model is the average life at which we expect most distribution transformers to be replaced. SARM assumes a normally distributed age and asset replacement profile for assets in the model. Further details on the SARM models can be found in the 'Modelling Overview document'.

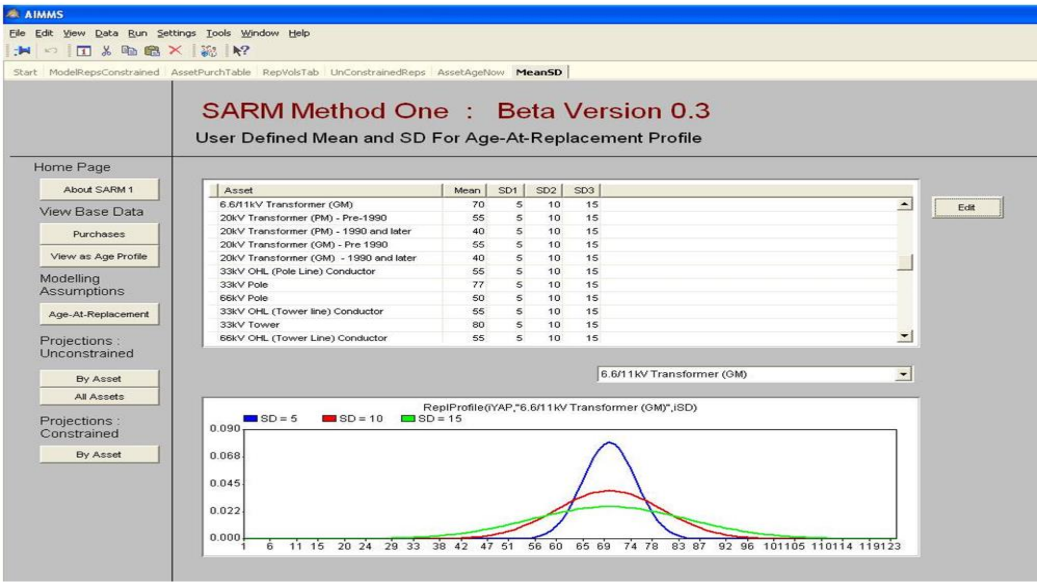

Figure 11 – Screenshot of normally distributed profile for different standard deviations (SARM model)

The SARM models are run for a range of inputs and the outputs are compared to historical replacement rates, fault rates and condition of the oldest 10% of the population to determine the right outputs to use for investment forecasts. Observed increases in historical condition-related fault trends usually imply that an increase in future rates of replacement is required and vice versa.

ED1 asset replacement forecasts, in SPN, are based on an average asset life of 70 years and standard deviation of 5 years.

The average asset life used was determined by comparing the condition of the oldest 10% of the population with historical replacement rates. An average asset life of 70 years and a standard deviation of 5 years implies that majority of transformers will be replaced when they are between 55 years and 85 years old. Section 7.2 explains the process for constructing the ED1 Distribution transformer replacement plan.

4.2 Asset Criticality & Network Risk

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
- Safety
- Financial Impact; OPEX (Licence area, spares/obsolescence) and CAPEX (Voltage and licence area); and
- Environmental Impact

In order to compare consequences of failures for different asset categories, a monetary value is assigned to each of the four primary criticality categories – network performance, safety, financial and environmental impact.

The criticality of an asset is determined from the sum of the consequences of failures (in monetary terms) for each of the four primary criticality categories. This is then converted to an OFGEM criticality index C1-C4.

A detailed methodology for calculating the criticality index can be found in 'Commentary Document 15: Model Overview'.

Criticality has not been used to set the long-term forecast for ED1 but will be used to prioritise planned replacements in ED1.

Criticality index calculations are still under development as part of the OFGEM working group for His and criticality.

4.3 Data Validation

All data used in the statistical models is validated 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. An exception report is issued on completion of the validation process. The exception report provides details of non-compliances. This forms a key part of the data quality improvement process.

4.4 Data Verification

A sampling approach to data verification is carried out following each data upload to the SARM model to ensure accurate transfer of data into the models.

4.5 Data Completeness

Asset Type	Completeness	Accuracy	Timeliness
Distribution Transformers	94%	*	*

Table 5 – CAT score

Source: Decision Lab report "CAT Scoring" 8th February 2013

** Not available: quality standards are under review*

Further information on CAT scores can be found in 'Commentary Document 15: Model Overview'

Inspector training courses and cyclic inspection schedules will improve data completeness and accuracy over the coming years.

4.6 HI Profiles With and Without Investment

Figure 12 shows the outputs from the models with and without the planned DPCR5 and ED1 investment, highlighting the start point for ED1. The investment levels during the eight year period have been set to manage the risk at a constant level. The HI profiles indicated are derived from condition related investment only and exclude the contribution from load related expenditure.

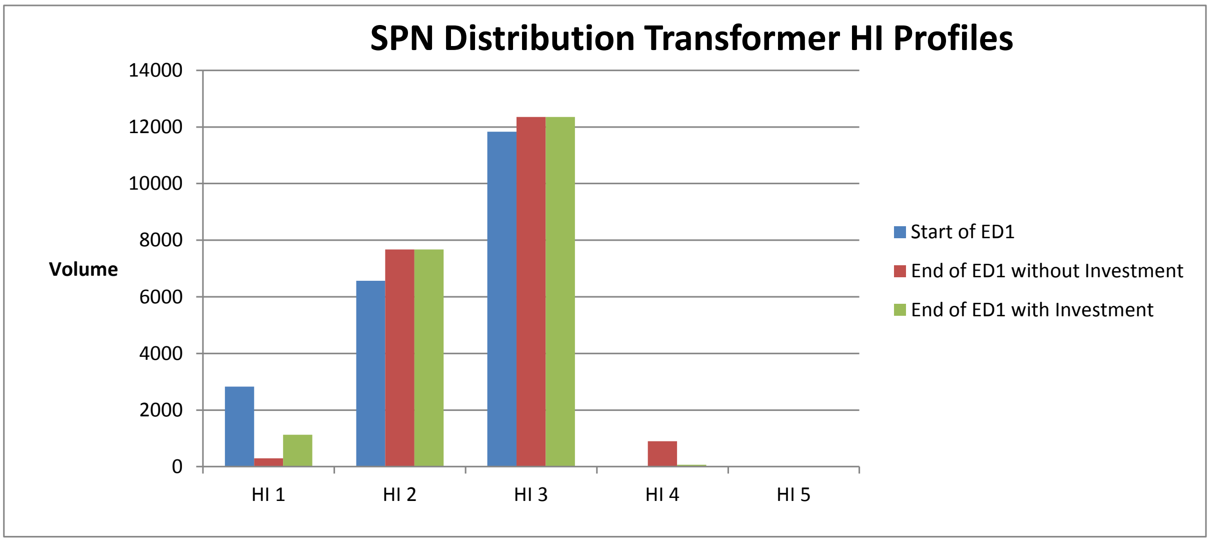

Figure 12 - HI Profile (Start and end of ED1)

