Document 1
Asset Category – Towers and Conductors
SPN

Asset Stewardship Report 2014

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Document History

Version	Date	Details	Originator	Revision Class	Section Update
1.0	13/02/2014	Original submission	N/A	N/A	N/A
1.1	13/02/2014	Changes to HI Graphs – due to error correction. Inclusion of new appendices 8, 9 and 10 Update all costs in document to reflect revised NAMP 19th February 2014 Correction to foundation costs Update to third part audit date	Nick Xydas	Minor	7.2 Appendices 8, 9 and 10 All NAMP based cost references Table 1 and 6 Section 4.6
1.2	25/02/2014	Updates following release of new version of checklist and Preface added	Richard Gould	Minor	Preface Appendix 10
1.3	26/02/2014	Figure and table numbers added to Appendices.	Richard Gould	Minor	Appendix 1-10
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1.5	28/02/2014	Update following R. Wakelen review	Richard Gould	Minor	Appendix 9

1.6	04/03/2014	Tower Age Profiles updated with latest BPDT V5 profile	Richard Gould	Minor	
1.7	05/03/2014	Align with final HI profiles	Brian Matthews	Minor	Appendix 2
2.0	05/03/2014	Final version	Brian Matthews	Minor	None

Preface

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

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

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

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

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

1. **Appendix 8 - Output NAMP/ED1 RIGS reconciliation:** This section explains the 'line of sight' between the UKPN Network Asset Management Plan (NAMP) replacement volumes contained in the Ofgem RIGS tables. The NAMP is the UKPN ten year rolling asset management investment plan. It is used as the overarching plan to drive both direct and indirect Capex and Opex interventions volumes and 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 and 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 Tower Lines

1.1 Scope

This document details SPN's NLRE (non-load related expenditure) replacement proposals for 33kV and 132kV overhead tower lines for the RIIO-ED1 period.

There are 1,234 circuit km of conductor in SPN, on 2,575 132kV towers and 575 33kV towers, with a total estimated MEAV of £523m. The proposed investment for 33kV and 132kV tower lines in SPN is £18.6m and this equates to 3.4% of the MEAV for these asset categories.

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 abbreviations is included in Section 6.0 of Document 20: Capex Opex overview.

A reconciliation between NAMP and RIGS outputs is included in Appendix 8.

Investment type	ED1	NAMP line	RIGs
Asset replacement (including insulators and fittings): 33kV overhead tower line	£0.3m	1.02.02	**Volumes – Table CV3** **Additions:** · Row 56 – EHV – 33kV OHL (Tower line) Conductor · Row 58 – EHV – 33kV Fittings **Removals:** · Row 170 – EHV – 33kV OHL (Tower line) Conductor · Row 172 – EHV – 33kV Fittings **Costs – Table CV3** · Row 56 – EHV – 33kV OHL (Tower line) Conductor · Row 58 – EHV – 33kV Fittings
Asset replacement (including insulators and fittings): 132kV overhead tower line	£17.4m*	1.02.03 and 1.02.90	**Volumes – Table CV3** **Additions:** · Row 89 – 132kV – 132kV OHL (Tower Line) Conductor · Row 91 – 132kV – 132kV Fittings **Removals:** · Row 203 – 132kV – 132kV OHL (Tower Line) Conductor · Row 205 – 132kV – 132kV Fittings **Costs – Table CV3** · Row 89 – 132kV – 132kV OHL (Tower Line) Conductor · Row 91 – 132kV – 132kV Fittings
Asset replacement (including insulators and fittings): 33kV overhead tower line	£0.9m	1.02.02	**Cost - Table CV5** Row 29 – 33kV Tower refurbishment

Table 1 – Investment areas (ref: 2013 RIGs tables, CV3)

**excludes PO route refurbishment High Value Project (this is detailed in CV9a)*

1.2 Investment Strategy

The long-term investment proposal for the replacement of overhead tower lines has been informed using the age profile of the overhead tower lines. The investment levels have been set to manage the network risks by keeping the number of overhead tower line assets that have a high Health Index (HI4 or HI5) to a reasonable level.

1.3 Innovation

A range of innovative asset management solutions is being trialled in DPCR5 and will be implemented in ED1. These include:

- **Foundation condition:** A trial was carried out of non-invasive condition-assessment techniques using TDR (transient dynamic response) and PR (polarisation response) in 2011. This will be rolled out as policy within UK Power Networks.

- **Foundation reinforcement :** Mini-piles were used in 2010 for foundation reinforcement as an efficient alternative to excavation and reinstallation. This will be used throughout ED1 particularly where Malone anchors are found to exist

- **Insulator condition assessment verification:** A study comparing the actual laboratory-measured performance of insulator strings against the expected condition from visual assessment was completed. The results of the test provided a better understanding of the relationship between visual inspections and the residual strength of overhead line assets.

- **ACCC:** A conductor type with a very low thermal expansion core called ACCC (Aluminium Conductor Carbon Core) was installed on the PRA Bolney–Three Bridges overhead line. The main advantage of using this conductor is the ability to uprate the capacity without the need to raise or strengthen the existing towers.

1.4 Risks and Opportunities

	Description of similarly likely opportunities or risks arising in ED1 period	**Level of (uncertainties)/ cost growth (£m)**
Risk/Opportunity	Implement non-invasive condition assessment techniques for foundations	May increase or decrease the level of investment required for foundations in ED1 +/- 5% of ED1 investment plan
Risk/Opportunity	Cormon test results might lead to a change in the ED1 forecast	May increase or decrease the level of investment required for overhead tower line restrings by +/- 5%

Table 2 – Risks and opportunities

2.0 Description of Overhead Line Population

This document focuses on NLRE investment proposals for broad-based towers supporting 33kV and 132kV overhead line circuits. Narrow-based towers are outside the scope of this document. Figure 1 shows the comparative designs of typical narrow-based and broad-based steel towers.

Figure 1 – a narrow-based (left) and broad-based (right) tower, side-by-side, illustrating the differences in design and construction

2.1 Overhead Line Assets

2.1.1 Conductors

In the SPN region, there are 1,234km of conductor installed, the majority of which are the conventional aluminium conductor with steel reinforcement (ACSR); the balance is the more contemporary all-aluminium alloy conductor (AAAC). Figure 2 shows the split of conductor types across the region by km of length installed.

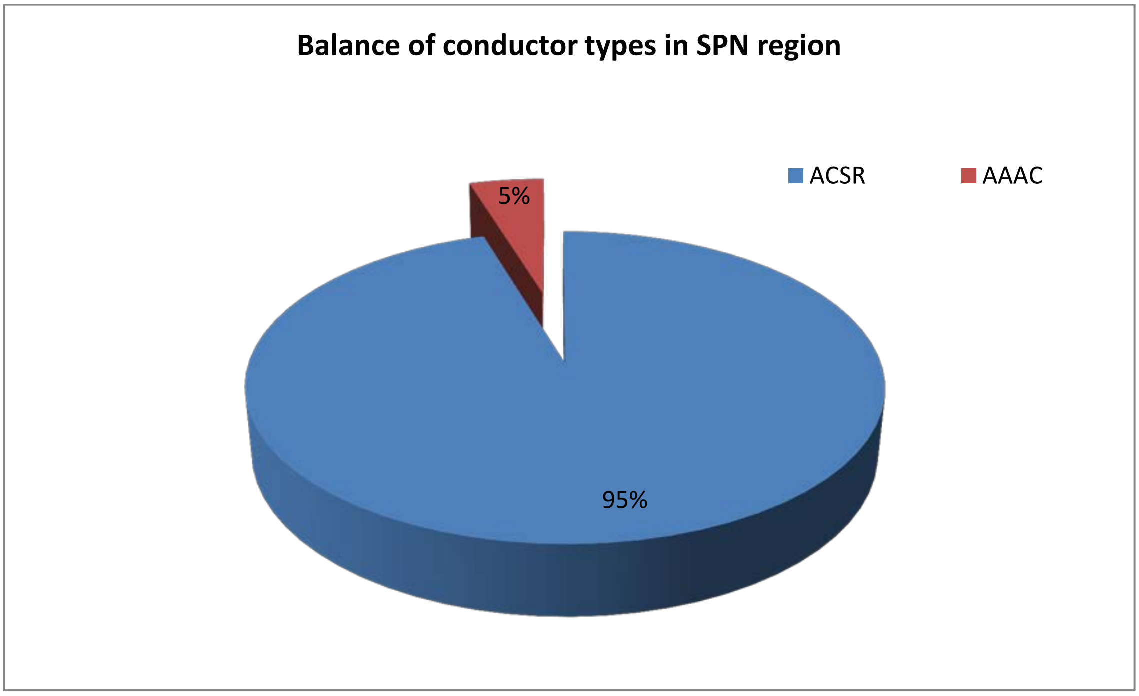

Figure 2 : Breakdown of conductor types across the SPN region by ratio of installed km

An innovative conductor type has been introduced to the SPN network. ACCC has a carbon-based tension-bearing element, offering considerable savings in remedial work and power losses. This is discussed further in section 6.4.

The mean average age of the 132kV conductors is 30 years (1983 installation) and the mean average age of the 33kV conductors is 60 years (1953 installation). The full age profiles are shown in Figures 3 and 4..

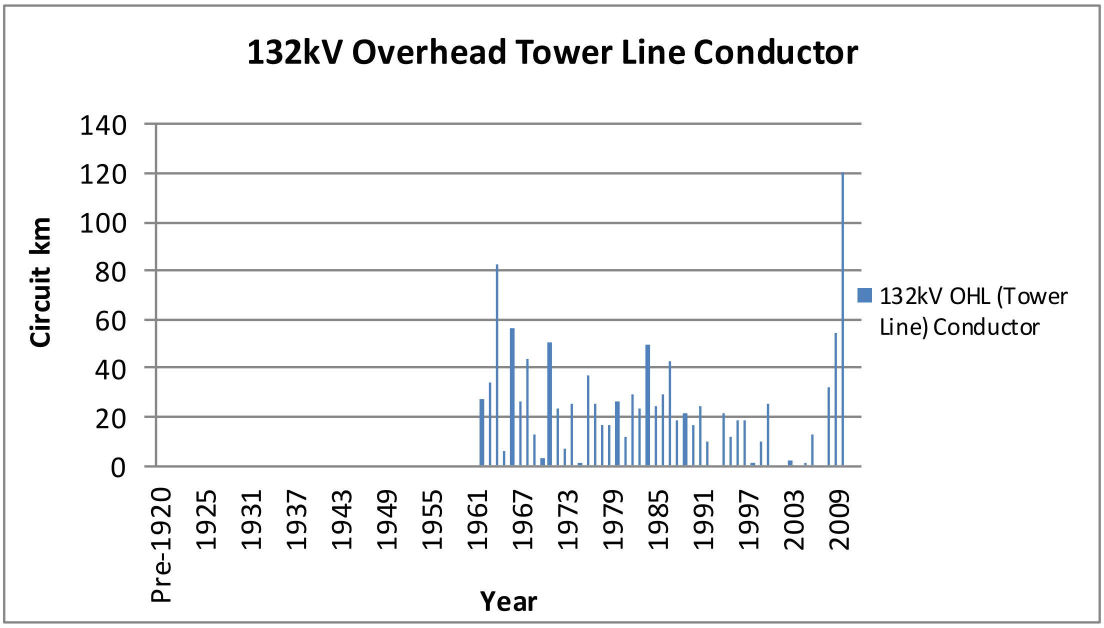

Figure 3: 132kV conductor age profile in SPN region (V5 2012 RIGs)

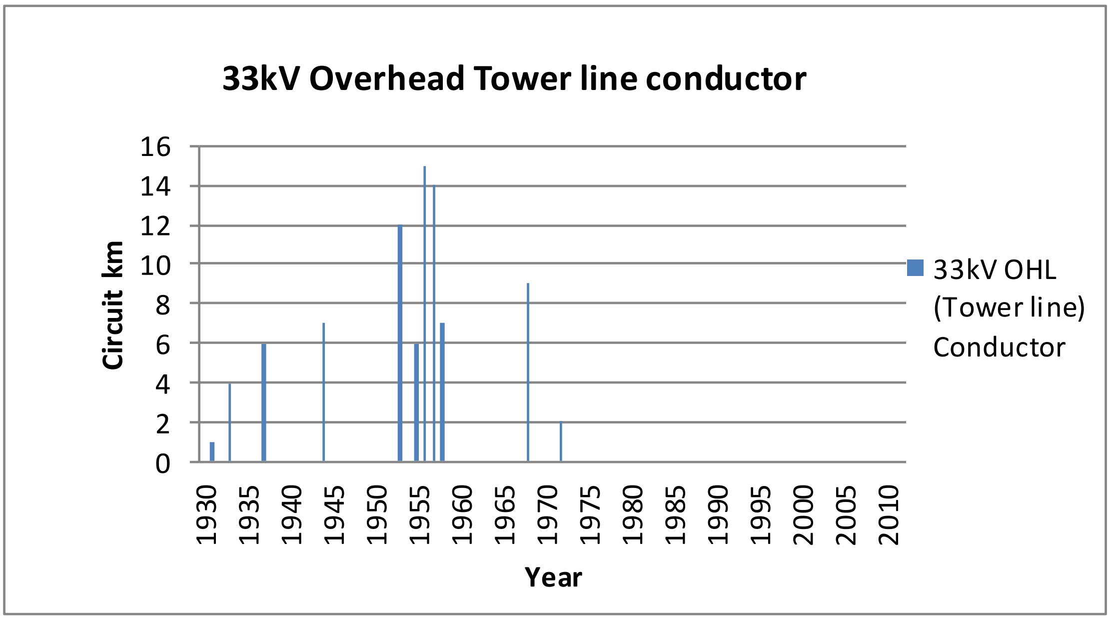

Figure 4 : 33kV conductor age profile in SPN region (V5 2012 RIGs)

2.1.2 Towers

In the SPN region, there are 2,575 132kV and 575 33kV broad-based steel towers. The mean age of these all of these towers is 64 years (1949 construction), with the average age of the oldest 10% being 83 years old. Figure 5 illustrates the balance of 33kV and 132kV tower types. Figures 6 and 7 show the full age profile of 132kV and 33kV towers across the SPN region.

