**Document 1
Asset Category – Towers and Conductors
LPN**

Asset Stewardship Report
2014

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Approved by Richard Wakelen / Barry Hatton

Approved Date 03/03/2014

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	Inclusion of appendices 8,9 and 10	Nick Xydas	Minor	Appendices 8,9 and 10
		Update of appendix to reflect corrected 66kV conductor volumes			Appendix 5
		Update all costs in document to reflect revised NAMP 19th February 2014			All NAMP based cost references
		Update volume and expenditure graphs to reflect corrections to 66kV conductor volumes			
		Update Third party audits date			Section 7.4
					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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Version	Date	Details	Originator	Revision Class	Section Update
1.4	27/02/2014	Updates following C. Jeffrey review	Richard Gould	Minor	1.1 7.4 Appendix 5, 8, 9, 10
2.0	05/03/2014	Final version	Brian Matthews	Minor	None

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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

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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.

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1.0   Executive Summary Tower Lines

1.1 Scope

This document details LPN's NLRE (non-load related expenditure) replacement proposals for the 66kV and 132kV overhead tower lines for the RIIO-ED1 period.

There are 22 circuit km of conductor in LPN, on 46 towers, with a total estimated MEAV of £6m. The proposed investment is £1.1m in ED1 which equates to 17% of the MEAV.

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 reconciliation between NAMP and RIGS output is included in Appendix 8 and Appendix 10 contains a summary of the material changes between the original submission of this document in July 2013 and this submission.

Investment type	ED1	NAMP line	RIGS
Asset replacement (including insulators and fittings): 66kV overhead tower line	£0. 7m	1.02.02	**Volumes – Table CV3** **Additions:** · Row 59 – EHV – 66kV OHL (Tower line) Conductor · Row 61 – EHV – 66kV Fittings **Removals:** · Row 187– EHV – 66kV OHL (Tower line) Conductor · Row 172 – EHV – 66kV Fittings **Costs – Table CV3** · Row 59 – EHV – 66kV OHL (Tower line) Conductor · Row 61 – EHV – 66kV Fittings
Asset Replacement(including insulators and fittings): 132kV overhead tower line refurbishment	£0.4m	1.02.03	**Volumes** **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** · Row 89 – 132kV – 132kV OHL (Tower Line) Conductor · Row 91 – 132kV – 132kV Fittings

Table 1: Investment areas (ref: 2012 RIGS tables, CV3)

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

1.2 Investment Strategy

The long-term investment proposal for the replacement of 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

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2.0   Description of Overhead Line Population

This document focuses on NLRE investment proposals for broad-based towers supporting 66kV and 132kV overhead line circuits. Narrow-based towers are addressed in document 2. 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, illustrating the differences in design and construction

2.1   Overhead Line Assets

2.1.1   Conductors

In the LPN region, there are 15km of 66kV and 7km of 132kV overhead line conductor installed. All of the conductors are ACSR conductors. The mean average age of the conductors is 54 years (66kV) and 27 years (132kV). The age profiles are shown in Figures 2 and 3.

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Figure 2: 132kV Conductor age profile (V5 2012 RIGS)

2.1.2   Towers

In the LPN region, there are 18 broad-based towers (132kV) and 28 broad-based towers (66kV). The mean age of these towers is 28 years (66kV towers) and 49 years (132kV towers).

Figure 3: 132kV Tower age profile (V5 2012 RIGS)

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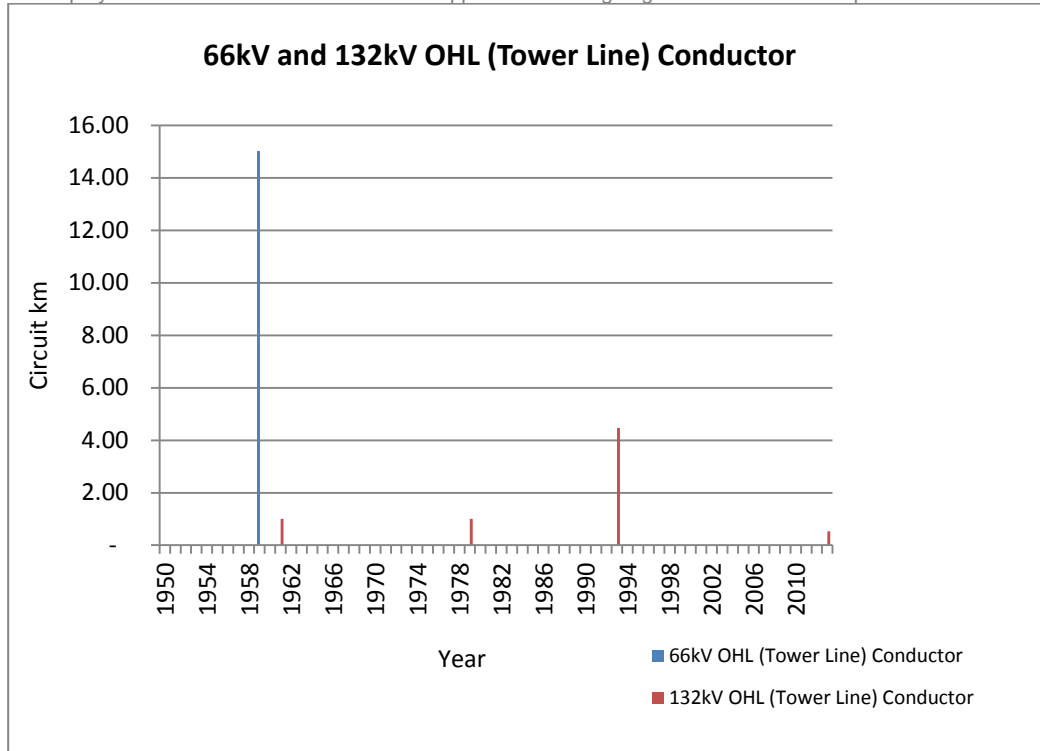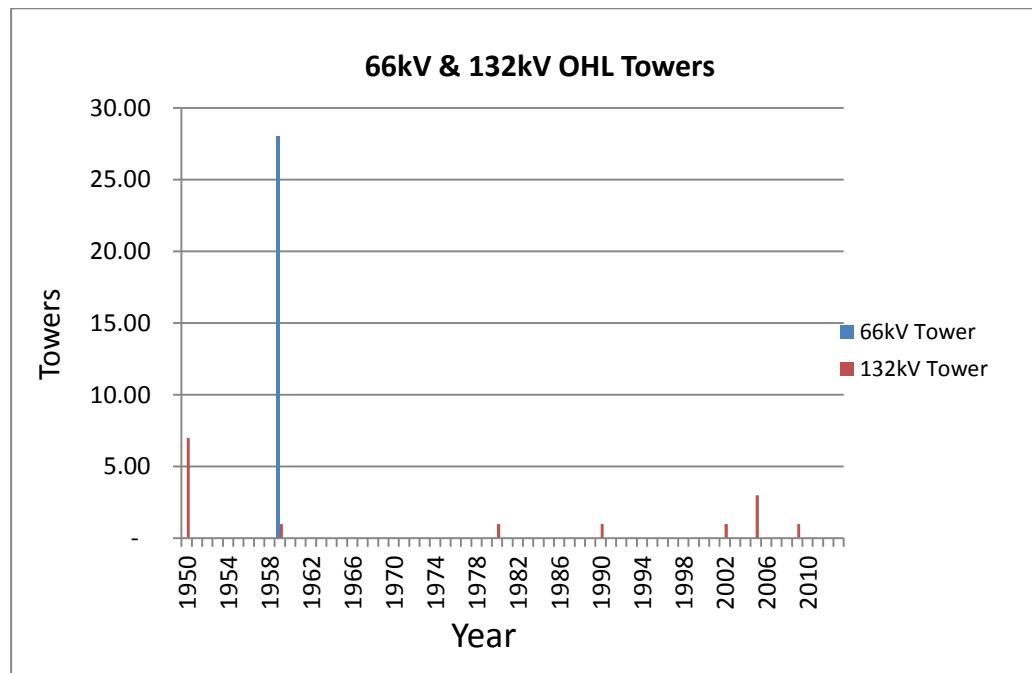2.1.3   Insulators/Fittings