5 Intervention policies

5.1 Interventions: Description of intervention options

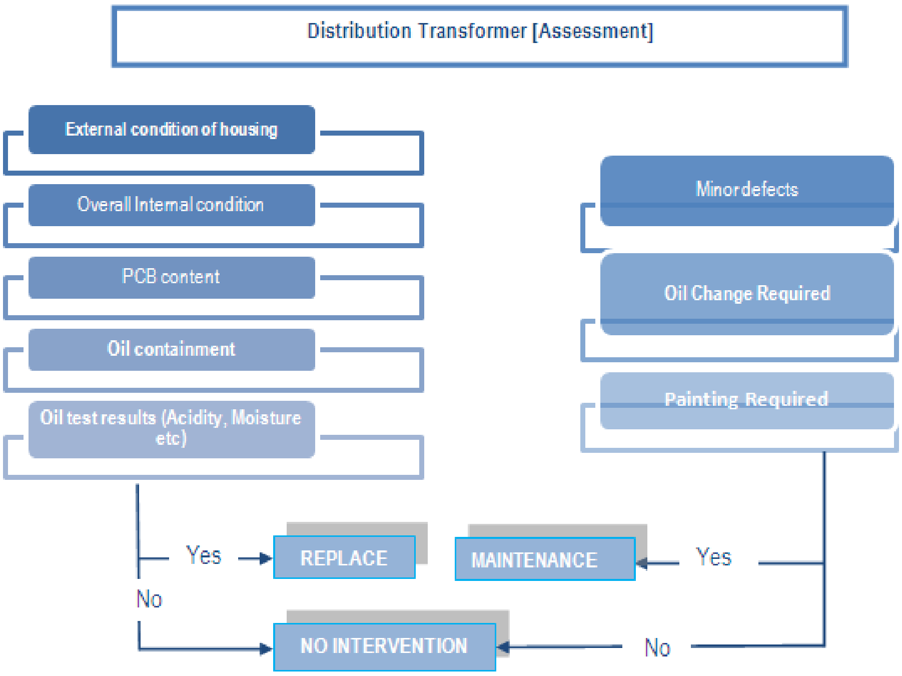

Figure 13 - Decision tree for interventions

Figure 13 shows the decision tree for interventions on distribution transformers. Interventions carried out on distribution transformers to improve condition include:

- Asset replacement and
- Maintenance

Asset replacement will be carried out when condition measurements from routine inspections show the overall health of a transformer is poor and or the transformer contains more than 500ppm of PCB. For less critical defects (such as damaged maximum demand indicators, defective cable boxes, taps etc.) repairs will be carried out as part of routine maintenance activities.

The refurbishment of distribution transformers has been discounted in ED1 because it is not cost effective. However maintenance activities such as oil change, painting etc. will be carried out in line with UK power networks maintenance policy, during ED1. Maintenance proposals for distribution transformers, in ED, are held in *“Document 14 - I&M, Faults and Trees*”.

6 Innovation

A bespoke plug-in ‘Mekufa’ bushing previously supplied only for LPN transformers will be supplied on all new transformers for use in EPN and SPN (refer to Figure 14). By introducing the ‘Mekufa’ bushing, the oil handling and connecting of internal leads to the RMU associated with EPN and SPN transformers is removed from the plant assembly process. This significantly reduces the time to assemble unit substations (typically by a few hours).