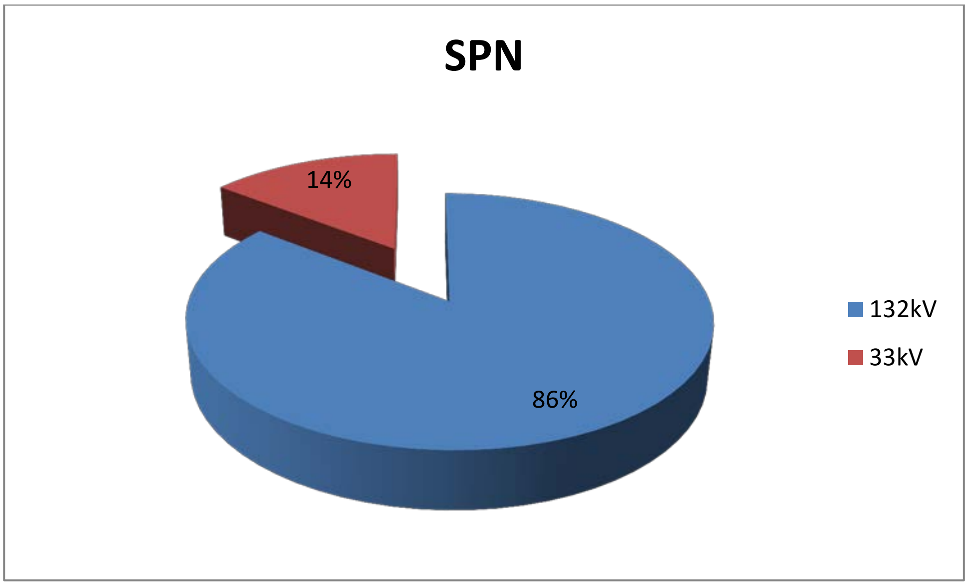

Figure 5 : Breakdown of tower types across SPN (132kV or 33kV)

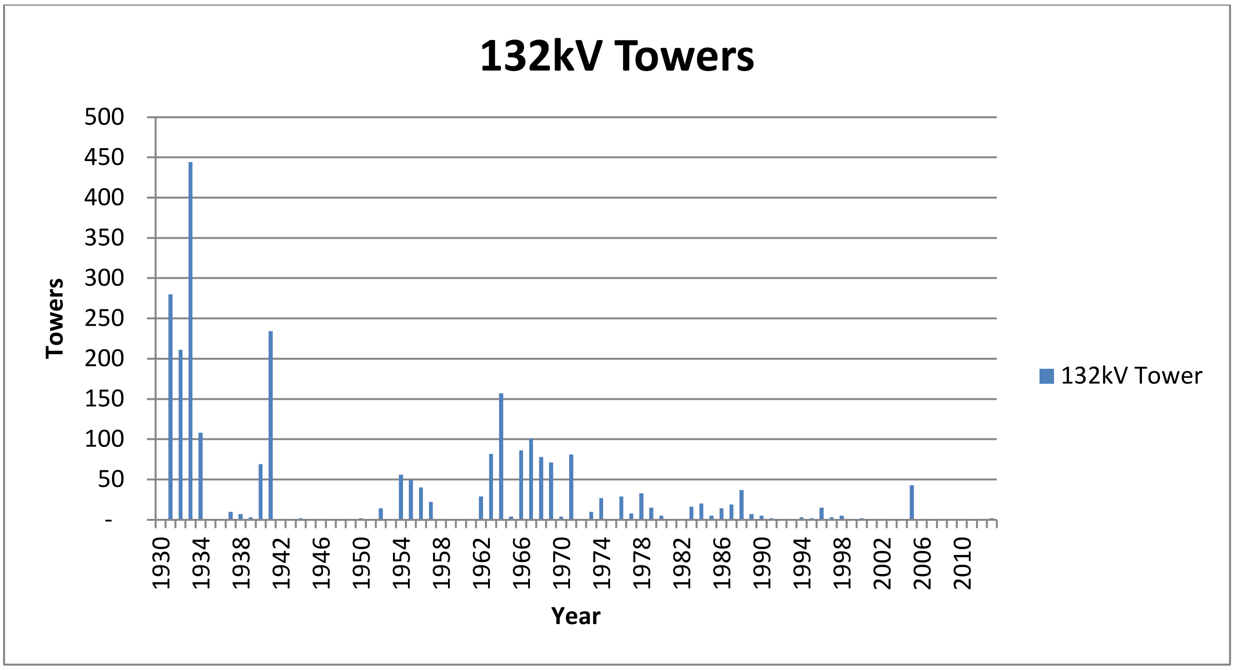

Figure 6 : 132kV tower age profile (V5 2013 RIGs)

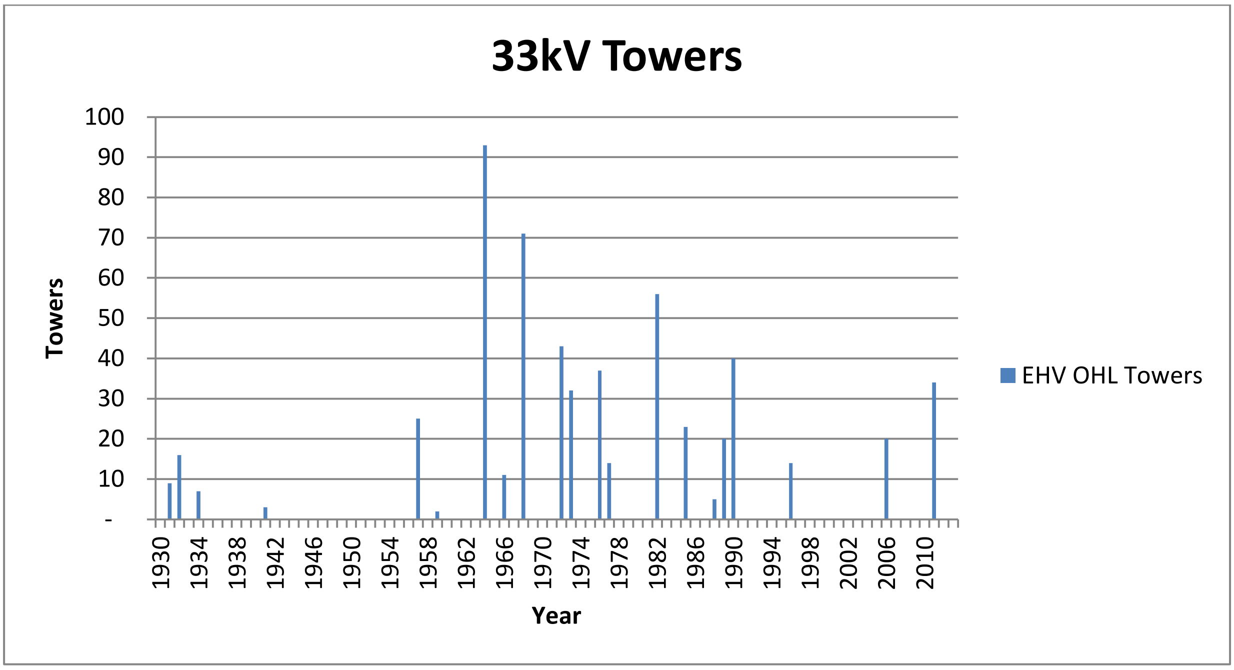

Figure 7: 33KV tower age profile (V5 2013 RIGs)

2.1.3 Insulators/Fittings

This section includes all the components between an overhead line tower attachment plate and the end of an insulator string. All the insulators/fittings on one side of a tower are considered as a set of insulators/fittings hence there are two sets of insulators/fittings on double circuit overhead line routes and one set on single circuit routes.

In the SPN region, there are 5,682 fittings. The mean age of the fittings is 47 years (1966 installation).

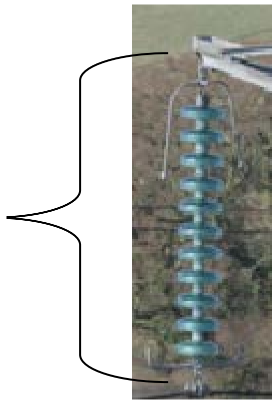

Figure 8 : Insulator/fitting (overhead tower line)

Insulators and fittings are replaced by default as part of restring (conductor replacement) schemes and standard insulator and fittings replacement schemes. For this reason the age profile of insulators/fittings is similar to the age profile of the associated overhead line conductor.

3.0 Investment Drivers

The high-level investment drivers for overhead line assets are detailed in EDP 00-0010, *Asset Lifecycle Strategy: Overhead Tower Lines*. In summary, the strategy for investment decisions is based on minimising risk to the public and maximising asset performance, while managing environmental impact.

To achieve this, several key indicators are used to highlight the requirement for replacement or refurbishment:

- Asset condition reports are based on routine inspections of overhead lines using foot patrol surveys, helicopter surveys or Cormon tests. Each of these is described in section 3.1.
- Network performance records are analysed and collated to summarise Customer Interruptions (CIs) and Customer Minutes Lost (CML) each year.
- Failure mode and effect analysis is conducted to ensure that a reliability-centred maintenance approach is taken to the management of asset condition.
- Electricity Supply, Quality and Continuity Regulations (ESQCR) issues are highlighted through safety patrols, as directed by the *UK Power Networks Overhead Line Inspectors Handbook*.
- Condition-based reliability studies are periodically carried out. An example of a recent reliability study is described in section 6.0.
- UK Power Networks is a regular member of the STP2 forum, hosted by EA Technology, where emerging technologies are discussed and reviewed.

3.1 Condition

3.1.1 Visual assessment

The primary source of up-to-date asset condition data comes from a comprehensive overhead line inspection regime. The *UK Power Networks Overhead Line Inspectors' Handbook* gives guidance on the inspection of all aspects of the overhead line network, including overhead structures and supports, conductors, spans, plant and equipment, risk and accessibility to the general public and mitigation work to minimise risks to the public.

Figure 9 focuses on part of one tower on the PO route, which runs from Eastbourne to Lewes on the south coast. This was subsequently repaired, but is a good illustration of the level of degradation that can occur, particularly in coastal regions. The steelwork has clearly lost its galvanising and the structural integrity of the member has been compromised to the point that it is beyond repair and requires replacement.

Figure 9 : A very poor condition tower steelwork member, illustrating the extremes of deterioration that can be found on the UK Power Networks assets

In addition to regular foot patrol inspections UK Power Networks carries out helicopter-based aerial photography that provides very-high-resolution imagery of towers and associated components. Figures 11 and 12 show, respectively, a high-resolution image and an enlarged portion of the same image with a closer detail view of the condition of the steelwork. This level of resolution permits a detailed condition assessment to be made from the desktop (**Note:** This image is at a much higher resolution when viewed outside of this report). This enables the asset management team to view in considerable detail the condition of the structures and components, complementing the information available from visual assessment and from historical data sources.

In addition to degradation from corrosion, some of these components are subject to relatively high mechanical load from both static and dynamic processes. Wear is a mechanical process that is common between moving parts; over time, the small movements that occur between these types of components can weaken the capabilities significantly. Figure 10 shows a considerably worn mechanical link, where the movement between the parts has worn away more than 50% of the load-bearing material.

Figure 10 : A worn shackle showing the extent of degradation that can occur on fittings from mechanical processes such as wear

Figure 11 : High-resolution image of a portion of an SPN tower on route PCA

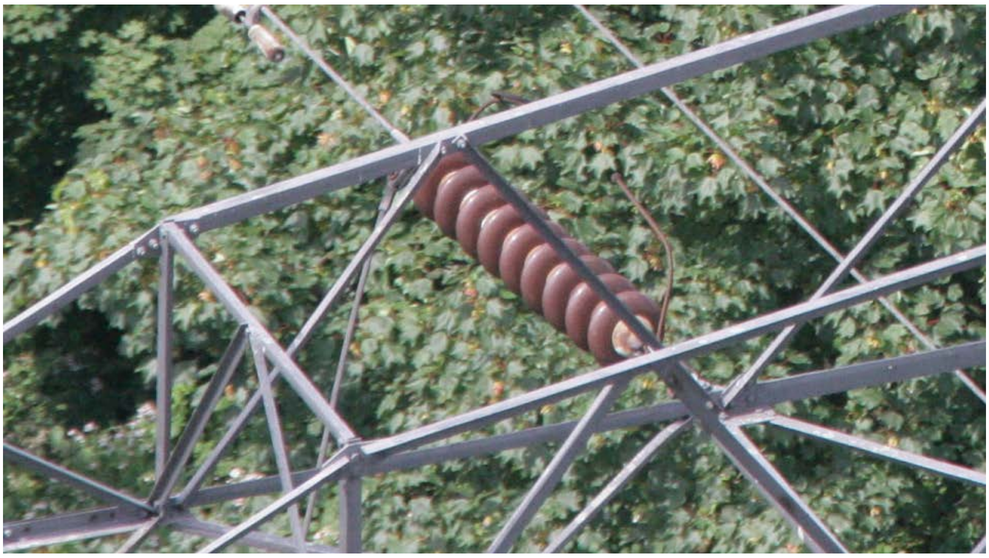

Figure 12 : An enlarged portion of 1, showing the level of detail that can be seen as part of a desktop assessment/condition appraisal

UK Power Networks document EMS 10-0002– *Inspection and maintenance frequency schedule* specifies the inspection and maintenance frequencies for all plant. Inspection is currently carried out bi-annually for broad-based towers and annually for sites identified as high risk. For conductors, Cormon tests are carried out (further details are provided in section 3.1.2). Thermal imaging is also carried out every two years on overhead lines to identify hot spots on the conductors or fittings.