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 LPN region, there are 90 fittings. The mean age of the fittings is 44 years (1969 installation).

Insulator/fittings:
Insulators, including arcing horns and tower attachment plates

Figure 4 - 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 (CI) and Customer Minutes Lost (CML) each year.

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- Failure mode and effect analysis is conducted to ensure that a reliability-centred maintenance approach is taken to the management of asset condition.

- Electricity Safety, Quality and Continuity Regulations (ESQC) 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 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 networks, 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 5 focuses on part of one tower on the PO route that 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 5: A very poor condition tower steelwork member, illustrating the extremes of deterioration that can be found on 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 6 and 7 show a high-resolution image and an enlarged portion of the same image with a closer detail view on 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 historical data sources.

Figure 6: High-resolution image of a portion of an LPN tower
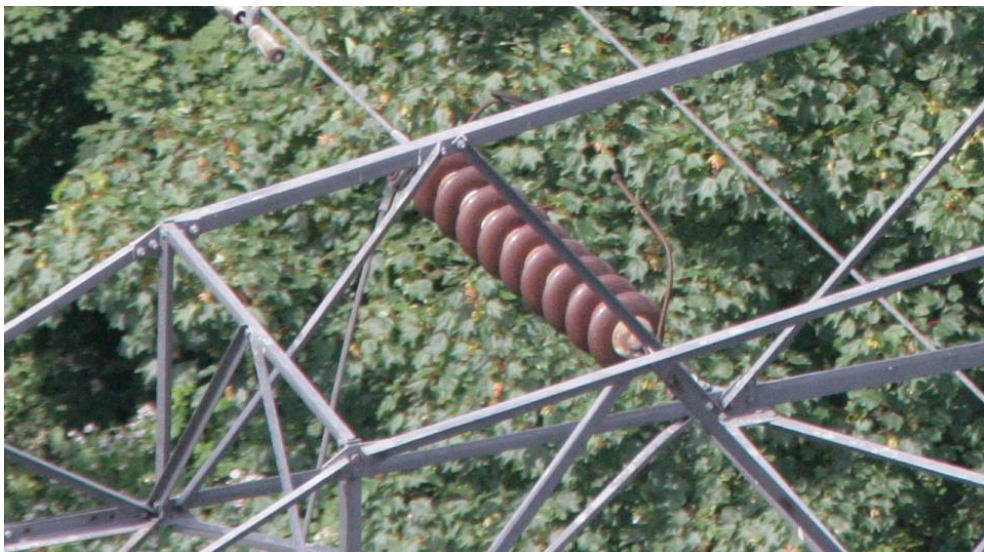
Figure 7: An enlarged portion of an LPN tower, highlighting the level of detail possible in a desktop condition assessment

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 deteriorate the capabilities significantly. Figure 8 shows a considerably worn mechanical link where the movement between the parts has worn away more than 50% of the load-bearing material.

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Figure 8 : Photo of a worn shackle, showing the extent of degradation that can occur on fittings from mechanical processes such as wear

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, or annually for sites identified as high risk. For conductors, there is a Cormon test after 40 years, with subsequent Cormon tests carried out at 10-year intervals, along with thermal imaging every two years.

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.

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	Condition assessment measures	Description
Conductor	Circuit 1 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
	Circuit 2 Cormon condition	
	Earth Cormon condition	
	CCT1 conductor damage	These condition measures are collected during foot patrols. They are visual assessments of the conductor and based on indicators such as stranding, bird caging, etc
	CCT2 conductor damage	
	Earth conductor damage	
Insulators and fittings	CCT1 insulator/fittings condition	Visual assessment based on foot patrols and helicopter surveys
	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	
Tower steelwork	Condition of steelwork	Visual assessment based on foot patrols and helicopter surveys
	Condition of tower painted surface	
	Condition of steel structure	
	Paint condition (steel structures)	
Tower muffs	Condition of paintwork on muff	Visual assessment based on foot patrols
	Muffs defective	
Other tower assets	Earth dampers defective	Visual assessment based on foot patrols and helicopter surveys
	CCT1 dampers defective	
	CCT2 dampers defective	
	CCT1 arcing horns defective	
	CCT2 arcing horns defective	
	CCT1 spacers defective	
	CCT2 spacers defective	

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

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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.

Age Band	Count					Percentage			
	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 old, 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 will be Cormon-tested in ED1 are expected to be Condition 4. Another 11% of conductors between 40 and 50 years old are expected to fail a Cormon test in ED1.

The ED1 plan has been determined based on an expected average asset life of 55 years for overhead line conductor. A 55-year threshold has been chosen as a reasonable life expectation, 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 9 shows 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 9: A poor condition ACSR conductor from an LPN route showing the extent of hidden corrosion that can occur between conductor strands

3.2   Fault Rate

Due to the small population of overhead tower lines in LPN and their relatively good condition, there are very few overhead line faults in LPN.

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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 some 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 have 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 that provides details of every non-compliance and allows continual improvement of data quality.

4.5 Data Verification

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

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4.6 Data Quality

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

Area	Result
Completeness	65%
Accuracy	TBC
Timeliness	100%

Table 5: Data CAT scores

Source: ARP Steel Tower data quality report 08th February 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.