Figure 14 – Mekufa bushing

7 ED1 Expenditure Requirements for HV Transformers

7.1 Method

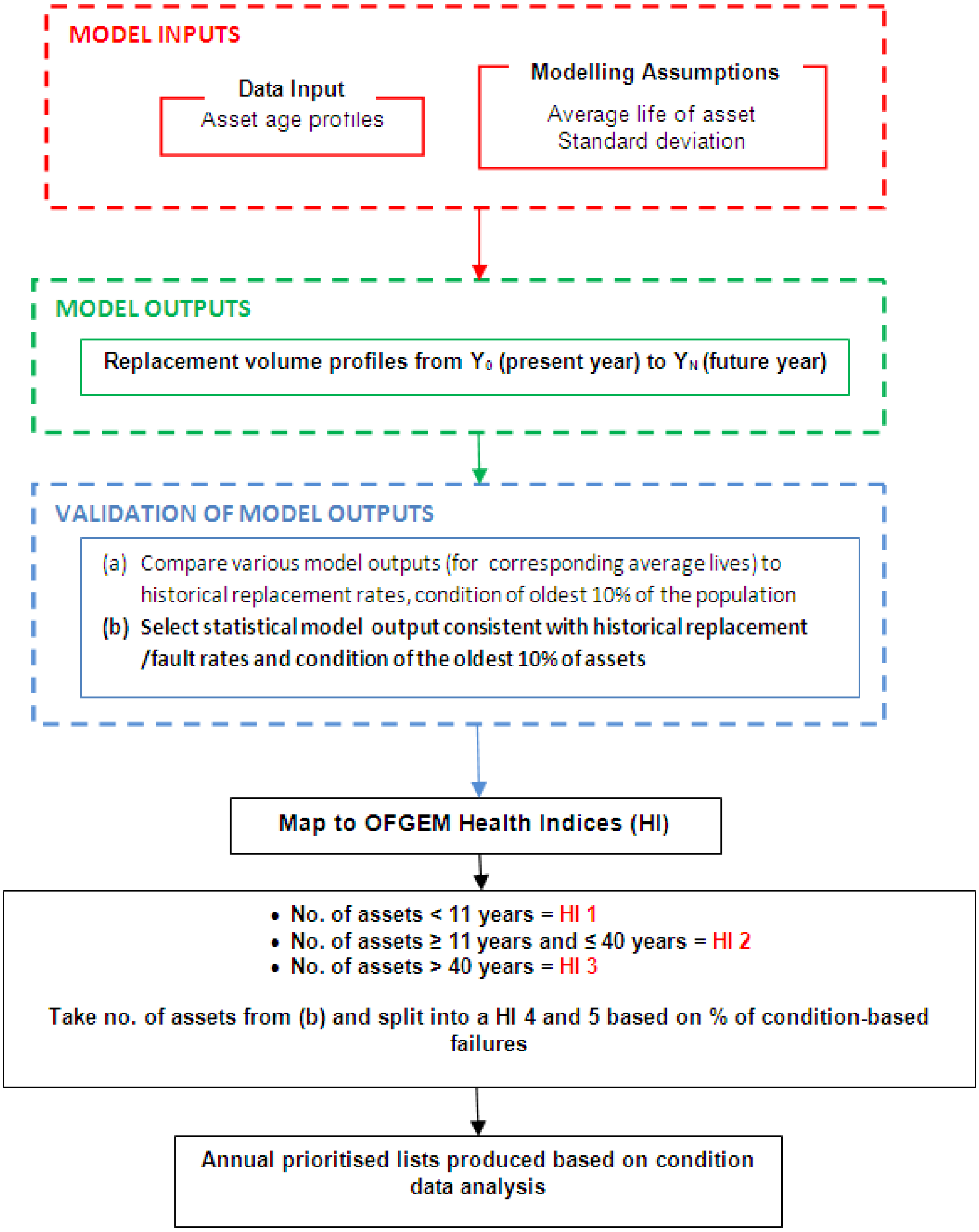

Figure 15 – Decision flow diagram

The statistical asset replacement model (SARM) is used to determine the overall number of poor condition transformers in the future. The model outputs are not asset-specific. Specific transformers that require replacement each year are determined from condition data analysis. The key condition measures used to qualify transformers for replacement each year are outlined in section 3.2.

Figure 15 shows the process for determining the volume requirements for distribution transformers. The key stages are as follows:

- **Key inputs:**
  - Age profiles,
  - Average asset life (i.e. Point at which most distribution transformers are expected to be replaced before they fail) and
  - Standard deviation (used to specify the variation around the mean)

- **Model outputs:**
  - The outputs produced are the number of transformers that are likely to be in poor condition annually.
    - *Note - The SARM model is run to obtain several outputs for different average asset life inputs*

- **Validation of outputs:**
  - Validation of the output is done by comparing various model outputs (for corresponding average lives) to historical replacement rates and condition of the oldest 10% of the population.
  - The statistical model output consistent with historical replacement/fault rates and condition of the oldest 10% of assets is selected to set the ED1 NLRE forecast.

- **Producing HIs:**
  - The number of transformers forecast to be in poor condition annually (model output) is split between HI4 and HI5 based on historical condition-based failures as a fraction of all transformer failures.
  - HI1, HI2 and HI3 splits are determined using the age-related assumptions shown in figure 15.

Annual prioritised lists are determined by assessing the condition and criticality of the assets

7.2 Constructing the plan

The investment levels set in ED1 were determined based on the statistical asset replacement model (SARM). A range of average asset lives (from 60 to 75 years, all with a standard deviation of 5 years) were used as inputs to SARM.

The corresponding outputs were compared to historical replacement rates and the condition of the oldest 10% of distribution transformers in service. Table 6 shows the outputs from the statistical models for various average asset lives and standard deviations. The figures shown in Table 6 assume no investment is made between 2012 and 2023.

Inputs		Intervention Volumes for ED1		
Average asset life	**SD**	**2012**	**2015**	**2023**
65	5	108	468	2,815
70	**5**	**49**	**194**	**1,144**
75	5	25	97	438

Table 6: Statistical model (SARM output)

The outputs obtained by using an average life of 75 years are too small based on the population and condition of distribution transformers. An average life of 70 years and standard deviation of 5 years showed the closest correlation to historical replacement rates (76/year between 2007/2008 and 2011/2012). Table 7 shows the forecast replacement volumes in ED1.

	2015/2016	2016/2017	2017/2018	2018/2019	2019/2020	2020/2021	2021/2022	2022/2023	Total
Distribution transformer replacement **(Planned)**	94	94	94	94	94	94	94	94	752
Distribution transformer replacement **(Capitalised faults)**	10	10	10	10	10	10	10	10	80

Table 7. ED1 forecast distribution transformer replacements (Source: 19th February 2014 NAMP Table O)

An average life of 70 years implies that most transformers will be replaced between 55 years and 85 years. This is consistent with the observed condition of the oldest 10% of distribution transformers. The oldest 10% of distribution transformers in SPN is 56 years (will rise to 67 years by 2023 if there is no investment) and they are in relatively good condition.

7.3 Additional Considerations

We have made a strategic decision to retain the majority of Scott transformers and 2kV single-phase transformers on the SPN networks as the costs of converting all the Scott network and 2 kV network to current standards offers reduced cost benefits. Carrying out like for like replacements of Scott transformers and 2.5 kV transformers will cost £25k and about £5k respectively.

The comparative cost of converting a Scott substation or 2.5kV network area would be between £200k and £400k as it would involve replacing long lengths of LV cables. The variance in cost will depend on the comparative lengths of cables that would need to be replaced.

However there is a scheme in Croydon (Croydon Scott Transformer Network Replacement – 1.34.07.8948) involving the replacement of 10 Scott Transformers which sits outside the majority scope of replacing these transformers like for like. The benefits for this project are outlined as Load Related in the improvement in resilience with a better interconnected LV network, higher rated transformers to increase current capacity, reduce CI/CML's, reduce future operational costs and provide cheaper connections for our customers. This project will make available decommissioned Scott transformers for use as strategic spares.

In addition we are working to source new Scot Transformers from manufacturers. We have approached and received quotes from two manufacturers to supply Scott and 2.5kV transformers. This will be followed through to type approval based on new specifications for these units.

The availability of decommissioned Scott transformers as strategic spares and the new agreed specification and type approvals will ensure we have sufficient support for the remaining 369 Scott transformers.

Where justifiable, distribution transformer replacements will be carried out in tandem, with distribution switchgear replacements on the same site as part of an asset replacement project.