In all cases, condition levels are recorded as 1 (as new), 2 (normal for age, no work needed), 3 (remedial work needed in the medium term, next maintenance cycle) or 4 (replacement needed).

Examples of condition data collected during inspection and maintenance are shown in Table 3.

	Condition assessment measures	Description
Conductor	Circuit 1 Cormon condition Circuit 2 Cormon condition Earth Cormon condition	Condition of conductor determined from Cormon test results. Cormon results show the degree of loss of galvanising of the steel, which is an indication of the condition of the conductors
	CCT1 conductor damage CCT2 conductor damage Earth conductor damage	These condition measures are collected during foot patrols. They are visual assessments of the conductor, based on indicators such as stranding, bird caging, etc.
Insulators and fittings	CCT1 insulator/fittings condition CCT2 insulator/fittings condition CCT1 insulator shattered cracked flashed over CCT2 insulator shattered cracked flashed over CCT1 fitting wear CCT2 fitting wear Earth insulator/fittings condition	Visual assessment based on foot patrols and helicopter surveys
Tower steelwork	Condition of steelwork Condition of tower painted surface Condition of steel structure Paint condition (steel structures)	Visual assessment based on foot patrols and helicopter surveys
Tower muffs	Condition of paintwork on muff Muffs defective	Visual assessment based on foot patrols
Other tower assets	Earth dampers defective CCT1 dampers defective CCT2 dampers defective CCT1 arcing horns defective CCT2 arcing horns defective CCT1 spacers defective CCT2 spacers defective	Visual assessment based on foot patrols and helicopter surveys

Table 3 – Example condition points used in overhead line ARP models

3.1.2 Cormon testing and monitoring for conductors

The Cormon test is a corrosion-monitoring test carried out on steel-reinforced aluminium conductors to detect loss of galvanising. Loss of galvanising means that the aluminium strands are susceptible to galvanic corrosion and would result in the conductor condition deteriorating rapidly. Cormon test results provide a good indication of the extent to which corrosion is likely to have occurred inside a conductor body where the tension-bearing element resides.

As a policy, Cormon assessments are carried out on overhead line circuits that are more than 40 years old. If this test indicates that the conductor is in poor condition (condition rating 4), the conductor is replaced. Circuits that pass a Cormon test at 40 years are retested after 10 years.

UK Power Networks has carried out Cormon testing since 1988. A summary of the results of the 466 spans in EPN and SPN, across 65 overhead line routes is shown in Table 4.

	Count					Percentage			
Age Band	CR1	CR2	CR3	CR4	Total	CR1	CR2	CR3	**CR4**
40-50	8	15	8	4	35	23%	43%	23%	**11%**
>50	5	10	1	14	30	17%	33%	3%	**47%**

Table 4 : Summary of Cormon test results

This shows that 47% of the conductors over 50 years old failed a Cormon test. This is a marked increase from test results for conductors between 40 and 50 years of age, of which only 11% failed the Cormon test. The average age of conductors when they failed the Cormon test was 52 years.

Based on the analyses, about half of conductors over 50 years old that are Cormon-tested in ED1 are expected to be condition 4. Another 11% of conductors between 40 and 50 years of age are expected to fail a Cormon test in ED1.

The ED1 plan has been determined based on conductor age profile analysis. A 55-year threshold has been chosen as a reasonable life expectancy, supported by these analyses. Cormon testing will continue through ED1 and the increased dataset will be used to calibrate future life expectations. This indicates an increase in expected average asset life of 132kV and 33kV conductors from 40 years in DPCR5 to 55 years in ED1.

Figure 13 shows sample results from a piece of poor condition ACSR conductor recently retrieved from the PV route near Folkestone on the south coast and disassembled for analysis. The top figure shows surface corrosion on the conductor before disassembly; the bottom figure shows the corrosion that has occurred in between the component strands of the conductor. An increase in corrosion directly relates to a decrease in tensile strength and increased risk of failure. Much of this degradation can be hidden from view, but would likely appear on the Cormon test.

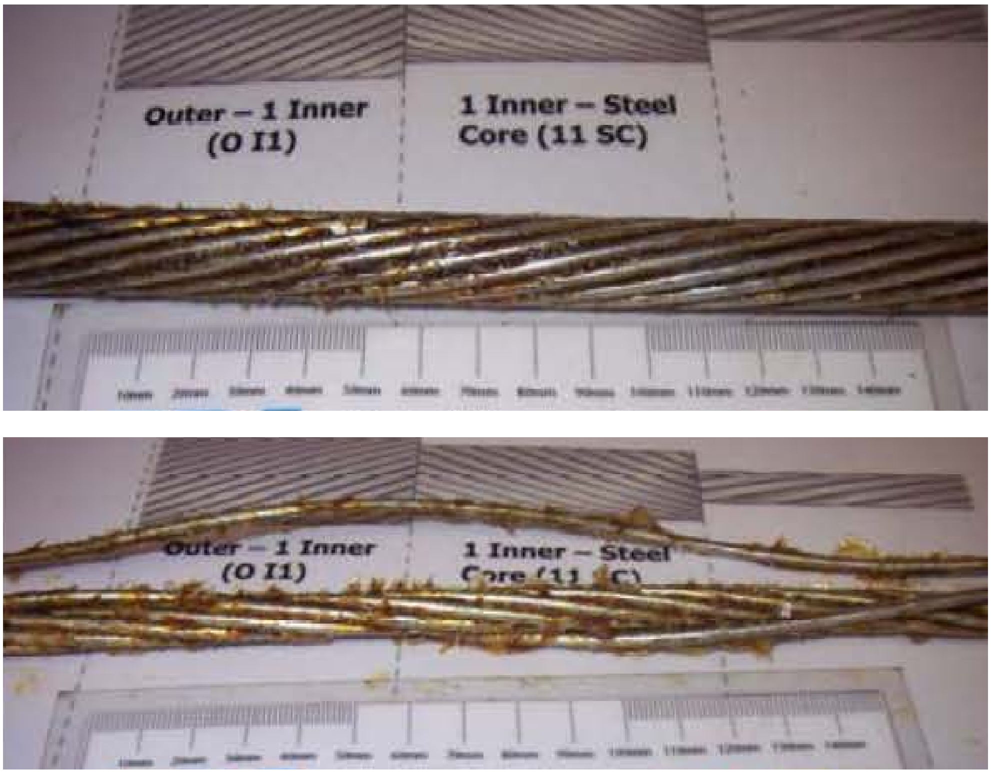

Figure 13 : A poor-condition ACSR conductor from an SPN route, showing the extent of hidden corrosion that can occur between conductor strands

3.2 Fault Rate

The fault rates, split by condition and non-condition causes, are shown in Figures 14 and 15.

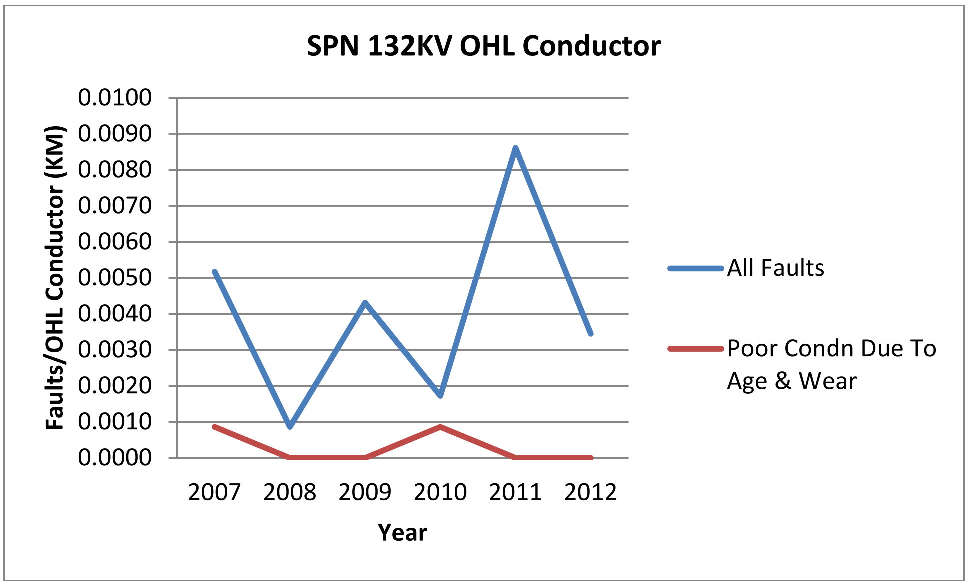

Figure 14 : 132kV OHL fault rates (fault cube)

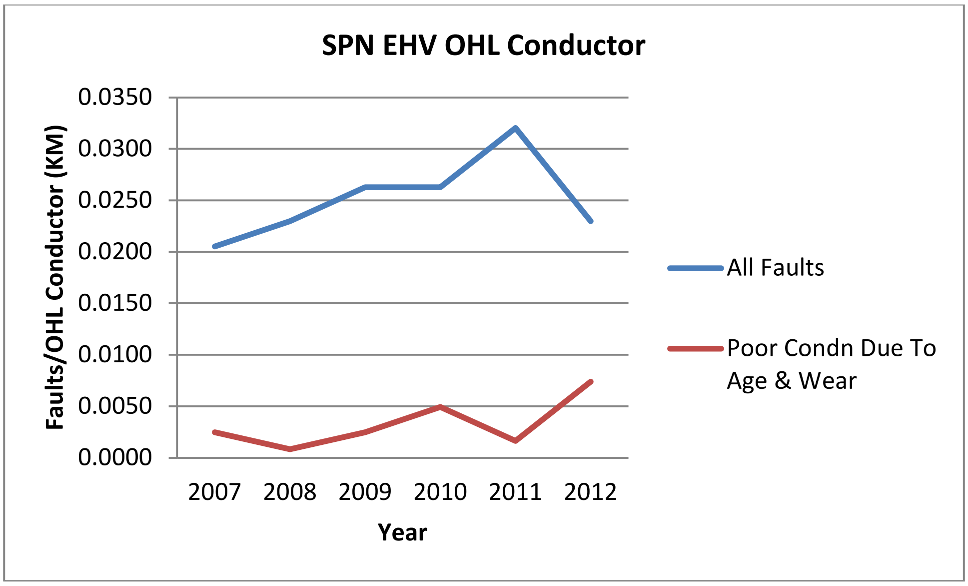

Figure 15 : 33kV OHL fault rates (fault cube)

Across all conductors, condition-related faults have been steady for the past six years and relatively low compared to the total faults that have arisen. There have been very few at 132kV, but there has been a slight rise in 33kV faults. However, this is not a significant proportion of the population base. We are aware of a recent incident on a 132kV line that will increase 2013's fault figures when they are available. So while the fault frequency is not a driving cause for the required investment, it is likely that investment primarily for condition and age will maintain a manageable fault rate across the ED1 period.

4.0 Asset Assessment

4.1 Asset Health

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

The general methodology for the ARP model can be found in *Document Commentary 15: Model Overview*.

The overhead line ARP models use the age of an asset, location information and condition data to calculate an overall Health Index. An age-related HI is calculated from the average asset life and the location of the asset in terms of the environmental effects of its geographical positioning. Proximity to coast, pollution levels and altitude have an effect on the degradation of these assets and are reflected in the ARP model.

A condition-related HI can be derived from either the helicopter inspection data or the foot patrol data, depending upon the reliability of the information. The acceptable reliability level can be set within the model's calibration parameters.

From this, an overall HI can be calculated using a method that is dependent upon the asset type.

The ARP model for overhead lines has been used to inform decisions regarding the investment plans presented in this documents but not as the sole decision making tool. The overhead line model is undergoing further development to improve the asset degradation forecasts so age based modelling has been used in support of ARP.

4.2 Asset Criticality

The ARP model also holds location and asset data that allows the criticality of each overhead line asset to be easily reviewed. The ARP criticality function is currently under development for steel towers so has not been used to drive this plan. This methodology is described here and will be further developed and implemented throughout 2013.

The ARP model outputs a Criticality Index 1 to 4, with 1 being the least critical and 4 being the most. A detailed methodology for calculating the criticality index can be found in *Document Commentary 15: Model Overview*.

In the overhead line ARP model, four main areas can be considered when calculating the criticality of an asset(s): network performance, safety, financial and environmental. A number of key factors are considered in each of these areas.

For network performance, the key factors are the circuit rating, fraction of load at risk during failure and average value of unsupplied energy. The safety criticality specific to overhead lines is based around the ESQCR and proximity of major crossings. The financial criticality is split into operational and capital expenditure sections. All faults have been associated with an operation cost for the overhead line model, and grouped by major crossings, environmentally sensitive areas and tower type, distinguishing 33 and 132kV. Finally, the environment section considers the proximity of major crossings and environmentally sensitive areas.