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5.0 Intervention Policies

5.1 Selecting Preferred Interventions

When determining what type of interventions is required for ED1, there are three broad categories of intervention available. Figure 10 describes each of these in order of significance of work required and also the decision-making p
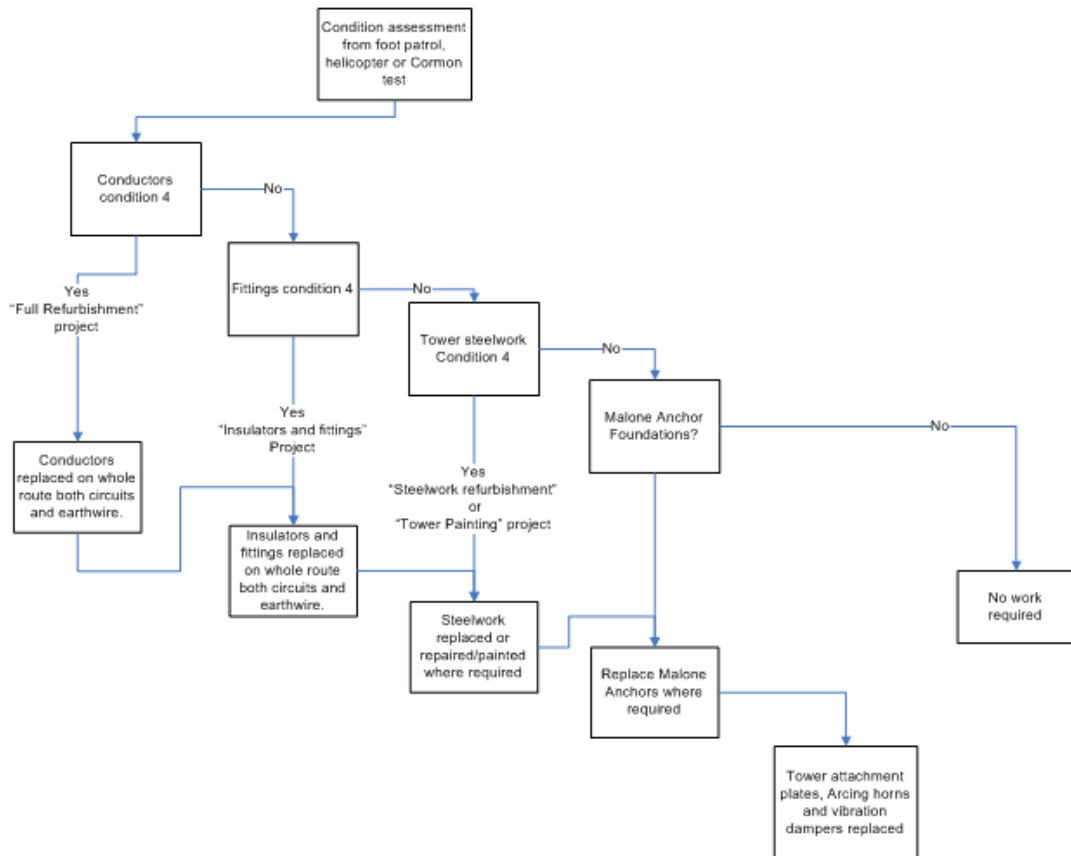

Figure 10: Project scope decision process flow

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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, the replacement of that span will be carried out along with all other spans in that circuit, including the earthwire, based on the assumption that they will be in a similar condition and under 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 a 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, 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 in place to prevent the breakdown of the coatings 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

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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 will form 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 EOP 09-0061; 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.

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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

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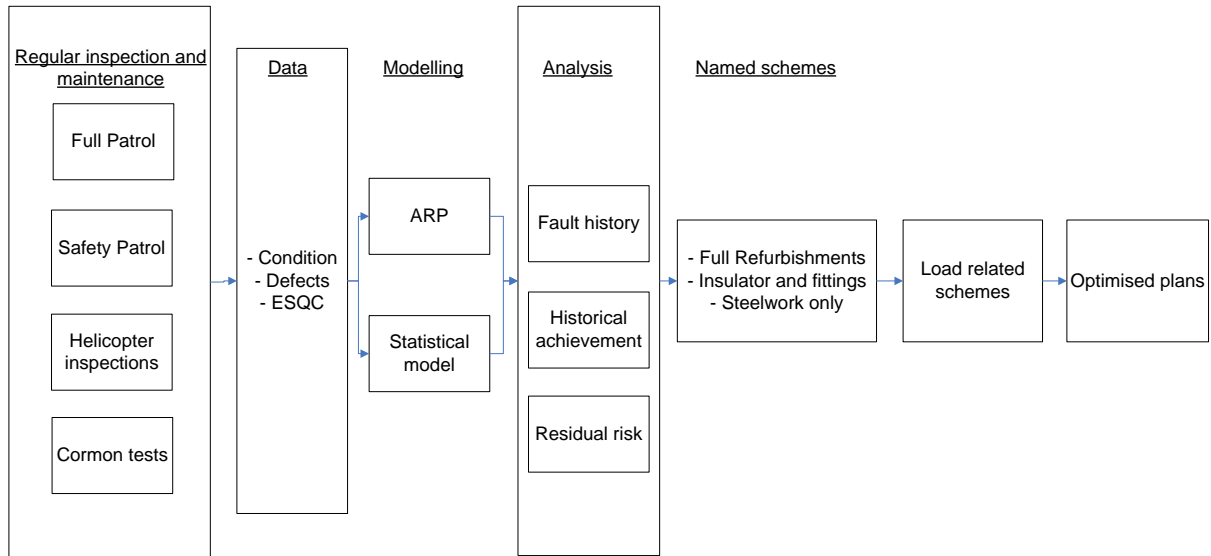

Figure 11: Constructing the NLRE plan

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 only intervention option being proposed in ED1 is asset replacement. 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. tower steelwork, resolution of minor defects, etc.

There are four projects proposed in ED1 that are driven by the number of HI4s and HI5s on the route: 16 circuit kms of conductor will be replaced.

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Figures 12 and 13 show the sum of HI4 and 5s at the start of ED1 period for conductors across LPN and at the end of ED1 – with and without investment. Further profiles are found in Appendix 2.

