Document 3
Asset Category – Cables
EPN

Asset Stewardship Report 2014

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Document History:

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		All tables amended		Minor	Section 1
		Minor text amended and tables updated		Minor	Section 2
		First paragraph amended		Minor	Section 7.2.1
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		Data table added		Minor	Appendix 2
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1.3	05/03/2014	Updated Appendix 10 and removed Appendix 11	Richard Gould	Minor	Appendix 10, 11
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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 costs. The volume and cost data used in this ASR to explain our investment plan is taken from the UK Power Networks NAMP. Appendix 8 explains how the NAMP outputs are translated into the Ofgem RIGS tables. The translation of costs from the NAMP to the ED1 RIGS tables is more complex and it is not possible to explain this in a simple table. This is because the costs of 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 about 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 Underground Cables

1.1 Scope

This document details UK Power Networks' non-load related expenditure (NLRE) investment proposals for underground cables for RIIO-ED1 period. Where possible, indicative proposals for the ED2 period are also included.

There are 62,081 circuit kilometres of cable in EPN with an estimated MEAV of £8,313m. The intervention cost for ED1 is £83.5m across the eight year period.

The proposed investment is £10.4m per annum, which equates to an average annual 0.1% of the MEAV for this asset category.

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

Investment type	ED1 Investment £m	NAMP line	RIGs reference
Fluid-filled cable asset Replacement/refurbishment	£11.4m	1.29.01 1.29.02 1.31.02 1.31.04 1.31.08	Additions CV3 Row 63 – 33kV UG Cable (Oil) CV3 Row 93 – 132kV UG Cable (Oil) Removals CV3 Row 191 – 33kV UG Cable (Oil) CV3 Row 221 – 132kV UG Cable (Oil)
Solid cables asset replacement	£72.1m	1.07.02 1.07.90 1.18.01 1.18.03 1.32.09	Additions CV3 Row 9 – LV Main (UG Consac) CV3 Row 10 – LV Main (UG Plastic) CV3 Row 11 – LV Main (UG Paper) CV3 Row 29 – 6.6/11kV UG Cable CV3 Row 62 – 33kV UG Cable (Non Pressurised) Cv3 Row 92 – 132kV UG Cable (Non Pressurised) Removals CV3 Row 137 – LV Main (UG Consac) CV3 Row 138 – LV Main (UG Plastic) CV3 Row 139 – LV Main (UG Paper) CV3 Row 157 – 6.6/11kV UG Cable CV3 Row 151 – 6.6/11kV OHL (Conventional Conductor) CV3 Row 190 – 33kV UG Cable (Non Pressurised) CV3 Row 220– 132kV UG Cable (Non Pressurised)

Table 1 – Investment summary

Source: 21st February 2014 ED1 Business Plan Data Tables

1.2 Investment Strategy

The investment strategy for RIIO-ED1 is detailed in UK Power Network's Engineering Design Procedure EDP 00-009, *Asset Lifecycle Strategy-Underground Cables*. It is to ensure the lifetime cost of the underground cable assets are kept to a minimum while optimising performance and ensuring safety and regulatory compliance.

The current fluid-filled cable leakage rate for EPN is around the national average leakage rate and strategy is to maintain this position over the ED1 period.

1.3 ED1 Proposals

Fluid-filled cables

Table 2 shows the planned interventions for Fluid-filled cable (FFC) assets in EPN through RIIO-ED1.

NAMP line	Description	15/16	16/17	17/18	18/19	19/20	20/21	21/22	22/23	ED1 total
1.29.01	EHV FFC replacement	6.50	0	3.10	0	0	2	0	0	**11.60**
1.29.02	132kV FFC replacement	0	0	0	0	0	3.40	0	8	**11.40**
1.31.01	Replace aluminium cable joint plumbs	21	21	21	21	21	21	21	21	**168**
1.31.04	Install remote pressure-monitoring equipment	7	7	7	7	7	7	7	7	**56**
1.31.08	Replace pressurised cables ancillary equipment	21	21	21	21	21	21	21	21	**168**

Table 2 – RIIO-ED1 intervention volumes of FFC assets

Source: 19th February 2014 NAMP Table O

Table 3 shows the planned interventions for solid cable assets in EPN through RIIO-ED1.