4.3 Network Risk

Risk can be incorporated to provide a more complete means of optimising investment. The risk of an asset failing is a combination of the probability of failure (such as age, duty, etc.) and the consequence of failure (such as network performance, etc.). 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, opex
- Environmental

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. This approach to assessing asset risk is currently under development and has not been used in the preparation of the ED1 plan.

4.4 Data Validation

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

4.5 Data Verification

A sampling approach to data verification follows each data upload to ensure accurate transfer into the models.

4.6 Data Quality

The completeness, accuracy and timeliness of the data used in the ARP model are routinely checked. For the results for the data used in the ARP model for tower lines, refer to Table 5.

Area	Result
Completeness	68%
Accuracy	TBC
Timeliness	94%

Table 5 : Data CAT scores

Source: ARP Steel Tower data quality report 5th April 2013

The completeness score indicates that data flow is reasonably good for the majority of asset groups and some gaps have been identified, which are due to the time elapsed since data extraction from the source and ARP. The accuracy score indicates whether the data accuracy is at an acceptable level based on the inspector's personal experience and the knowledge of independent surveys undertaken by a third-party independent consultant. Third party surveys are planned for 2014 for steel towers.

The timeliness score places a good emphasis on maintenance and inspection operations of UK Power Networks' assets, and defines to what extent the data is timely and up to date.

5.0 Intervention Policies

5.1 Selecting Preferred Interventions

When determining what types of interventions are required for ED1, there are three broad categories of intervention available. Figure 16 describes each of these, in order of significance of work required, and also the decision-making process.

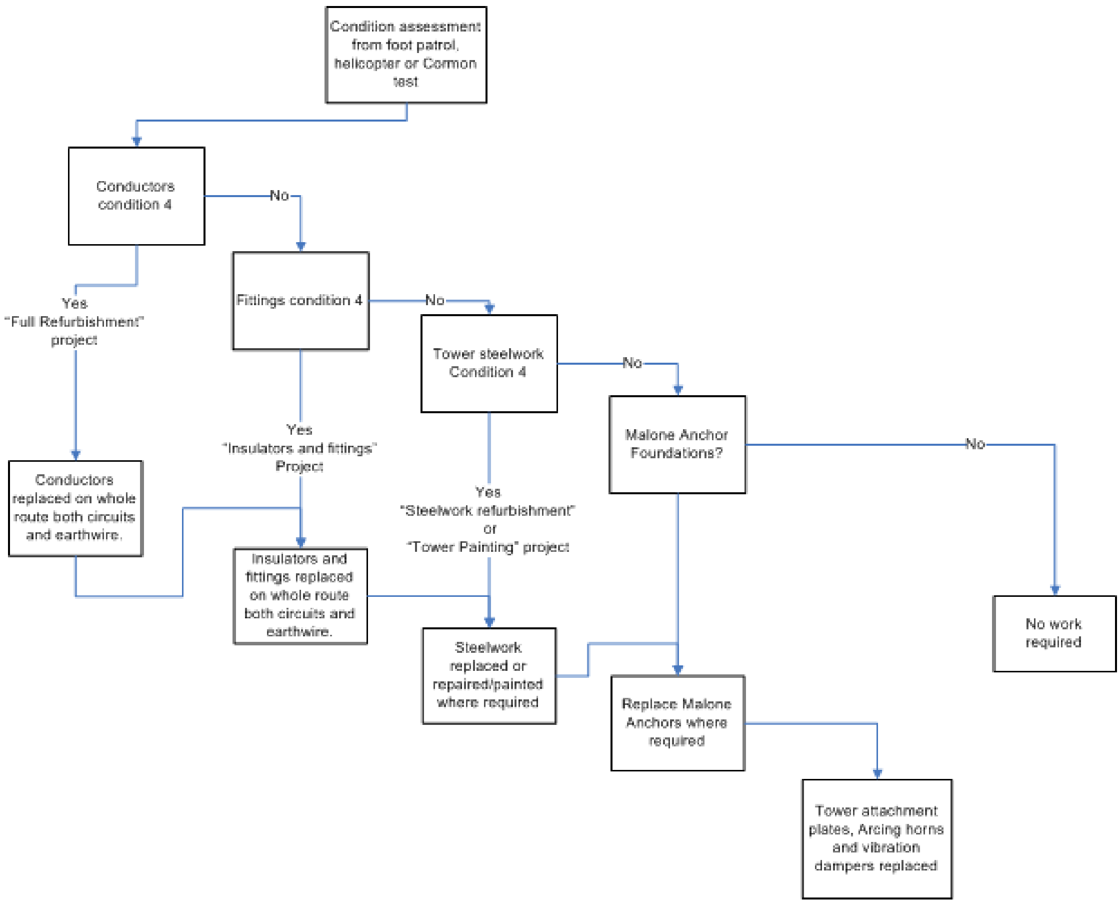

Figure 16 : Project scope decision process flow

5.2 Interventions: Description of Intervention Options

5.2.1 Asset replacement project

Where a span of conductor is identified as condition 4 from Cormon testing, that span will be replaced along with all other spans, of the same age profile, in that circuit. This is based on the all the spans on the same circuit being of a similar construction and having similar duty requirements. This is stated in UK Power Networks process documents *EDS 01-0003 Refurbishment and replacement standard for broad-based towers*.

The scope of an overhead line asset replacement project will typically include:

- Replacement of all the conductors
- Replacement of all the insulators and fittings associated with the reconductored span
- Remedial work on tower steelwork where required
- Replacement or reinforcement of Malone anchors where required
- Other minor replacements, such as step-bolts, repair of muffs, ACDs, etc.

In most cases the conductor will be replaced "like-for-like", i.e. a similar or equivalent conductor.

5.2.2 Insulator and fittings replacement projects

Where insulators or fittings are identified as condition 4 from visual inspection, either helicopter or foot patrol, they will be replaced. At the same time, the following items will also be replaced: all insulators and fittings on the same circuit and any tower steelwork that requires remediation, along with the tower attachment plates, arcing horns and vibration dampers, and Malone anchors where necessary.

5.2.3 Tower steelwork replacement projects

If the conductor and insulators and fittings are in sound condition, it is possible to carry out steelwork replacement projects where only steel members are replaced, along with the tower attachment plates, arcing horns and vibration dampers, and Malone anchors where necessary.

A regular tower-painting programme is required to prevent the breakdown of the coatings that are in place and avoid further deterioration of reasonable condition towers.

When the regular tower-painting programme is inadequate for the rate of deterioration, the steelwork below can continue to degrade. At the point that the steelwork degrades to condition 4 and recoating is no longer a viable option, replacement of the member is required. If more than 50% of the steelwork is below condition 4, replacing the whole tower is a more cost-effective measure.

5.2.4 Foundation replacement or reinforcement projects

In all types of project if Malone anchors are the existing foundation type they will be replaced or reinforced. Depending upon the nature of the conductor, fittings and steelwork refurbishment required a range of foundation replacement options can be implemented.

One reinforcement solution, implemented in DPCR5, is a mini-pile enhancement. This increases the structural capability of the existing Malone anchor by driving many small piles into/through the existing foundation, restoring full foundation performance without excavation or associated works.

Mini-piling is a useful solution in some circumstances and will be implemented forming part of the foundation replacement/reinforcement options for ED1.

5.2.5 Other interventions

ESQCR replacements will be carried out when routine inspection identifies extra mitigation. The full ESQCR policy is found in *EOS 09-0061 Assessing the risk to the public from distribution network assets*; in summary, it identifies sites with an increased risk to the public, and defects, such as over-growing vegetation, which can cause electrical clearance infringements. ESQCR interventions and scope are detailed in Document 12 - ESQCR.

6.0 Innovation

6.1 Foundation condition

Understanding the condition of tower foundations is a critical part of the management of the towers. Degradation occurring below ground presents a different range of challenges. One technique that has been developed for use on towers is a combination of TDR (transient dynamic response) and PR (polarisation response). Both are non-intrusive techniques that indicate the condition and integrity of the structure below soil. In 2009, UK Power Networks conducted trials on its network to understand and develop these techniques, which will be introduced during ED1.

6.2 Foundation reinforcement

A mini-pile solution, described in section 5, was implemented during 2010 for the first time in UK power networks on the POA route from Sundon – Bedford in EPN. This technique has particular advantages for strengthening traditional foundations by driving reinforcement into the existing foundation without the need for excavation. This will be further implemented during ED1, particularly as an efficient solution for dealing with Malone anchors, where performance capability is often uncertain.

6.3 Insulator condition-assessment verification

Following some insulator mechanical failures on the Peterborough to March 132kV tower route (PIA), along with an accelerated condition 4 replacement programme, UK Power Networks carried out a study comparing the actual laboratory-measured performance of insulator strings with the expected condition from visual assessment. Condition 4 strings were removed from service on the network and carefully transported to a laboratory, where they were tested mechanically and electrically against an expected performance level.

The results showed that each of the strings, despite being considered condition 4 from visual inspection, continued to have residual strength in excess of expectations, indicating a reasonable serviceable life remaining. These conclusions have initiated a further IFI-funded project to consider the visual inspection techniques employed, the modelling assumptions and condition-rating criteria.

6.4 ACCC

The SPN PRA Bolney–Three Bridges line required conductor replacement due to condition and an increase in capacity. Because of restrictions in the electrical clearances, an innovative alternative was implemented for the first time in the

UK Distribution Network Operators. A conductor type with a very low thermal expansion core called ACCC (Aluminium Conductor Carbon Core) was installed in place of the existing Lynx ACSR conductor. The primary advantage of this type of conductor is its ability to transmit a high current at a high temperature with very little change in sag. In theory, this permits installed tension to be relatively low compared to steel core conductors, where an increase in temperature causes significant sagging and clearance issues. In this scheme, the main advantage was an ability to uprate the capacity without the need to raise or strengthen the existing towers. In addition, the higher capacity of this conductor enabled the replacement of a twin conductor circuit with a single conductor, which removed the need for future maintenance of spacers.

7.0 ED1 Expenditure Requirements for Overhead Line

7.1 Method

Figure 17 shows an overview of the method used to construct the RIIO-ED1 NLRE investment plans.

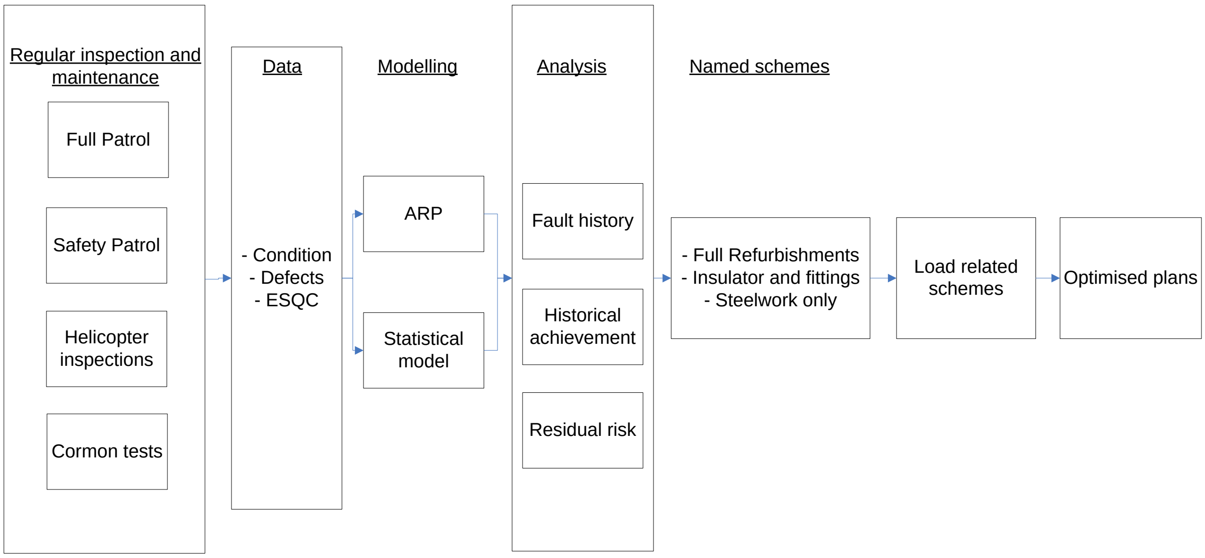

Figure 17 : Constructing the NLRE plan

The plan development progresses from left to right, starting with regular inspection and maintenance which produces data for inclusion into the predictive modelling. Following the modelling, analysis is conducted on the results and other data informing the decision on which type of condition related schemes to propose. The interface and overlap with load-related schemes is then considered and the resulting plans are the optimum solution.

7.2 Constructing the Plan

7.2.1 Intervention volumes

The business objective throughout the planning process for RIIO-ED1 NLRE was to maintain an approximately constant level of risk within each asset category. To achieve this, the age profile of the overhead tower lines was reviewed. Health Indices were assigned, with conductors over 55 years being targeted for replacement. This provided the basis for the volume of interventions required during RIIO-ED1. These sites were then assessed individually to see what level of intervention, if any, was appropriate.

7.2.2 Planned interventions

The two intervention options being proposed in ED1 are:

- Asset replacement
- Asset refurbishment.

The scope of asset-replacement projects will include replacement of the conductor, insulators and fittings and other remedial work that may be required, e.g. on tower steelwork and resolution of minor defects.

Refurbishment will simply involve the replacement of insulators and fittings and other remedial work where required.

Figures 18 and 19 show the sum of HI 4 and 5s at the start of the ED1 period for conductors across SPN, and at the end of ED1, with and without investment. The investment proposal is based on an expected life of 55 years for overhead line conductors (see section 3.1.2). This assumption will continue to be validated in ED1 through further Cormon testing.