Distribution transformers purchased for use on the network will be “low loss” units in compliance with the *Engineering Policy EI 08-0131 Guidance on the Management of Distribution Network Technical Losses.* The term ‘low loss’ relates primarily to the level of transformer iron losses. The use of low loss transformer units will reduce the technical losses on the network.

7.4 Asset Volumes & Expenditure

7.4.1 Volume Graphs (DPCR4 – ED2)

Figure 16 shows the number of distribution transformers installed and forecast to be installed through DPCR4 and ED2.

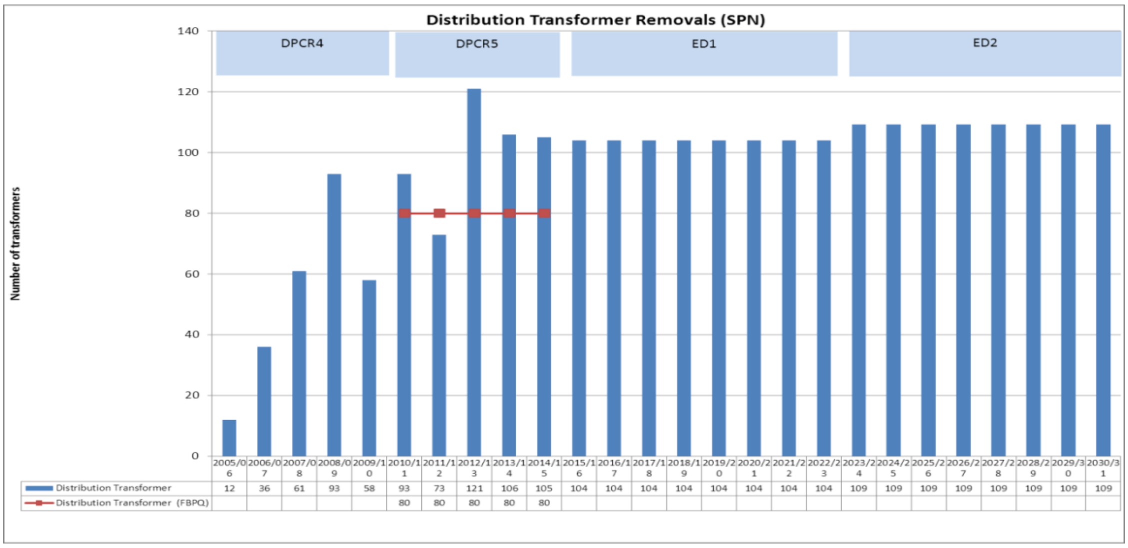

Figure 16: Distribution transformer volumes DPCR4 – ED2

Sources :
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 - Analysis from Age Based Model

7.4.2 Expenditure Graphs (DPCR4 – ED2)

Figure 17 shows the expenditure actuals and forecast during the period DPCR4 – ED2.

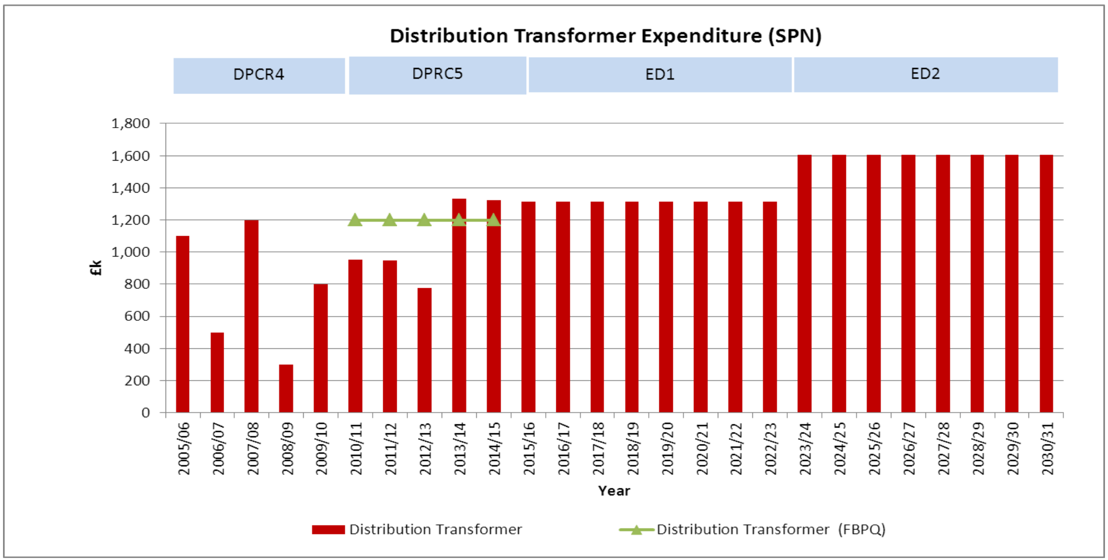

Figure 17: Distribution transformer costs DPCR4 – ED2

Sources:
DPCR4 & DPCR5 FBPQ - Table NL1 (DPCR5 FBPQ)
DPCR5 (First three years) - 2013/2014 RIGS CV3 table
DPCR5 (Last two years) – 14th June 2013 NAMP (Table JLI)
ED1 – 19th February 2014 NAMP (Table J Less Indirect)
ED2 - Analysis from Age Based Model * NAMP UCI

7.5 Commentary

The number of transformers forecast to be removed in DPCR5 will be higher than the planned volumes in the DPCR5 FBPQ. This is due to additional condition data inferred from results on oil samples from distribution transformers. Also, investment profiles peak in 2013 and 2014 due to a backlog of work in the last two years. The backlog was due to unavailability of key resources – Senior Authorised persons. The proposed level of investment for replacement of distribution transformers in SPN is £10.8m over the ED1 period, reflecting the increase in intervention volumes.

The investment levels have been set to maintain the same level of risk throughout ED1.

A statistical model has been used to develop the ED1 forecast and this has been validated against historical asset replacement rates and condition of the oldest 10% of the population. The ED1 volumes are set at a higher level compared to the average annual replacement throughout DPCR4 and DPCR5. As shown in Figure 9, this is due to an increase in the number of condition-based failures over the last six years. The age profile chart (Figure 6) shows high numbers of distribution transformers were commissioned during the 1960s and many are approaching their nominal design life. Furthermore, the majority of these assets are outdoors which increases the degradation rate.