NAMP line	Description	15/16	16/17	17/18	18/19	19/20	20/21	21/22	22/23	ED1 total
1.07.01	ED1 replace 33kV solid cable provision (planned)	3.08	3.08	3.08	3.08	3.08	3.08	3.08	3.08	24.64
1.07.02	ED1 replace 132kV solid cable provision	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	2.00
1.18.01	Replace HV cable (planned)	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	48.00
1.18.03	Replace LV cable (planned)	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	32.00
1.32.09	Underground 11kV Overhead Lines	24.40	24.40	24.40	24.40	24.40	24.40	24.40	24.40	195.20

Table 3 – RIIO-ED1 intervention volumes of solid cable assets in km

Source: 19th February 2014 NAMP Table O

1.4 Innovation

UK Power Networks has undertaken several initiatives to explore innovative solutions that will improve the performance of the underground cable network. Details of these are given in section 6 of the document.

Examples of innovation include online pressure monitoring, PFT leak location and partial discharge mapping.

1.5 Risks and Opportunities

	Description of similarly likely opportunities or risks arising in ED1 period	**Uncertainties**
Opportunity	Successful trials of self-healing fluids allow 10% of leaking FFC sections to remain in service.	£1.9m
Risk	10 % increase in the proposed ED1 intervention volumes due to sudden degradation of fluid filled cable (FFC) sections..	£1.8m

Table 4 – Risk and opportunities

2.0 Description of Underground Cables

There are 62,081 kilometres of underground cable installed in the EPN area. There are two types of cable construction: solid cable and fluid filled cable. There is no gas cable installed in EPN. The fluid-filled cables operate at either EHV or 132kV, while the solid cables operate at all voltage levels from LV to 132kV.

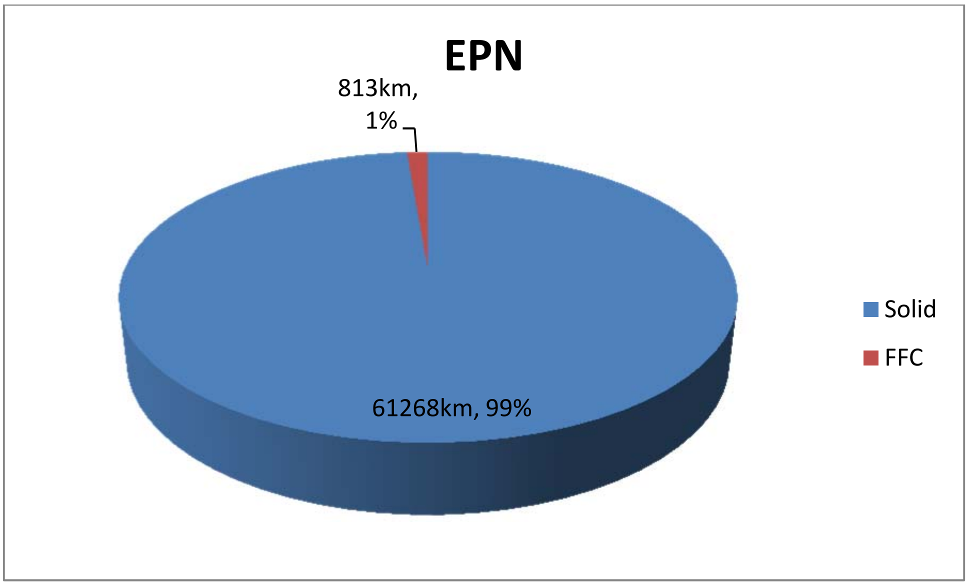


Figure 1 – Population of underground cables by type

Source: RIGs 2012 Table V5

The breakdown of EPN underground cable network by voltage is given in Figure 2.