On the 33kV overhead lines, there will be a small increase in the number of condition 4s and 5s between the start and end of ED1. On the 132kV network there will be no HI4 or HI5 assets at the start and end of ED1 due to the large investments planned over the next ten years. More detailed HI profiles are found in Appendix 2.

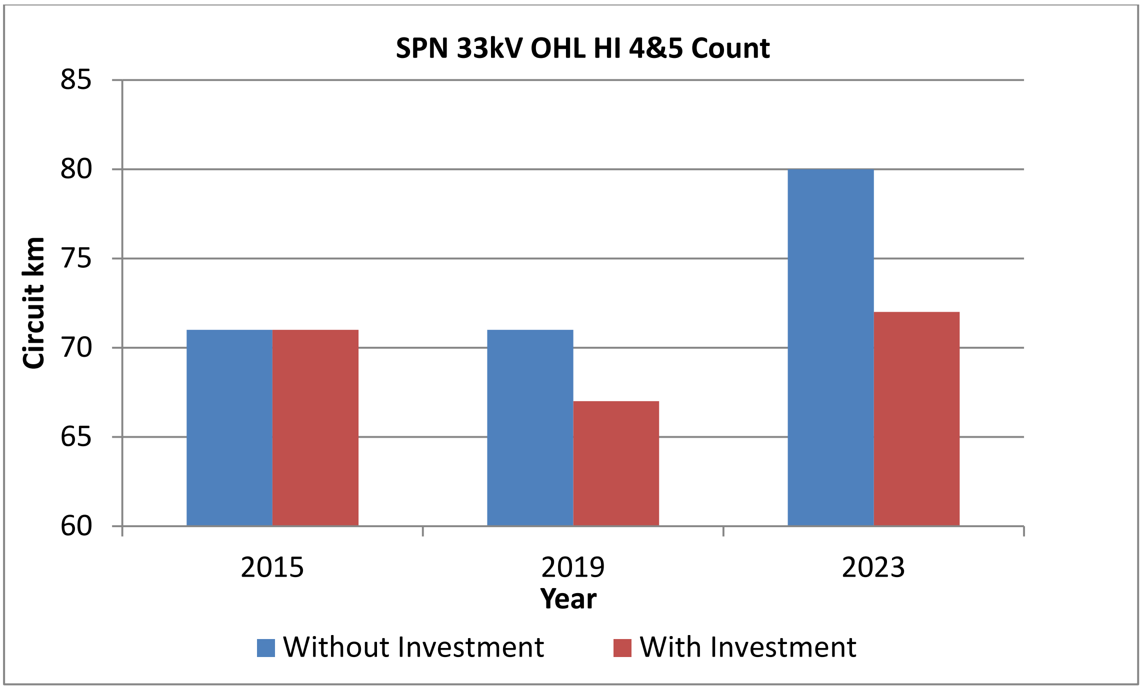

Figure 18 : Sum of HI 4 and 5's for 33kV conductors at the start and end of ED1 with and without investment.

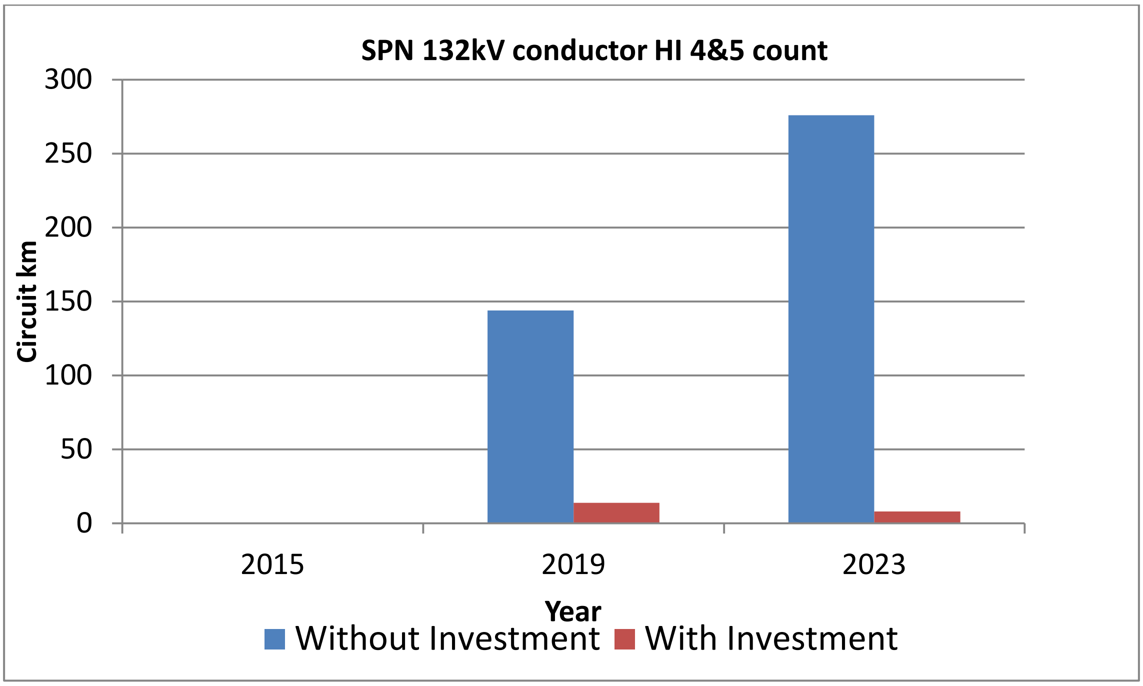

Figure 19 : Sum of HI 4 and 5's for 132kV conductors at the start and end of ED1 with and without investment.

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

7.3 Additional Considerations

Stakeholder engagement was an important part of the process to finalise the RIIO-ED1 plan. Maintenance engineers were consulted, as they are most familiar with the assets. They ensured that the data being used in the ARP model reflected their own assessments of each asset's condition.

There was also detailed consultation with the Infrastructure Planning teams involved in constructing the RIIO-ED1 LRE (load related expenditure). This ensured that the ED1 NLRE plans were optimised and there was no duplication of work in the NLRE and LRE plans.

7.4 Asset Volumes and Expenditure

The ED2 figures shown in this section have been derived from age-based modelling. Further work will be carried out in ED1 to explore additional intervention options that can be used to extend asset life.

7.4.1 132kV overhead tower lines

Proposed asset replacement conductor volumes for ED1 are shown in Figure 20, along with volumes for DPCR5 and ED2 for comparison.

Figure 21 shows the planned intervention expenditure for ED1 but includes expenditure on projects that address more than just the conductor, such as fittings and insulator replacements and foundation remedial work.

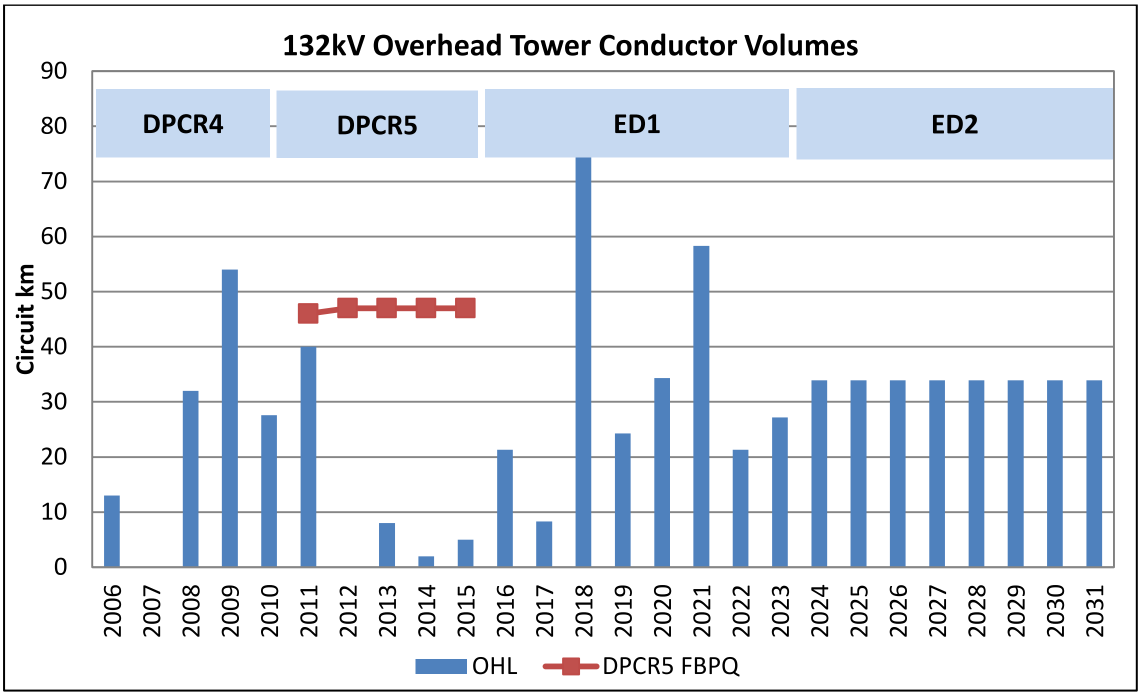

Figure 20 – SPN 132kV intervention volumes

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 – 21st February 2014 Business Plan Data Tables
ED2 - From Age-Based Analysis

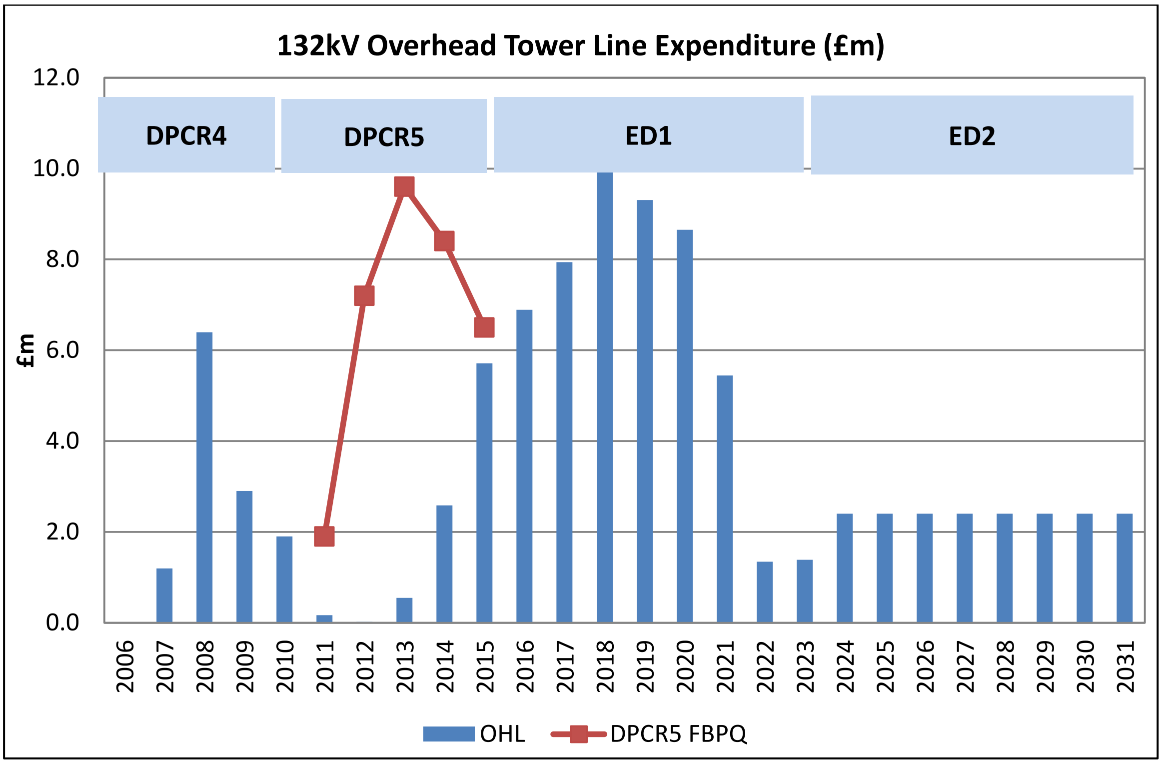

Figure 21 – SPN 132kV intervention expenditure - includes non conductor related expenditure

Sources :
DPCR4 & DPCR5 FBPQ - Table NL1 (DPCR5 FBPQ)
DPCR5 (First three years) - 2013/2014 RIGS CV3 table
DPCR5 (Last Two years) - 14 June NAMP (Table JLI)
ED1 - 19th February 2014 NAMP (Table JLI)
ED2 - From Age-Based Analysis

The level of investment in DCPR5 was lower compared to DPCR4. ED1 investment will increase significantly but £31m of the proposed ED1 investment is provision for the refurbishment or replacement of the PO route from Eastbourne to Lewes. This scope of this scheme is still uncertain. There are many landowner and planning issues that suggest that the overhead line route will not remain and an underground cable will replace it but the outcome remains unresolved at this time so £31m is included in the investment plan to cover this.

The decisions on which routes to reconductor have been, and will continue to be, driven by Cormon results. By the later part of ED1, replacement of the majority of the condition 4 and 5 assets targeted for this intervention will have been completed. The level of investment continues into ED2, when a constant level of replacement investment is expected.

7.4.2 33kV overhead tower lines

In DPCR5 there was very little investment in the 33kV overhead tower line network. There were a number of refurbishment schemes but no reconductoring jobs on the 33kV overhead lines. In ED1 a provision has been set to reconductor 8km of 33kV overhead lines.