LPN 132kV OHL HI 4&5 count
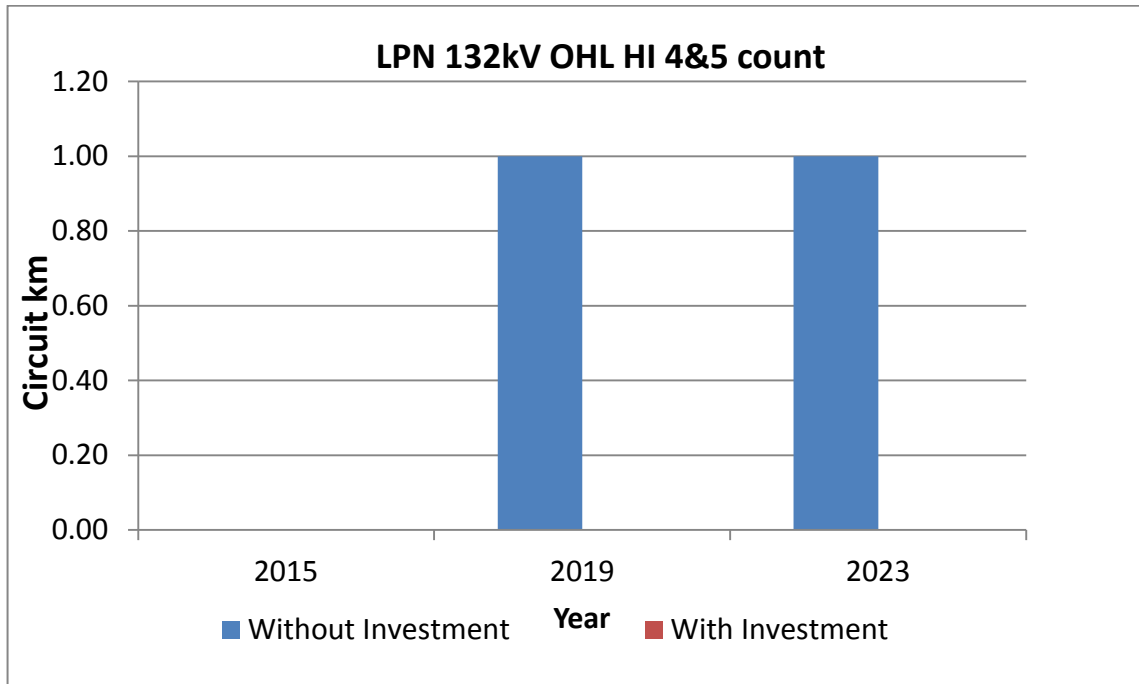
Figure 12 : Sum of HI 4 and 5s for132kV conductors at the start and end of ED1 with and without investment
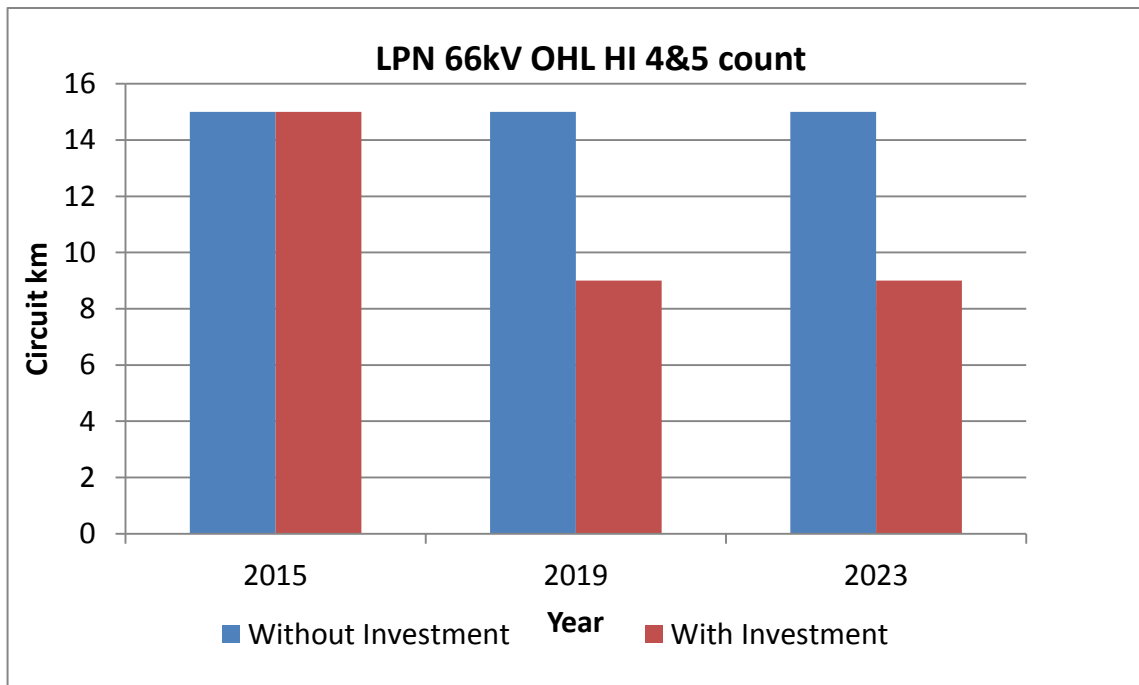
LPN 66kV OHL HI 4&5 count

Figure 13: Sum of HI 4 and 5s for 66kV conductors at the start and end of ED1 with and without investment.

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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 because 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 that 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. In total, there are four projects during ED1 that will address 16 circuit kms of conductor.

7.4.1 132kV overhead tower lines

Proposed asset-replacement volumes for ED1 are shown in Figure 14, along with volumes for DPCR5 and ED2 for comparison.

There has been no investment on the LPN network in recent years and the remedial work that is planned for ED1 will also maintain the network through ED2, so no further investment is planned.

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Figure 14: LPN 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 Business Plan Data Tables
ED2 - From Age-Based Analysis

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Asset Stewardship Report 2014

LPN 66kV and 132kV Overhead Tower Lines

Version 2.0

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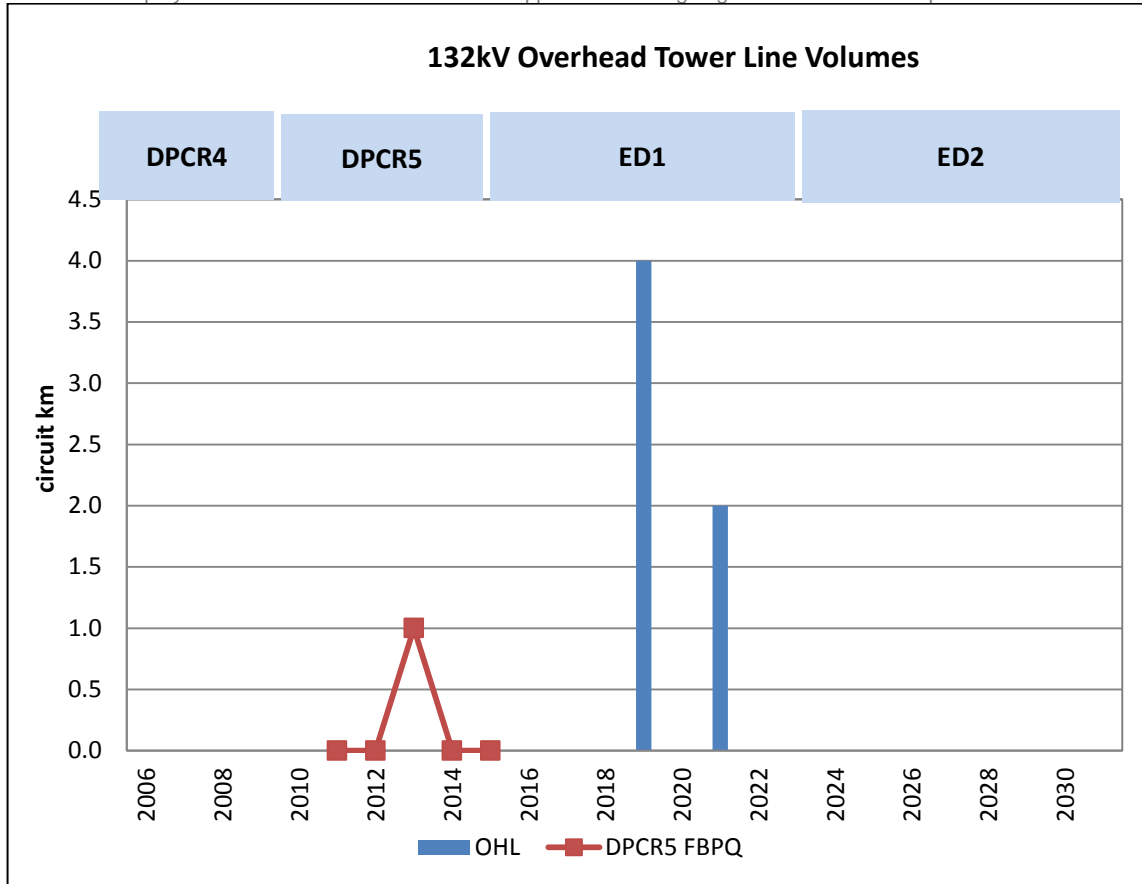UK Power Networks