The ED2 figures shown in the chart have been derived from age-based modelling hence the increase in volumes and expenditure. Further work will be done in ED1 to explore additional intervention options that can be used to extend asset life.

Sensitivity Analysis and Plan Validation

A review of different outputs from the SARM model, for different average asset lives, shows that there is a high degree of sensitivity. Table 8 shows a summary of the sensitivity analysis.

Inputs		Outputs at Year (N)			Sensitivity analysis	
Average asset life	**SD**	**2012**	**2015**	**2023**	**Change to no of HI4/5 assets** (If average asset lives other than 70 years is used)	**% Change to HI4/5 assets** (If average asset lives other than 70 years is used)
60	5	249	1,174	5,491	**4,347**	380%
65	5	108	468	2,815	**1,671**	146%
70	**5**	**49**	**194**	**1,144**	**0**	0%
75	5	25	97	438	**-706**	-62%

Table 8 - Sensitivity analysis

Reducing the average asset life by 5 years or 10 years will increase the number of HI 4/5 assets in 2023 by 146% and 380% respectively.

Increasing the average life by 5 years will reduce the number of HI4/5 assets in 2023 by 62%.

The volumes of HI4/5 and assets that will result from a 60-year or 65-year average asset life will present a delivery challenge due to the number of skilled resources required and the negative impact on CIs and CMLs, due to outages that would be required. The volumes of HI4/5 assets that will result from a 75-year average life will be too small compared to historical replacement rates.

7.6 Network Risk

An in-house criticality modelling technique for distribution transformers 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. Tables 9 and 10 show the health and criticality matrix for 2015 and 2023 with investment.

Asset categories	Criticality	Units	Estimated Asset Health and Criticality Profile 2015					Asset Register
			Asset health index					2015
			HI1	HI2	HI3	HI4	HI5	
Distribution TX	Low	No. TX	1,332	2,840	5,559	0	0	9,731
	Average	No. TX	651	1,916	2,720	0	0	5,287
	High	No. TX	566	1,209	2,366	0	0	4,141
	Very High	No. TX	283	605	1,183	0	0	2,071

Table 9 – Criticality and HI profiles for distribution transformers in 2015

Asset categories	Criticality	Units	Estimated Asset Health and Criticality Profile 2023					Asset Register
			Asset health index					2023
			HI1	HI2	HI3	HI4	HI5	
Distribution TX	Low	No. TX	523	3,457	5,717	34	0	9,731
	Average	No. TX	274	2,009	2,988	16	0	5,287
	High	No. TX	223	1,471	2,433	14	0	4,141
	Very High	No. TX	112	736	1,216	7	0	2,071

Table 10 - Criticality and HI profiles for distribution transformers in 2023

7.7 Risks: EU Directive

There will be a change in transformers supplied after 2014, based on the Ecodesign Directive (also known as ‘Energy-related Products’, or ‘ErP’). This is the EU's first ‘life cycle’ oriented directive addressing products. The draft Ecodesign regulation on transformers will improve the energy efficiency of power distribution transformers. Although transformers are already very efficient devices, their energy losses account for around 2.5% of the EU's final energy consumption. The proposed regulation, together with new European standards under development, will bring the EU in line with the strictest international transformer regulations. European manufacturers, electricity utilities and environmental NGOs are widely supportive of the proposed regulation, as it is likely to amplify existing market trends to design more efficient transformers. The impact on SPN is summarised below:

- Have to move from Aluminium to Copper
- Increases in weight up to 21%
- Increase in price of up to 10%

2kV/ 3.3kV Distribution Transformer Condition Overview:

There are a number of 2kV and 3.5 kV networks within SPN. These are largely underground and mainly supply large single residential properties or small hamlets in remote areas. The networks are a legacy of pre–nationalised Distribution Companies and are normally isolated with little or no interleaving to HV networks. These are predominantly found in Tunbridge Wells and surrounding areas. The location and condition of a number of the predominately air-insulated transformers is a cause for concern, and a Programme for replacement has been in place for several years. Spares can only be obtained from decommissioned units. The 2kV indoor type transformers and kiosk transformers are air cooled and are therefore vulnerable to damp.

To manage the risk we have approached two manufacturers with specifications and have received quotes for replacement transformers. We will also consider the use of 2kV and 3.5 kV compact substations as replacements for transformers and switchgear on these sites.

8 Deliverability

There are some challenges with regards to outages but we will endeavour to maintain supplies to customers via back-feeds (reconfiguration of the LV network) and/or generators where possible, during the planned replacement work.

The deliverability of the proposed replacement volumes in RIIO-ED1 have been reviewed and confirmed by the delivery teams. Contracts will be continually reviewed to ensure that we maintain the same level of contractor resource (Senior Authorised Persons and fitters) to deliver the work. Stakeholder consultations have been carried out with the delivery teams to ensure that the plans are deliverable.

The distribution transformer replacement work program will be prioritised based on the criticality indices for individual transformers. Prioritised replacement lists will be issued to the distribution planning teams for delivery.