The expenditure profile in Figure 23 illustrates the total level of expenditure across the 33kV network. The same level of investment is maintained through ED2.

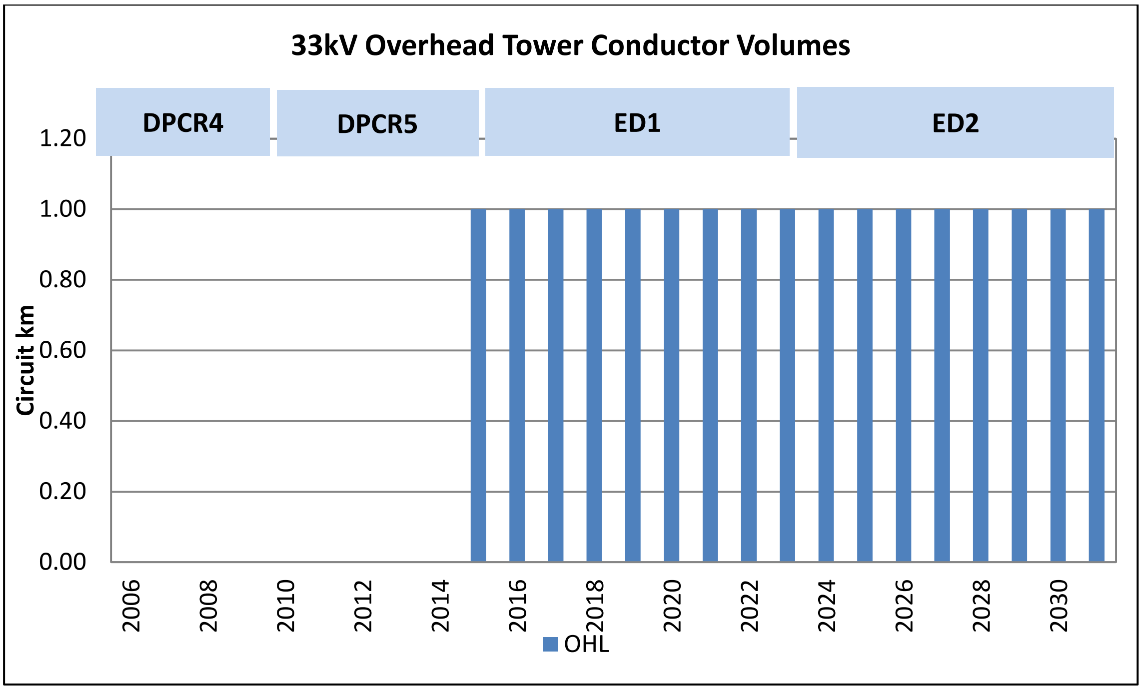

Figure 22 - SPN 33kV intervention volumes (DPCR4 to ED2)

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 – 21st February 2014 Business Plan Data Tables
ED2 - From Age-Based Analysis

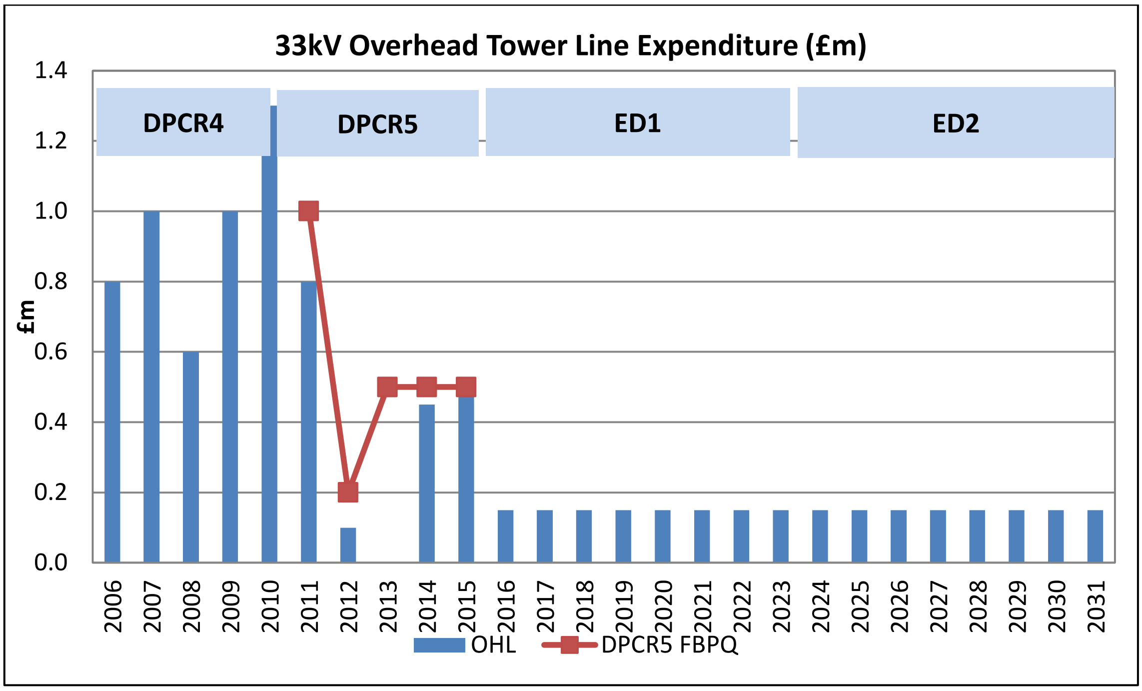

Figure 23 – SPN 33kV intervention expenditure - includes non conductor related expenditure

Sources :
DPCR4 & DPCR5 FBPQ - Table NL1 (DPCR5 FBPQ)
DPCR5 (First three years) - 2013/2014 RIGS CV3 table
DPCR5 (Last Two years) - 14 June NAMP (Table JLI)
ED1 – 19th February 2014 NAMP (Table JLI)
ED2 - From Age-Based Analysis

7.5 Commentary

An investment of £18.6m is proposed for asset replacement and refurbishment on 33kV and 132kV overhead tower lines in ED1. The investment levels set will ensure that the network risks associated with the overhead tower line population will be kept to a minimum. This will be achieved by maintaining the number of HI4 and HI5 overhead line assets at the start and end of the period.

The investment levels have been determined by reviewing the age profiles of the overhead line conductor population.

The 33kV tower line investment proposal in ED1 is a provision for reconductoring and refurbishment on 8km of 33kV overhead lines during ED1. The 1.2m investment planned will ensure that there are sufficient funds for asset reconductoring as well as ad-hoc asset replacements identified from routine line patrols and infrared patrols.

The 132kV tower line investment proposal in ED1 (£17.4m) is an increase on the investment levels in DPCR5. Achievements in DPCR5 have been less than proposed in the DPCR5 FBPQ for a number of reasons:

- The DPCR5 plan was based on an expected life of 40 years for conductors. However, Cormon test results during DPCR5 have shown that the expected life is much higher.
- A sample of Cormon results on 466 spans in EPN and SPN across 65 overhead line routes showed that the average age of conductors that failed a test is 52 years.

Based on a sample of Cormon test results, the expected average asset life of a 132kV conductor is 55 years. The investment levels proposed in ED1 will account for asset replacement and refurbishment on 268 circuit km. The increase in investment is due to the ageing asset population and enhanced condition-degradation modelling offered by ARP. The volumes of work proposed by the ARP models have been validated by Cormon test results, which show that the average age of conductors that fail the test is 52 years.

In ED1, £2.0m is proposed for tower replacement and refurbishment. The expenditure level is sufficient for the replacement of one tower per year, but will be used for refurbishment, rather than replacement, where feasible.

The average asset life of a tower is 75 years old. This is the point at which a tower is expected to require replacement or major refurbishment e.g. tower strengthening, replacement of tower members etc. The average asset life of a tower is dependent on the weather and environment and the frequency of tower painting. Two-coat alkyds have been used historically to paint towers in UKPN. These paint coatings have a typical life of 15 years.

This provision is required to maintain the health of the ageing asset population. The average age of the oldest 10% of towers is 82 years.

Throughout ED1, there will be continued innovation aimed at developing better methods for ascertaining foundation condition non-intrusively, using new conductor types. These will reduce losses, as well as the need for rectification work to existing structures and verification of the ARP model against laboratory-tested string sets.

8.0 Deliverability

The volumes of work proposed in each year in ED1 are comparable with the levels of work achieved in 2009 and are spread fairly evenly across the network, so access and outage availability issues are not anticipated.

All ED1 projects have been created in the project management system, PIMS. This application costs the project based on compatible units and automatically creates an entry in the Network Asset Management Plan (NAMP). The majority of projects are for specifically named schemes. Where this is not possible, a financial provision has been created.