Figure 15: LPN tower line 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

All of the cost numbers displayed in this document are before the application of on-going efficiencies and real price effects
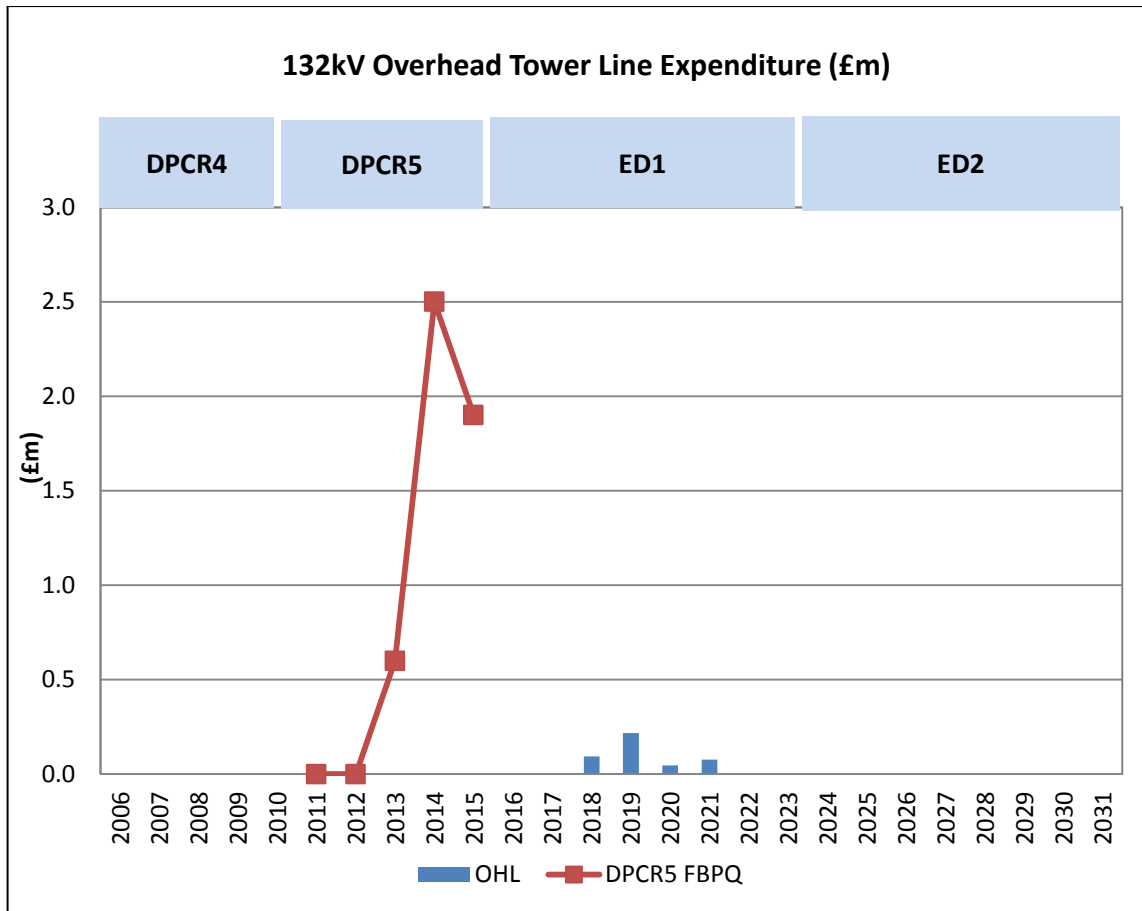
7.4.2   66kV overhead tower lines

Figure 16: LPN 66kV intervention volumes (19th February 2014 NAMP Table O)

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Figure 17: LPN tower line intervention expenditure (19th February 2014 NAMP Table JLI)- 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

7.4.3   RIGS references

Table 6 shows the references of the Asset Replacement table against RIGS CV3.

Investment type	ED1	NAMP line	RIGS
Asset replacement (including insulators and fittings): 66kV overhead tower line	£0.7m	1.02.02	**Volumes – Table CV3** **Additions:** · Row 59 – EHV – 66kV OHL (Tower line) Conductor · Row 61 – EHV – 66kV Fittings **Removals:** · Row 187– EHV – 66kV OHL (Tower line) Conductor · Row 172 – EHV – 66kV Fittings **Costs – Table CV3** · Row 59 – EHV – 66kV OHL (Tower line) Conductor · Row 61 – EHV – 66kV Fittings