Appendices

Appendix 1 – Age Profiles

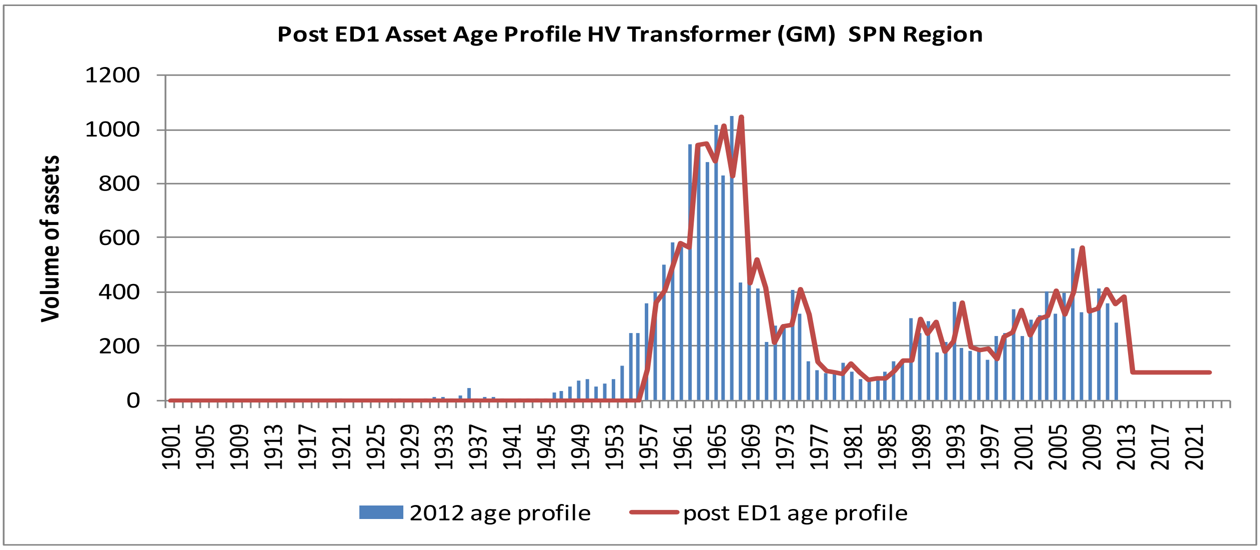

Figure 18 – Asset Age Profile (Source – RIGS 2012 CV3 Table V5)

Appendix 2 – HI and Criticality Profiles

Asset Health and Criticality

Asset categories	Criticality	Units	Estimated Asset Health and Criticality Profile 2015					Asset Register
			Asset health index					2015
			HI1	HI2	HI3	HI4	HI5	
Distribution TX	Low	No. TX	1,332	2,840	5,559	0	0	9,731
	Average	No. TX	651	1,916	2,720	0	0	5,287
	High	No. TX	566	1,209	2,366	0	0	4,141
	Very High	No. TX	283	605	1,183	0	0	2,071

Table 11 - Criticality and HI profiles for distribution transformers in 2015

Asset categories	Criticality	Units	Estimated Asset Health and Criticality Profile 2023					Asset Register
			Asset health index					2023
			HI1	HI2	HI3	HI4	HI5	
Distribution TX	Low	No. TX	523	3,457	5,717	34	0	9,731
	Average	No. TX	274	2,009	2,988	16	0	5,287
	High	No. TX	223	1,471	2,433	14	0	4,141
	Very High	No. TX	112	736	1,216	7	0	2,071

Table 12 - Criticality and HI profiles for distribution transformers in 2023

Appendix 3 – Fault Data

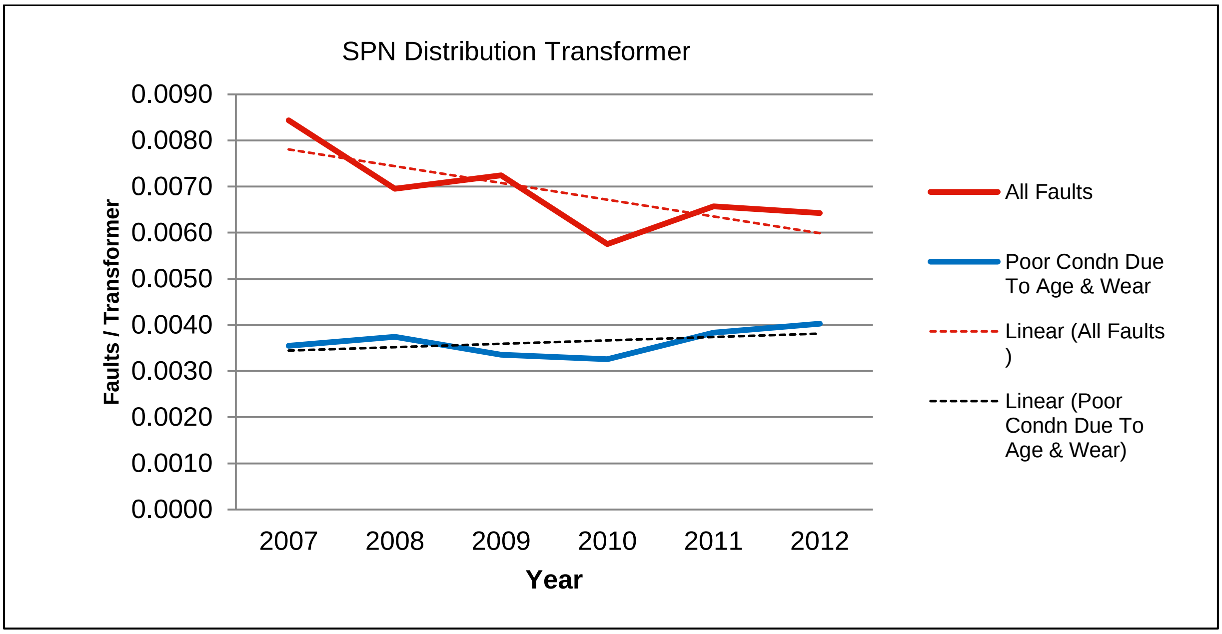

Figure 19 - Fault rate - distribution transformers in SPN (Source - UKPN Fault Cube)

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

Not relevant for distribution assets

Appendix 5 NLRE Expenditure Plan

NAMP lines	Description	15/16	16/17	17/18	18/19	19/20	20/21	21/22	22/23	ED1 Total
1.19.01.6653	Replace GM Distribution Transformers - 11kV	1,268	1,268	1,268	1,268	1,268	1,268	1,268	1,268	10144
1.19.26.6658	Replace 3.5 & 2KV Transformers	33	33	33	33	33	33	33	33	264
2.50.03	Capital replacement of damaged GM 11kV DTF	50	50	50	50	50	50	50	50	400
Total		1351	1351	1351	1351	1351	1351	1351	1351	10811

Table 13 - Summary Table of ED1 investment (Source – 19th February 2014 NAMP Table J Less Indirect)

ED1 Volumes (No. of transformers)									
NAMP lines	Description	2015/2016	2016/2017	2017/2018	2018/2019	2019/2020	2020/2021	2021/2022	2022/2023
1.19.01.6653	Replace GM Dist Transformers - 11kV	90	90	90	90	90	90	90	90
2.50.03	Capital replacement of damaged GM 11kV DTF	10	10	10	10	10	10	10	10
1.19.26.6658	Replace 3.5 & 2KV Transformers	4	4	4	4	4	4	4	4
Total		104	104	104	104	104	104	104	104

Table 14 - Table of ED1 intervention volumes (Source – 19th February 2014 NAMP Table O)