Appendices

Appendix 1 – Age Profiles

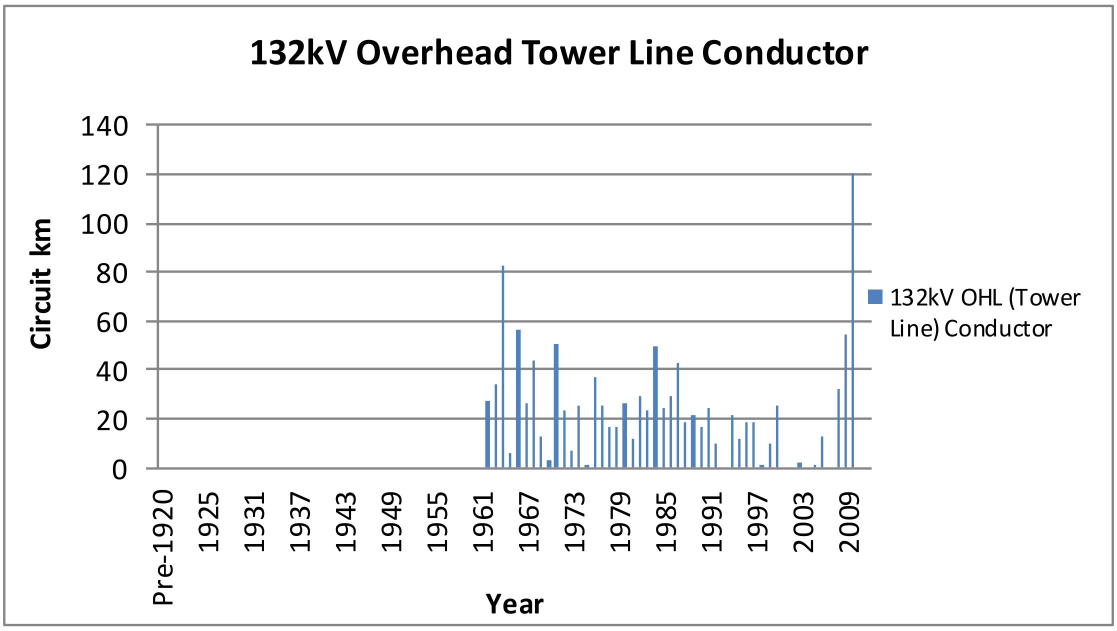

Figure 24 : 132kV OHL Conductor Age Profile

Source: V5 2012 RIGS

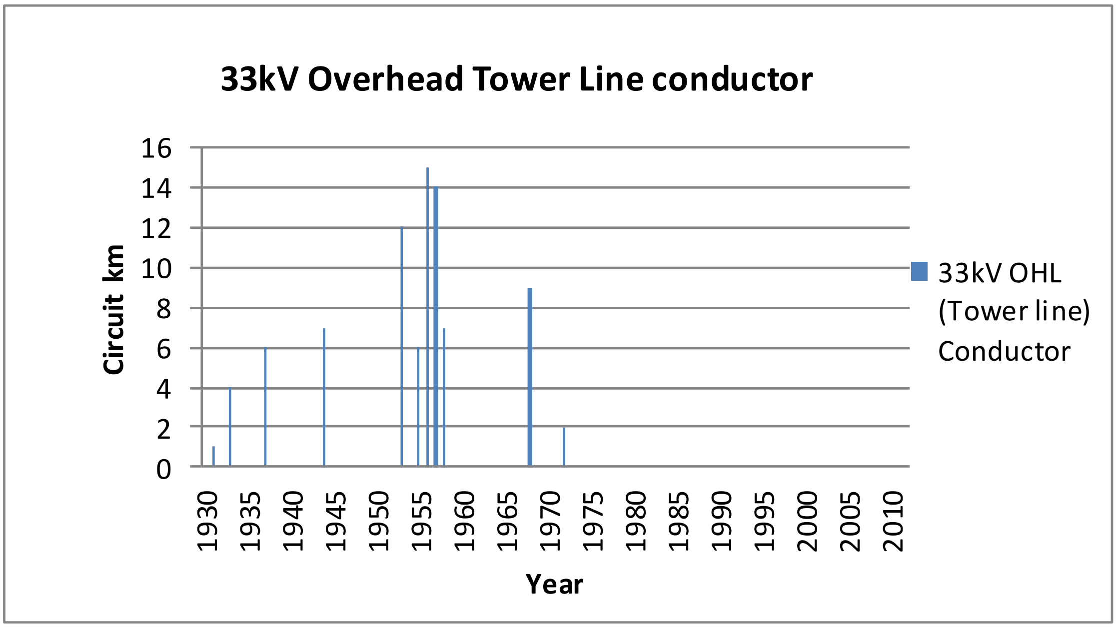

Figure 25 : 33kV OHL Conductor Age Profile

Source: V5 2012 RIGS

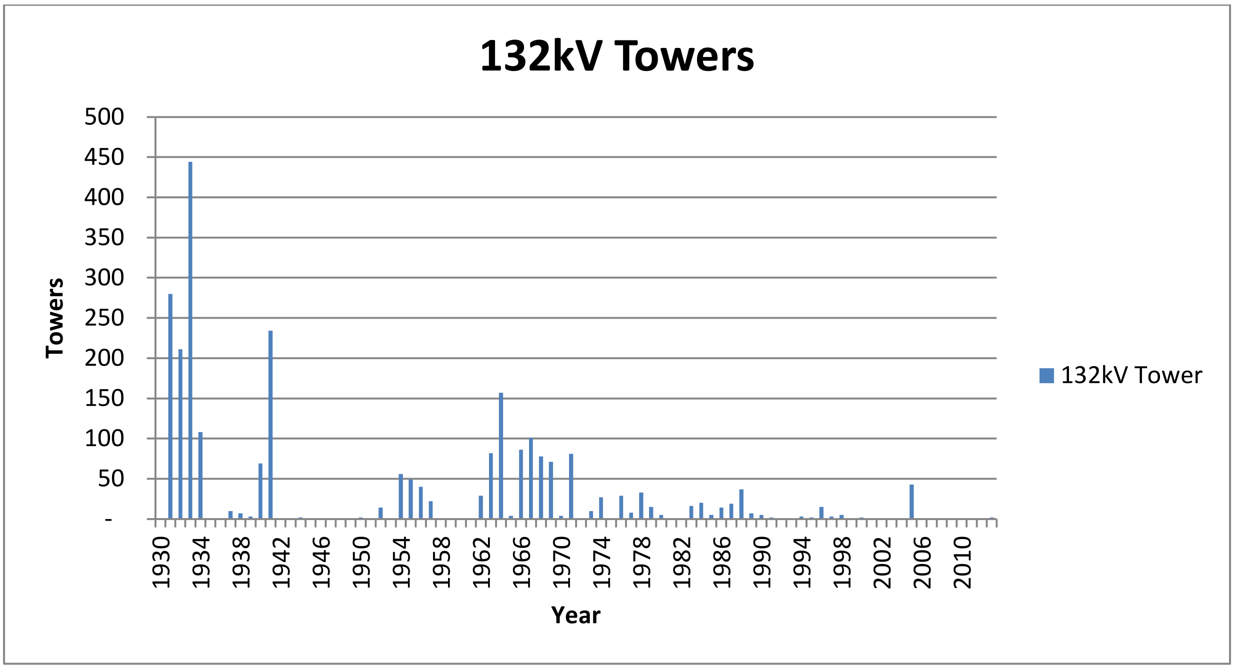

Figure 26 : 132kV Towers Age Profile

Source: V5 2013 RIGS

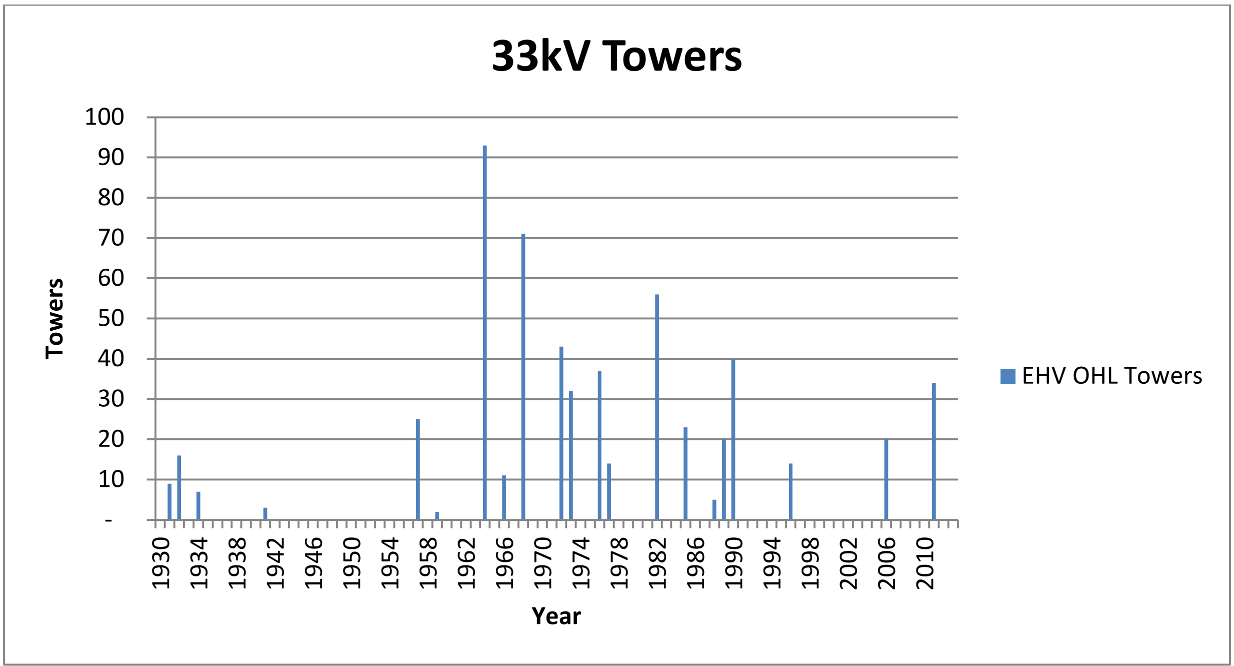

Figure 27 : 33kV Towers Age Profile

Source: V5 2013 RIGS

Appendix 2 – HI Profiles

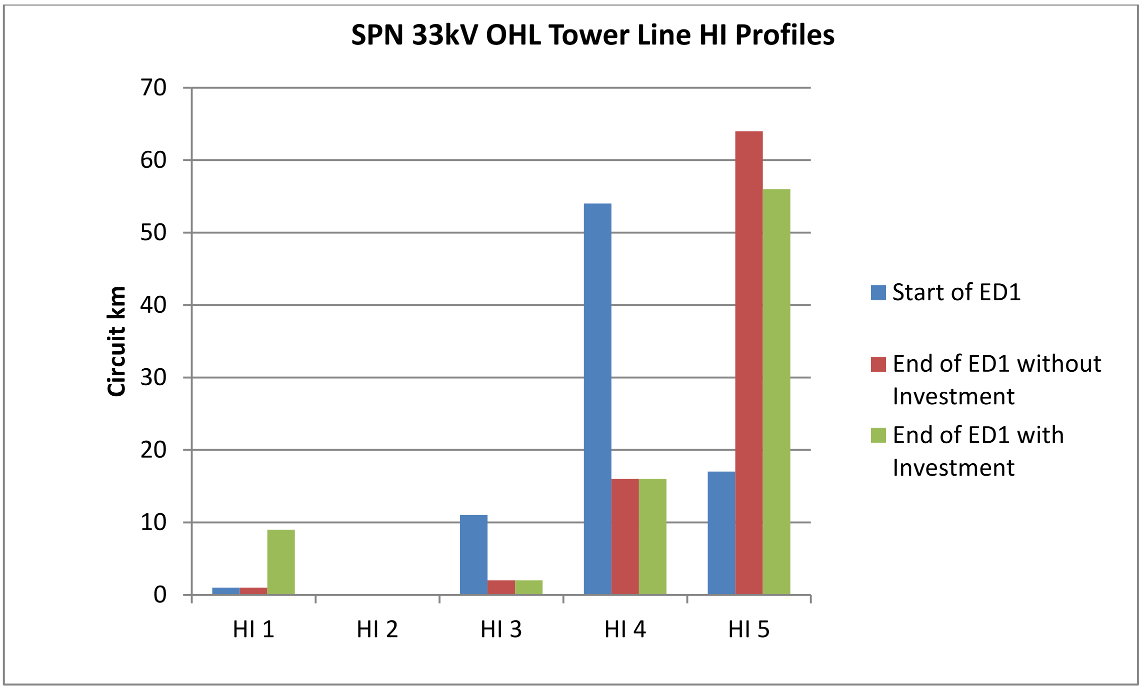

Figure 28 : 33kV OHL HI Profile

Source: Tower and Conductor ARP model

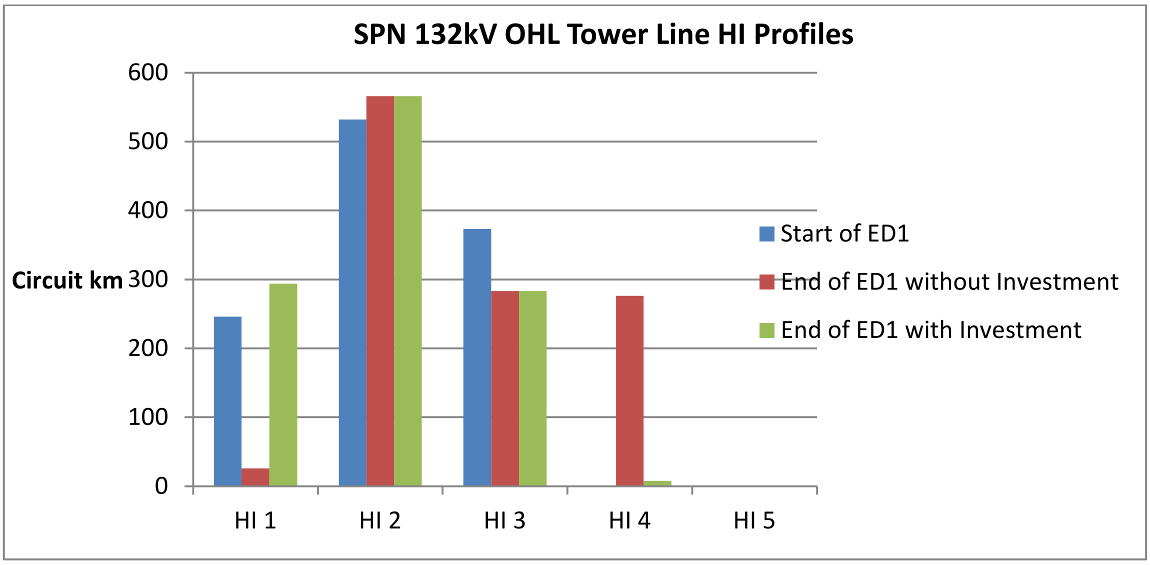

Figure 29 : 132kV OHL HI Profile

Source: Tower and Conductor ARP Model

Appendix 3 – Fault Data

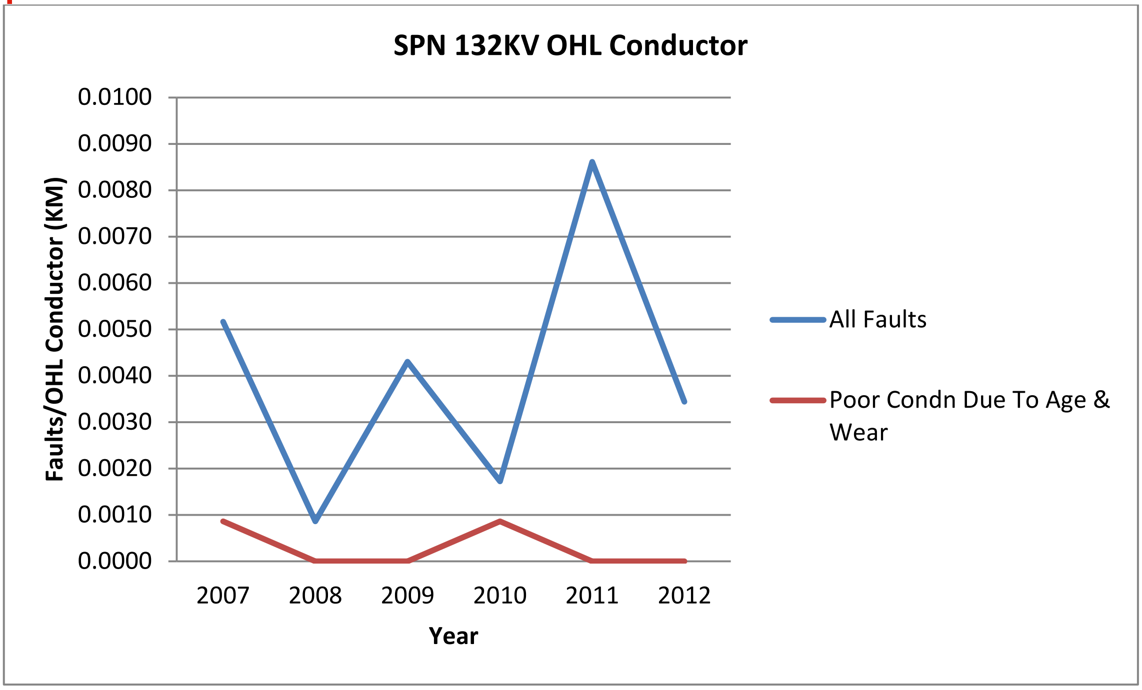

Figure 30 : Fault Rate 132kV OHL in EPN

Source: Fault Cube

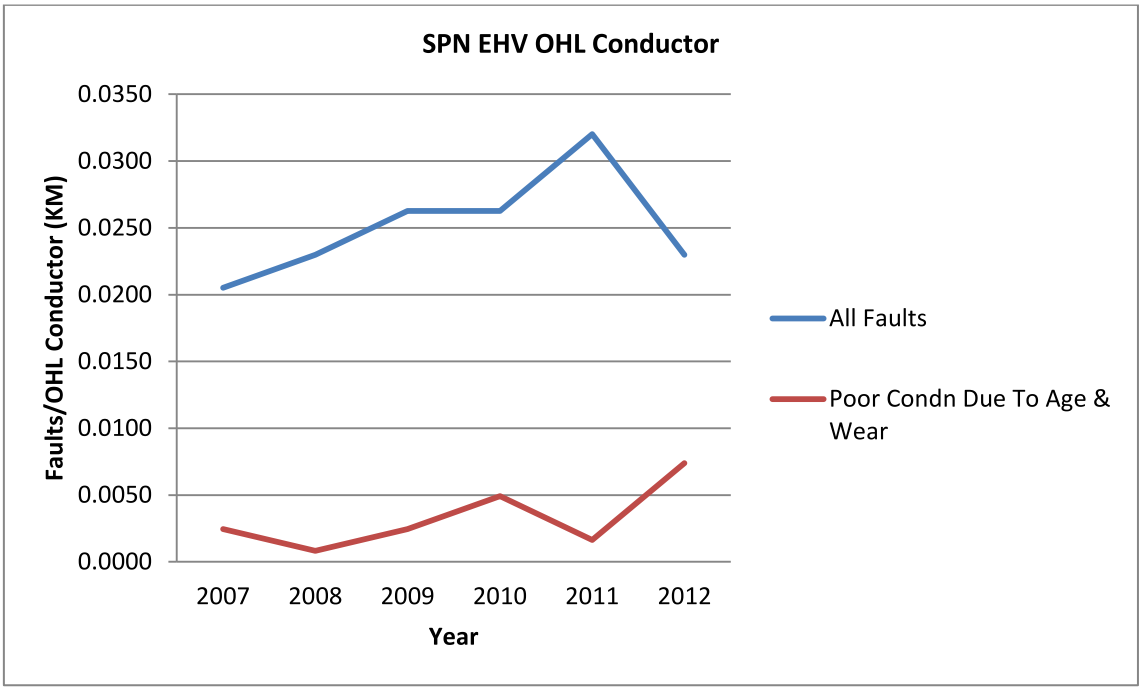

Figure 31 : Fault Rate EHV OHL in EPN

Source: Fault Cube

Appendix 4 – WLC Case Studies
risk, cost, performance, condition profiles for various options