All of the cost numbers displayed in this document are before the application of on-going efficiencies and real price effects
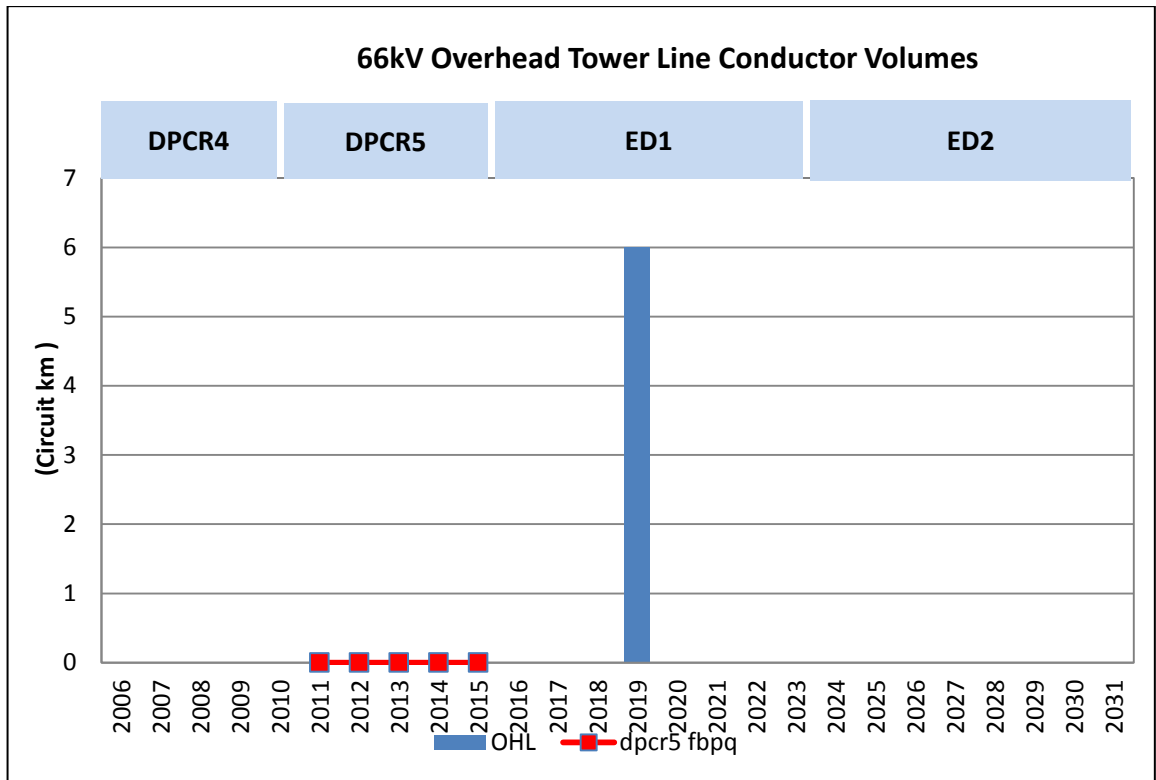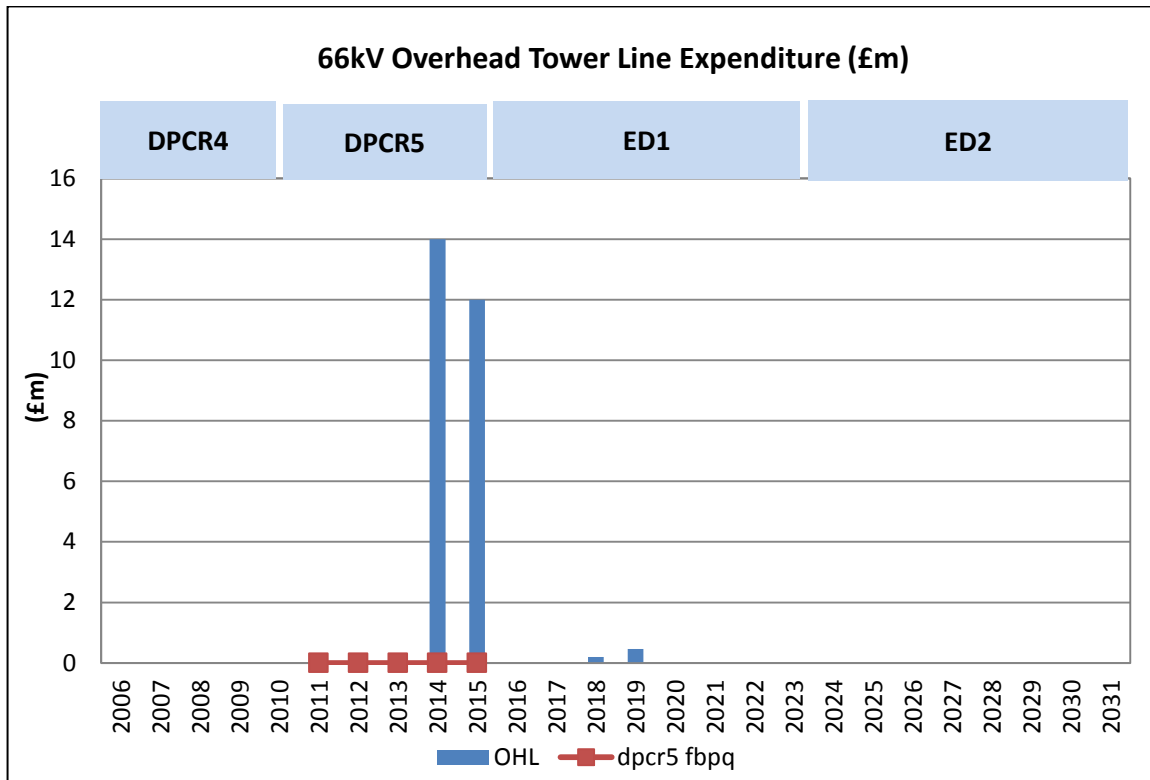
			Volumes **Additions:** · Row 89 – 132kV – 132kV OHL (Tower Line) Conductor · Row 91 – 132kV – 132kV Fittings **Removals:** · Row 203 – 132kV – 132kV OHL (Tower Line) Conductor · Row 205 – 132kV – 132kV Fittings **Costs** · Row 89 – 132kV – 132kV OHL (Tower Line) Conductor · Row 91 – 132kV – 132kV Fittings
Asset Replacement(including insulators and fittings): 132kV overhead tower line refurbishment	£0.4m	1.02.03	

Table 6: Asset replacement table to RIGS references

7.5   Commentary

An investment of £1.1m is proposed for asset replacement and refurbishment of the 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 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.

The tower line investment proposals in ED1 include four asset replacement projects (the entire OHL route) and is an increase on the investment levels in DPCR5. This will account for asset replacement and refurbishment on 18 circuit kms of conductor. The increase in investment is due to the ageing asset population. 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.

Throughout ED1, there will be continued innovation aimed at developing better methods of ascertaining foundation-condition non-intrusively, using new conductor types that reduce losses and the need for rectification work to existing structures.

8.0   Deliverability

The volumes of work proposed in ED1 are very low 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.

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Appendices

Appendix 1 Age Profiles
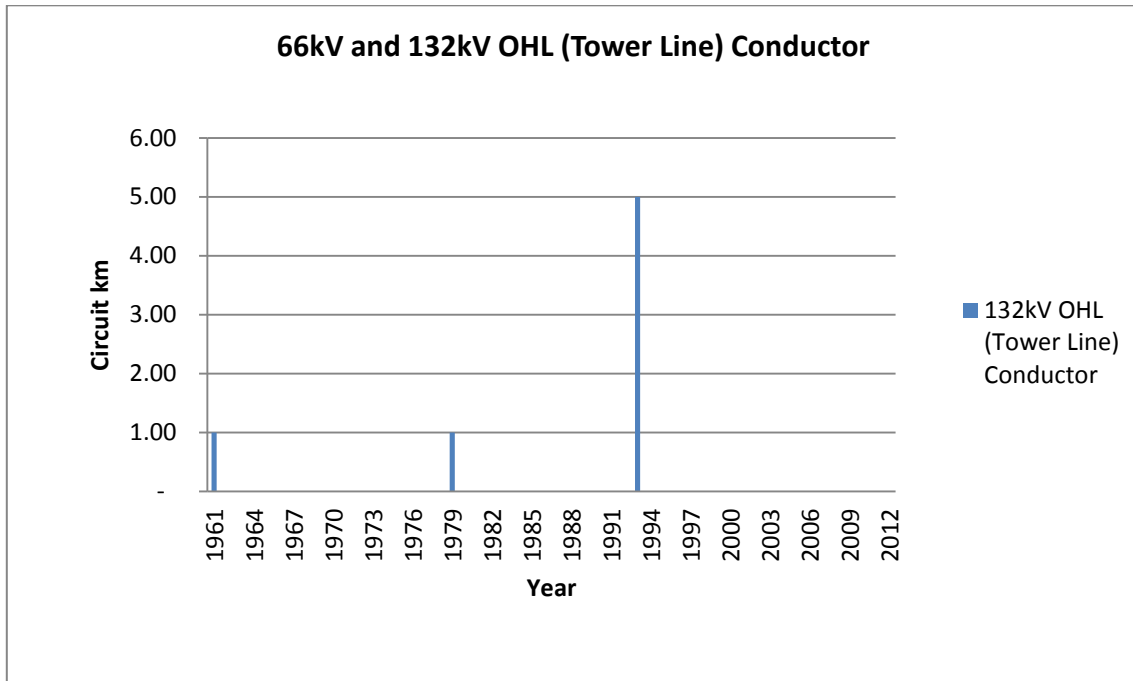
Figure 18 : 66kV 132kV OHL Conductor Age Profile