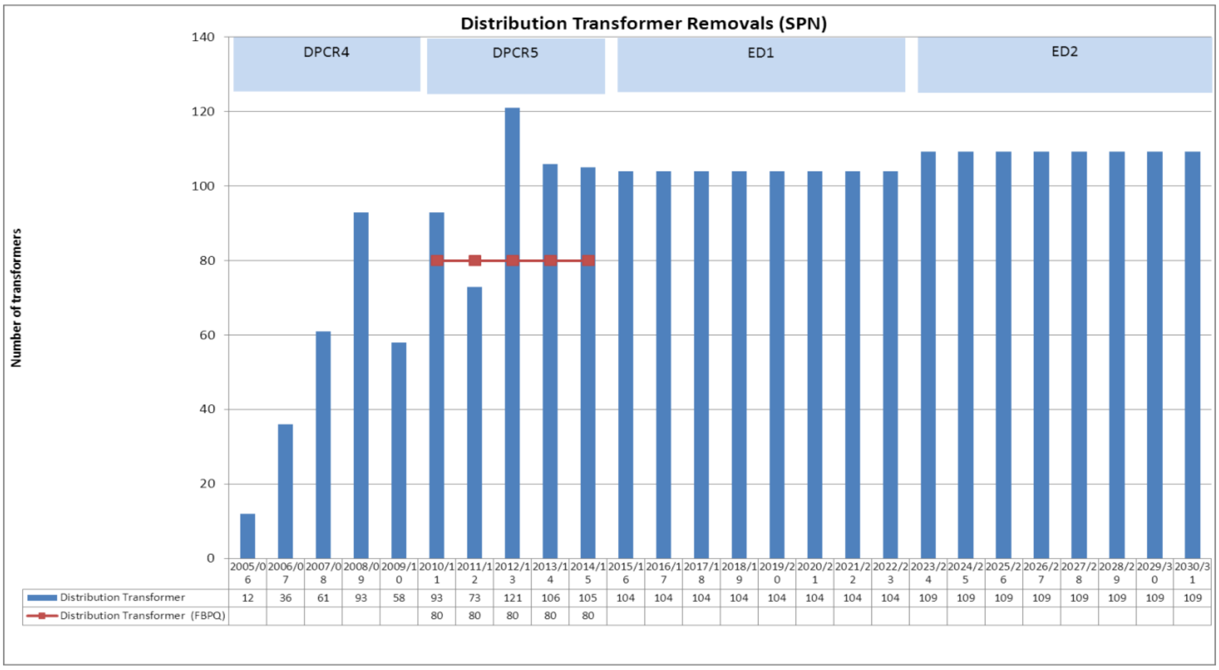

Figure 20: Distribution transformer volumes DPCR4 – ED2

Sources :
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 - Analysis from Age Based Model

8.1.1 Expenditure Graphs (DPCR4 - ED1)

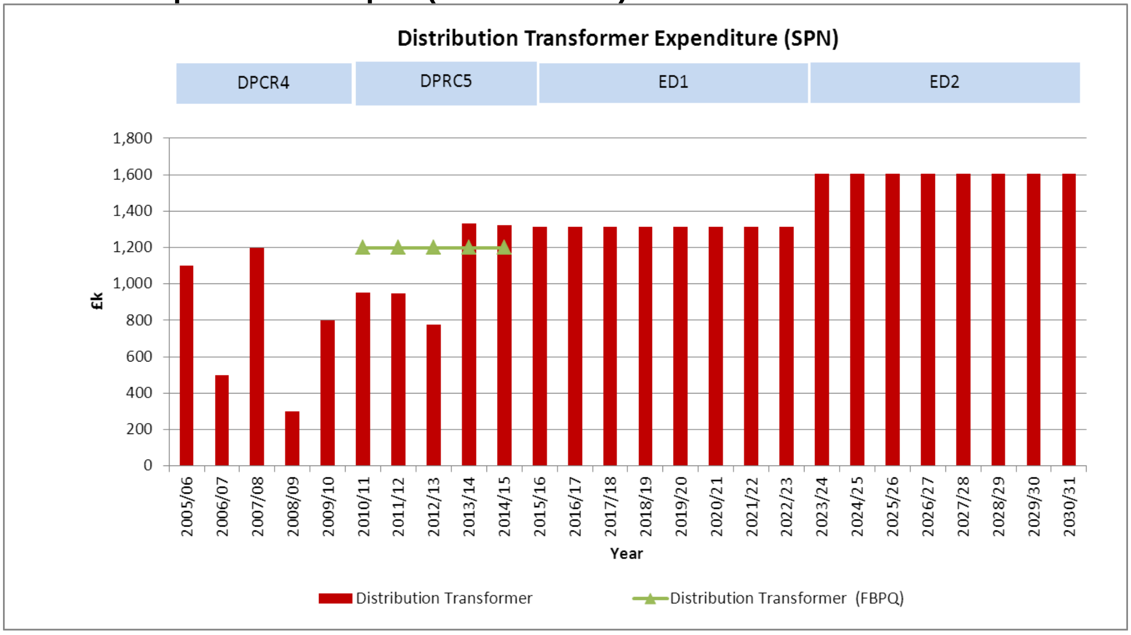

Figure 21: Distribution transformer costs DPCR4 – ED2

Sources:
DPCR4 & DPCR5 FBPQ - Table NL1 (DPCR5 FBPQ)
DPCR5 (First three years) - 2013/2014 RIGS CV3 table
DPCR5 (Last two years) – 14th June 2013 NAMP (Table JLI)
ED1 – 19th February 2014 NAMP (Table J Less Indirect)
ED2 - Analysis from Age Based Model * NAMP UCI