Whole-life costs analysis not shown for overhead tower lines because there is no cost-effective refurbishment solution for overhead line conductor.

Appendix 5 – NLRE Expenditure Plan

Expenditure

SPN	Sum of 2015/2016 (£m)	Sum of 2016/2017 (£m)	Sum of 2017/2018 (£m)	Sum of 2018/2019 (£m)	Sum of 2019/2020 (£m)	Sum of 2020/2021 (£m)	Sum of 2021/2022 (£m)	Sum of 2022/2023 (£m)
1.02.02	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
1.02.03	6.85	7.91	10.10	9.31	8.65	5.44	1.35	1.39
1.02.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.02.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1.02.90	0.05	0.03	0.00	0.00	0.00	0.00	0.00	0.00
Total	**7.04**	**8.09**	**10.25**	**9.46**	**8.80**	**5.59**	**1.50**	**1.54**

Table 6: OHL expenditure plan

Source: 19th February 2014 NAMP Table J Less Indirect

Volumes

SPN	Unit	2013-14	2014-15	2015-16	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22	2022-23
33kV	Circuit km	71	1	1	1	1	1	1	1	1	1
132kV	Circuit km	2	5	21	8	76	24	34	58	18	27

Table 7: OHL volumes

Source: 21st February 2014 Business Plan Data Tables

Appendix 6 – Sensitivity Analysis And Plan Validation

Sensitivity Analysis

No sensitivity Analysis was performed on this data due to the on-going development of the tower ARP model. This is being planned for completion in 2013.

Statistical analysis of ARP output

The ARP model has 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 tests, data flow testing and user and methodology testing. Each test was designed to capture potential errors in specific parts of the system. The completion of all tests provided assurance that a thorough evaluation had been carried out to ensure correctness and validity of the outputs.

Algorithm Testing

The ARP model comprises a set of algorithms implemented within the database code. The tester, in a spreadsheet, mimicked each algorithm and compared the results 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 were required to match the spreadsheet calculation.

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.

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.

User and Methodology Testing

The aim of the user and methodology testing was to ensure that the models were 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.

Appendix 7 – Named Schemes

Namp Line	Project ID	Description	2015/ 2016	2016/ 2017	2017/ 2018	2018/ 2019	2019/ 2020	2020/ 2021	2021/ 2022	2022/ 2023
1.02.02	3085	Provision - SPN Conductor Replacement	38,196	38,196	38,196	38,196	38,196	38,196	38,196	38,196
1.02.02	8390	Provision - SPN Tower Refurbishment	112,500	112,500	112,500	112,500	112,500	112,500	112,500	112,500
1.02.03	3115	PC - Woodnesborough Jnct - Newington T - Conductor Replacement	0	0	0	0	139,410	112,113	0	0
1.02.03	3116	PC - Woodnesborough Jnct - Etchinghill T- Potential Reinforcement	0	0	0	0	680,186	1,734,439	0	0
1.02.03	3137	Provision - SPN Conductor Replacement	0	0	0	0	0	0	0	0
1.02.03	3157	PBC - Bolney-Steyning - Conductor Replacement - BT21 driven	76,089	0	0	0	0	0	0	0
1.02.03	3318	PO - Route Replacement Strategy	5,169,726	6,274,788	6,200,625	5,752,581	4,751,763	2,834,481	0	0
1.02.03	4111	PMA Canterbury North-Canterbury South 132kV OHL Refurbishment, 1-3 All	70,754	53,066	0	0	0	0	0	0
1.02.03	4112	PG - Wormshill T - Sittingbourne - Conductor Replacement	0	113,364	289,073	0	0	0	0	0
1.02.03	4116	PW - Dormansland-Northfleet East - Conductor Replacement	316,895	0	0	0	0	0	0	0
1.02.03	4117	PU - Canterbury North-Etchinghill - Conductor Replacement	0	0	170,047	433,610	0	0	0	0
1.02.03	4118	PV - Sellindge - Folkstone - Conductor Replacement	0	0	85,023	216,805	0	0	0	0
1.02.03	4120	PYB - Three Bridges Main -Tilgate - Conductor Replacement	0	0	0	0	0	0	0	50,305
1.02.03	4121	PNA - Bolney - Horsham - Conductor Replacement	0	0	0	0	0	0	85,023	216,805
1.02.03	4123	PUA - Ninfield - Hastings Main - Conductor Replacement	0	0	0	0	0	184,217	469,744	0
1.02.03	4124	PN - Northfleet East - Maidstone - Conductor Replacement	0	0	0	0	0	0	212,558	542,012
1.02.03	4129	PJC Bolney-Smallfield 132kV OHL Refurbishment, 1-92 All	0	0	0	0	0	0	0	0
1.02.03	4376	PCA Reinforcment - Northfleet East - Hartley - on wrong line	0	0	436,650	1,746,600	1,309,950	0	0	0
1.02.03	5540	PLB - Lewes/Southern Cross - Tower Refurbishment	0	0	0	0	0	0	0	0
1.02.03	6147	Provisions - Tower Replacement	260,515	260,515	260,515	260,515	260,515	260,515	260,515	260,515
1.02.03	7959	PNB - Hartley to Hastings Main - Conductor Replacement	0	699,859	1,946,516	0	0	0	0	0

1.02.03	7960	TGR - Thanet Grid - St Peters - Conductor Replacement	0	0	20,280	30,612	0	0	0	0
1.02.03	7961	PR - Grove Bridge - Ruckinge - Conductor Replacement	0	20,280	30,612	0	0	0	0	0
1.02.03	7962	PE - Burham Grid - Medway Grid - Conductor Replacement	0	165,494	343,423	0	0	0	0	0
1.02.03	7963	PLB - Lewes - Southern Cross - Insulator and Fittings Replacement	0	0	0	104,250	163,593	0	0	0
1.02.03	7964	Canterbury North to Canterbury South 132kV Tower Line (PGA) - 132kV Tower Line Refurbishment	29,832	0	0	0	0	0	0	0
1.02.03	7975	PCA - Northfleet East to Hartley - Insulator and Fittings Replacement	603,824	0	0	0	0	0	0	0
1.02.03	7976	PHA - Richborough - Bettshanger - Conductor Replacement	0	0	0	190,941	419,762	0	0	0
1.02.03	7977	PBA - Tunbridge Wells - Marden Junction - Conductor Replacement	0	0	0	254,555	610,606	0	0	0
1.02.03	8658	Provision - SPN 132kV Insulators, Fittings and Conductoring provisions	318,040	318,040	318,040	318,040	318,040	318,040	318,040	317,737
1.02.05	5539	100MW20 - Dover/Folkstone Grid - Foundation Refurbishment	0	0	0	0	0	0	0	0
1.02.07	8180	Provision - SPN Cormon Tests	0	0	0	0	0	0	0	0
1.02.90	4113	PQA - Three Bridges Main/Three Bridges Local - Conductor Replacement	45,764	34,323	0	0	0	0	0	0
1.02.90	5568	PSA - Southern Cross/Worthing - Insulator & Fitting Replacement	0	0	0	0	0	0	0	0

Table 8 – OHL Named Schemes

Source: 19th February NAMP 2014 Table J Less Indirect

Appendix 8 – Output NAMP/ED1 RIGS reconciliation

Outputs		Asset Stewardship report									RIG Table										
Investment description	NAMP Line	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	Total	RIG Table	RIG Row	2015/16	2016/17	2017/18	2018/19	2019/20	2020/21	2021/22	2022/23	Total
33kV Conductor Replacements	1.02.02	1	1	1	1	1	1	1	1	8	CV3	184	1	1	1	1	1	1	1	1	8
33kV Insulator and Fittings Replace		0	0	0	0	0	0	0	0	0	CV3	186	0	0	0	0	0	0	0	0	0
132kV Conductor Replacements	1.02.03	21	8	76	24	34	58	18	27	268	CV3	217	21	8	76	24	34	58	18	27	268
132kV Insulator and Fittings Repla		222	5	284	70	229	212	52	88	1,162	CV3	219	222	5	284	70	229	212	52	88	1,162
										0											0
										0											0
										0											0
										0											0
										0											0
										0											0
										0											0
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										0											0
										0											0
										0											0
										0											0
Total		244	14	361	95	264	271	71	116	1,438			244	14	361	95	264	271	71	116	1,438

Table 9 NAMP to ED1 Business Plan Data Table Reconciliation

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

Appendix 9 – Efficiency benchmarking with other DNO's

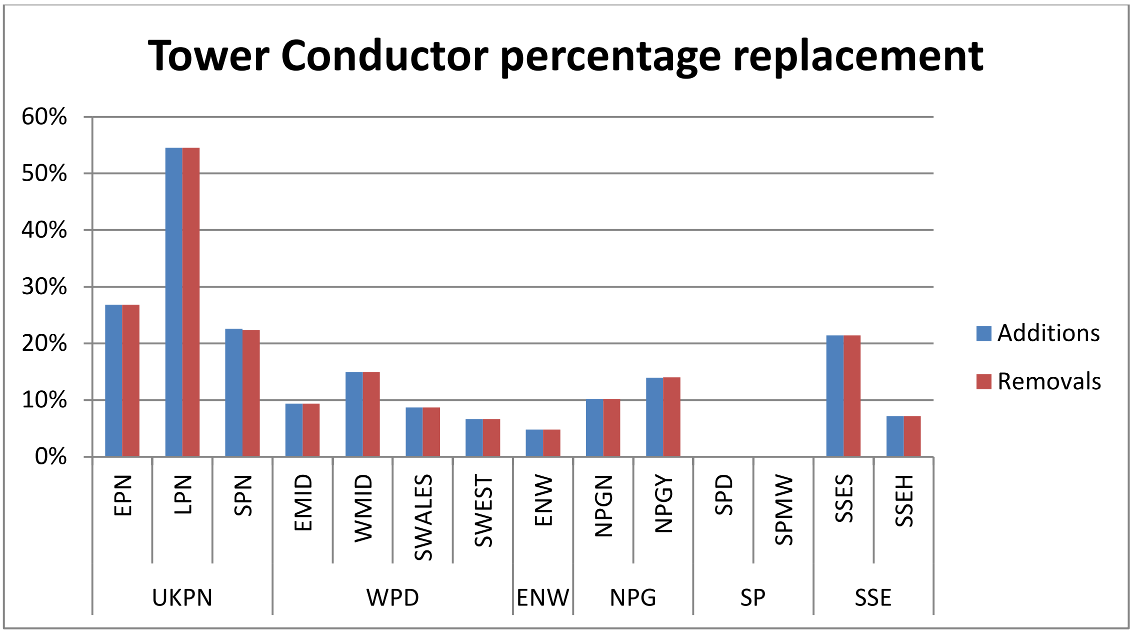

Figure 32 - Efficiency Benchmarking

Source: DNO Datashare_2013

There are no comparable industry age profiles available to benchmark average asset age against percentage volume replacement.

SPN conductor volumes are set at a level than manages risk of failure by targeting conductors at or soon after the onset of initial corrosion. This has been determined by an analysis of all Cormon tests (see section 3.1 for further details). This analysis shows that approximately half of the conductor spans Cormon tested older than 50 years fail and are classified as condition 4 (scale of 1-4). Additionally, 11% of conductor spans aged between 40 and 50 years fail the test. Based on this analysis as well as the age profile of the conductor in SPN and any addition condition data, UKPNs replacements plan is devised to avoid the risk of conductor failure and therefore risk to the public. Even with this level of replacement, condition 4 conductors will remain on the network.

Appendix 10 – Material changes since the July 2013 ED1 submission

There have been no changes to the SPN Overhead Tower line submission since the July 2013 submission.