Source: V5 2012 RIGS
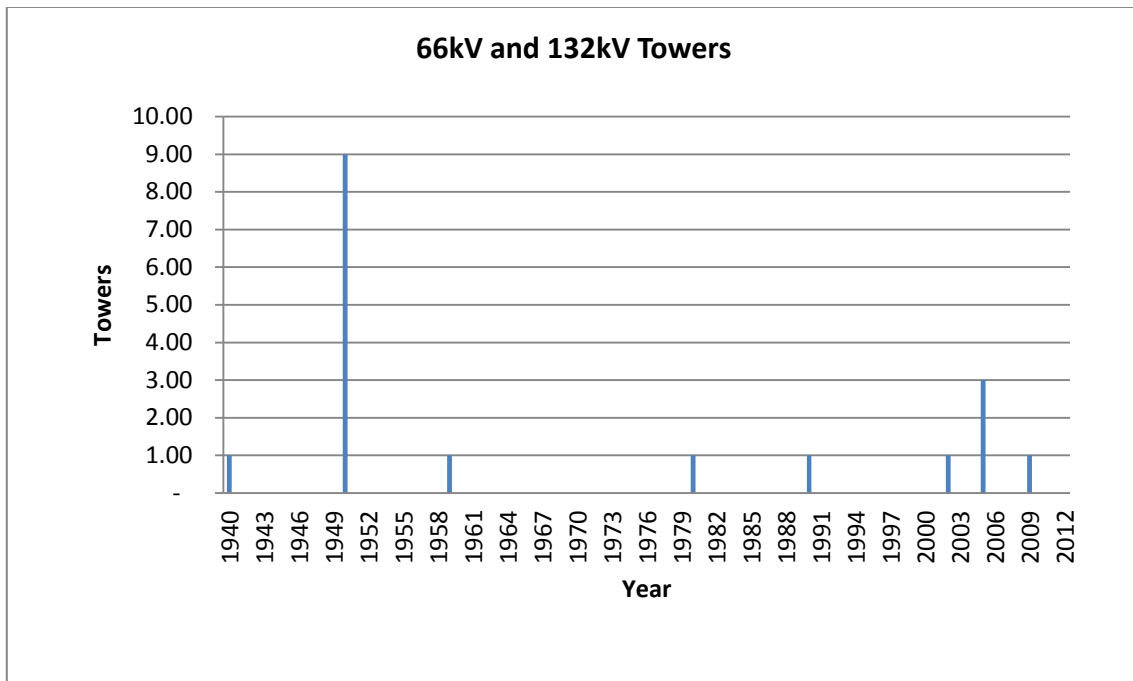
Figure 19 : 66kV and 132kV Towers Age Profile

Source: V5 2012 RIGS

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Appendix 2 - HI Profiles

Figure 20 : 66kV OHL HI Profile

Source: Tower and Conductor ARP model
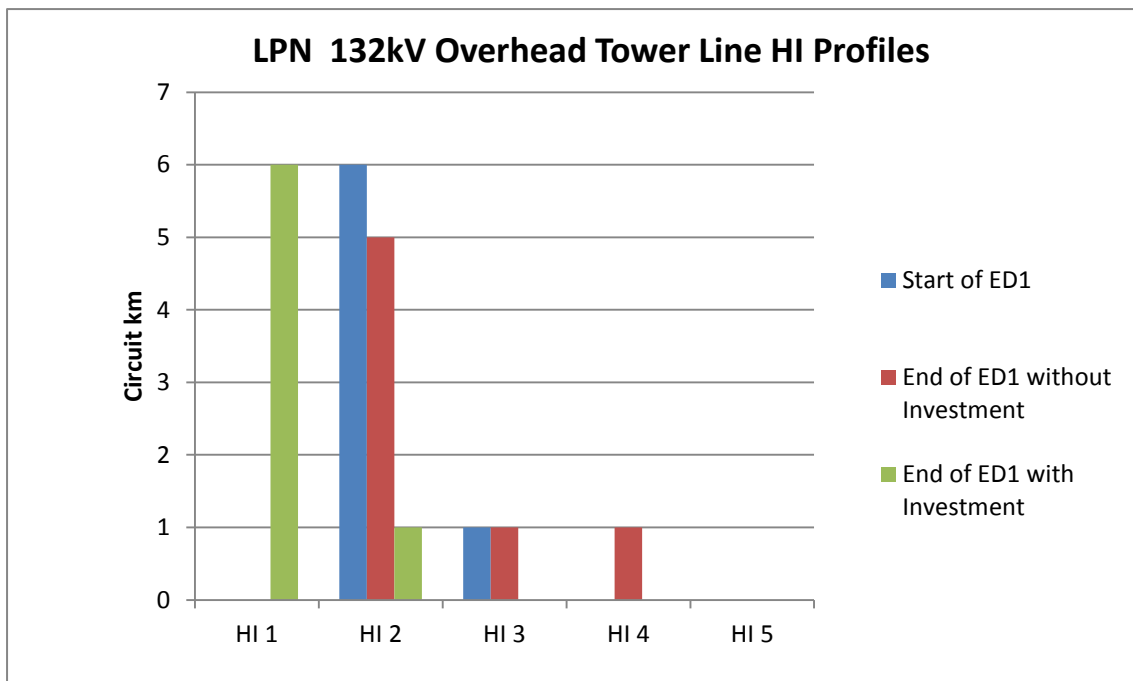
Figure 21 : 132kV OHL HI Profile

Source: Tower and Conductor ARP Model

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Appendix 3 – Fault Data

Not relevant: intentionally left blank

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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.

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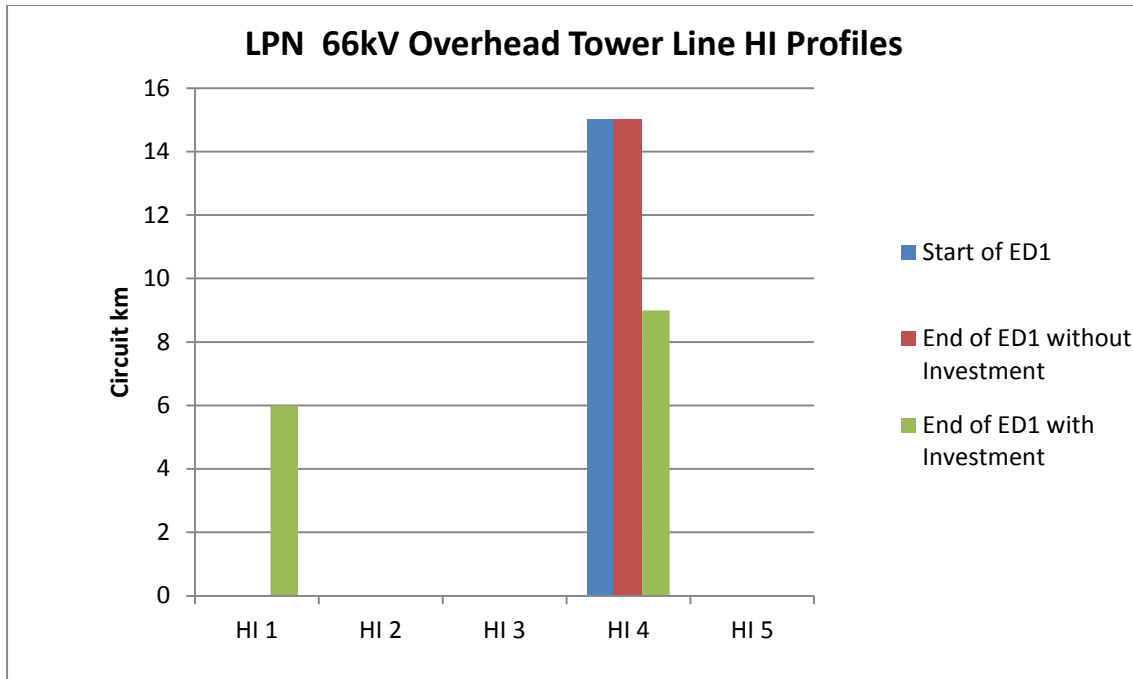
Appendix 5 – NLRE Expenditure Plan