Appendix 6 Sensitivity Analysis and Plan Validation

See Section 7.6

Appendix 7 Named Schemes

Not relevant for distribution assets – no named schemes

Appendix 8 Output NAMP/ED1 Business Plan Data Table Reconciliation

	VOLUMES																				
Outputs	**Asset Stewardship Reports**										**Business Plan Data Table**										
Investment Description	**NAMP Line**	**2015/16**	**2016/17**	**2017/18**	**2018/19**	**2019/20**	**2020/21**	**2021/22**	**2022/23**	**Total**	**RIGs Table**	**RIGs Row**	**2015/16**	**2016/17**	**2017/18**	**2018/19**	**2019/20**	**2020/21**	**2021/22**	**2022/23**	**Total**
6.6/11kV Transformer (GM)	1.19.01	90	90	90	90	90	90	90	90	**720**	CV3	48	94	94	94	94	94	94	94	94	**752**
Replace 3.5 & 2KV Transformers	1.19.26	4	4	4	4	4	4	4	4	**32**											
6.6/11kV Transformer (GM) (Capital)	2.50.03	10	10	10	10	10	10	10	10	**80**	V4B	48	10	10	10	10	10	10	10	10	**80**
Total		**104**	**104**	**104**	**104**	**104**	**104**	**104**	**104**	**832**			**104**	**104**	**104**	**104**	**104**	**104**	**104**	**104**	**832**

Table 15 – NAMP to ED1 Business Plan Data Table Reconciliation

[*Source: 19th February 2014 Namp Table O / 21st February 2014 ED1 Business Plan Data Tables]*

Appendix 9 Efficiency Benchmarking with other DNOs

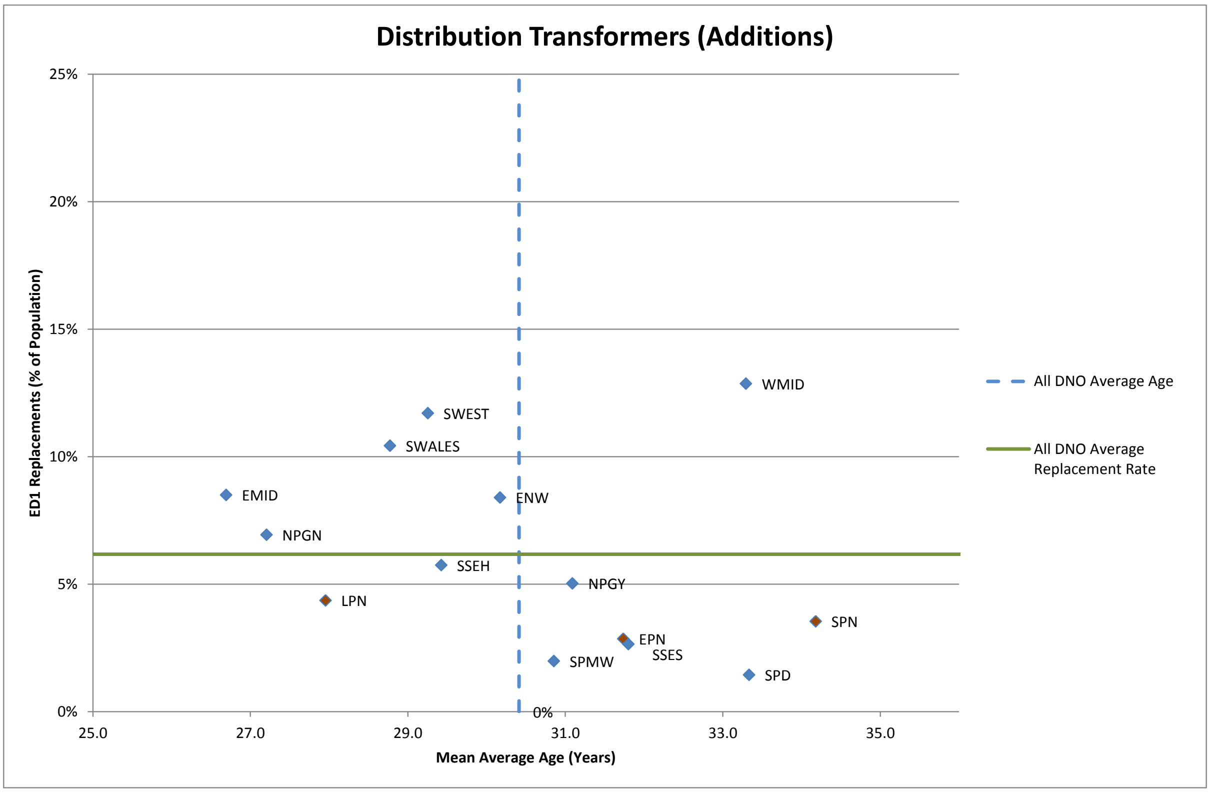

Figure 22 – Efficiency Benchmarking [Source: DNO Datashare_2013]

Figure 22 shows that SPN has a lower replacement rate than the industry average per percentage of population and a higher average age. As discussed in Section 7.2, the average life of a distribution transformer in SPN is 70 years, implying that most transformers will be replaced between 55 years and 85 years. Furthermore, the plan for ED1 has been based not only on the output from the age based statistical model but also compared to historical replacement rates, fault rates and condition of the oldest 10% of the population to determine the right outputs to use for investment forecasts.

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
6.6/11kV Distribution Transformers & 3.5/2kV Transformers	Replace	Volume (Additions)	752	752	0
		Volume (Removals)	752	752	0
		Investment (£m)	7.22	*10.44	3.22
		UCI (£k)	9.60	13.89	4.29

Table 16 – Material Changes to July 2013 ED1 Submission (CV3)

[Source: ED1 Business Plan Data Tables following the OFGEM Question and Answer Process / 21st February 2014 ED1Business Plan Data Tables]

The increase in investment between the 2013 and 2014 submission is due to partial discharge monitoring benefits that were negatively mapped to CV3 48 (as part of OFGEM question Ph1-84) being removed from this line.

The total investment for the replacement of distribution transformers, excluding fault restoration costs is £10.41m (as shown in Tables 1 and 2 of this document). This is split into the following tables:

- £9.95m maps to CV3 (asset replacement as shown in Table 16 above); and
- £0.46m maps to CV6 (plinth replacement).

There is a further £0.49m mapping to CV3 (*totalling £10.44m) for consequential costs from major projects.

Faults (V4b/CV15a)

Asset Type	Action	Change Type	2013 Submission	2014 Submission	Difference
6.6/11kV Distribution Transformers	Replace	Volume (Additions)	80	80	0
		Volume (Removals)	80	80	0
		Investment (£m)	Changes to capitalised fault restoration expenditure can be found in Document 14: SPN I&M and Faults		

Table 17 – Material Changes to July 2013 ED1 Submission (V4b)

[Source: ED1 Business Plan Data Tables following the OFGEM Question and Answer Process / 21st February 2014 ED1Business Plan Data Tables]