Expenditure

LPN	2015/2016 (£m)	2016/2017 (£m)	2017/2018 (£m)	2018/2019 (£m)	2019/2020 (£m)	2020/2021 (£m)	2021/2022 (£m)	2022/2023 (£m)
1.02.02	0.00	0.00	0.20	0.46	0.00	0.00	0.00	0.00
1.02.03	0.00	0.00	0.09	0.22	0.05	0.08	0.00	0.00
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	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	**0.00**	**0.00**	**0.29**	**0.68**	**0.05**	**0.08**	**0.00**	**0.00**

Table 7: OHL expenditure plan

Source: 19th February 2014 NAMP Table J Less Indirect

Volumes

LPN	Unit	2015-16	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22	2022-23
1.02.02	Circuit km	0.0	0.0	0.0	6	0.0	0.0	0.0	0.0
1.02.03	Circuit km	0.0	0.0	0.0	4.0	0.0	2.0	0.0	0.0

Table 8: OHL volumes

Source: 21st February Business Plan Data Tables

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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 testing, 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.

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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
1.02.03	3886	PMC - Brunswick Wharf - West Ham - Conductor replacement	0	0	26,264	78,792	0	0	0	0
1.02.02	7938	LL - Barking/East Ham Tee Tower Line - Conductor Replacement	0	0	195,919	463,758	0	0	0	0
1.02.03	8198	PJA - Littlebrook - Dartford 3&4 - Conductor Replacement	0	0	0	0	46,081	77,018	0	0
1.02.03	8199	PWD - Littlebrook - Dartford 1&2 - Conductor Replacement	0	0	66,597	138,567	0	0	0	0

Table 9 – OHL Named Schemes

Source: 19th February NAMP 2014 Table J Less Indirect

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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
66kV Conductor Replacements	1.02.02	0	0	0	6	0	0	0	0	6	CV3	187	0	0	0	6	0	0	0	0	6
66kV Insulator and Fittings replacements		0	0	0	64	0	0	0	0	64	CV3	189	0	0	0	64	0	0	0	0	64
132kV Conductor Replacements	1.02.03	0	0	0	4	0	2	0	0	6	CV3	217	0	0	0	4	0	2	0	0	6
132kV Insulator and Fittings Replacements		0	0	0	28	0	12	0	0	40	CV3	219	0	0	0	28	0	12	0	0	40
										0											0
										0											0
										0											0
										0											0
										0											0
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										0											0
										0											0
										0											0
										0											0
										0											0
										0											0
										0											0
Total		0	0	0	102	0	14	0	0	116			0	0	0	102	0	14	0	0	116

Table 10 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

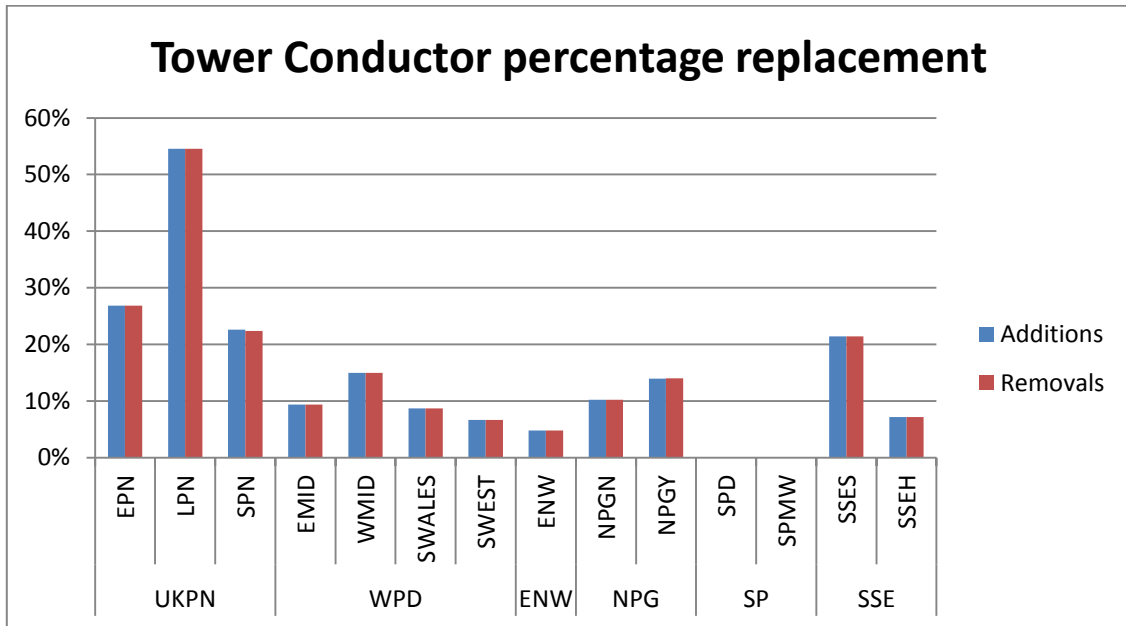## Appendix 9 – Efficiency benchmarking with other DNO's

Figure 22 - Efficiency Benchmarking

Source: DNO Datashare_2013

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

The LPN percentage replacement appears high due to the very low population of that network (22km total). Replacement volumes are low at only 12km.

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Appendix 10 – Material changes since the July 2013 ED1 submission

Changes between the July 2013 submission and the March 2014 re-submission are summarised and discussed below.

Asset type	Action	Change type	2013	2014	Difference (Reduction)	Comment
132kV Conductors	Replace	Volume (Additions)	12	6	(6)	Error correction
		Volume (Removals)	12	6	(6)	Error correction
		Investment (£m)	0.4	0.4	-	Error correction

Table 11 - Material Changes to July 2013 ED1 Submission (CV3)

Source: Final LPN Business Plan Data Tables following OFGEM Question and Answer Process and 21st February 2014 ED1 Business Plan Data Tables

132kV Conductors

The replacement volume of 132kV conductors was 12km but was incorrectly counted. The correct volume is 6km and this has been reflected in the re-submission changes. The cost component was already correct.