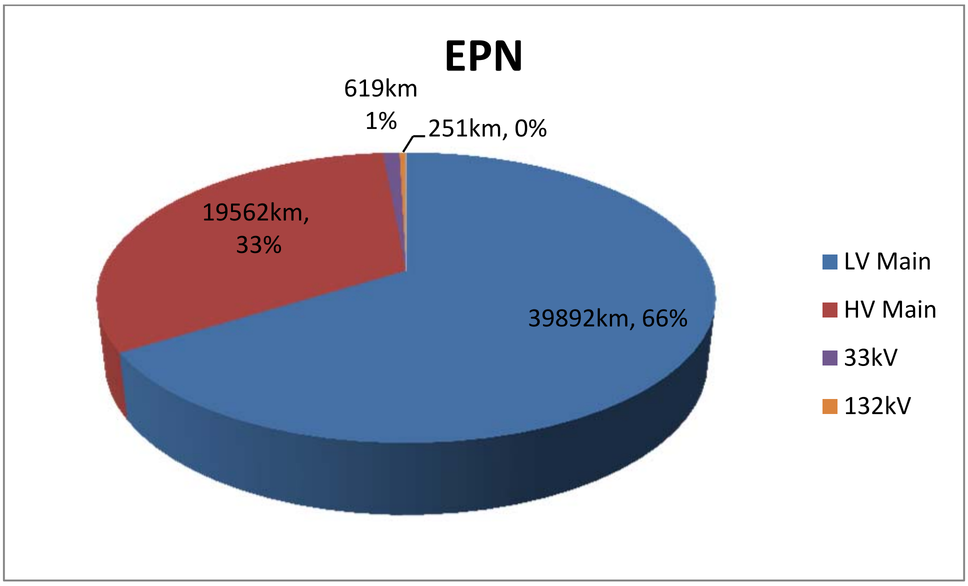


Figure 2 – Population of underground cables by voltage

Source: RIGs 2012 Table V5

The 132kV underground cable network has more fluid filled cable installed than any other type – refer to Figure 3.

Of the 132kV underground cable network, 77% is constructed of fluid-filled cable.

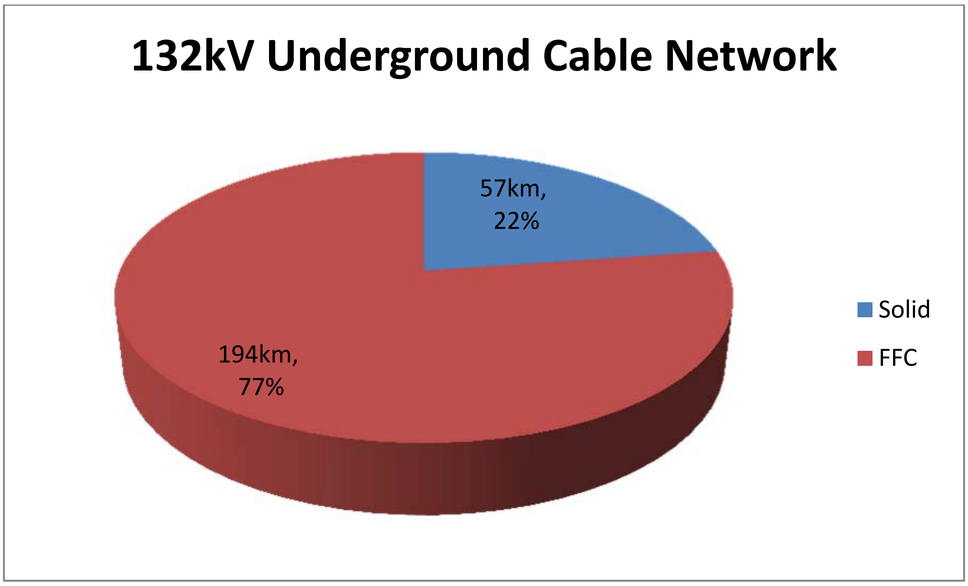


Figure 3 – 132kV underground cable by type

Source: RIGs 2012 Table V5

In contrast, the EHV underground cable network is predominantly of solid construction, as shown in Figure 4.

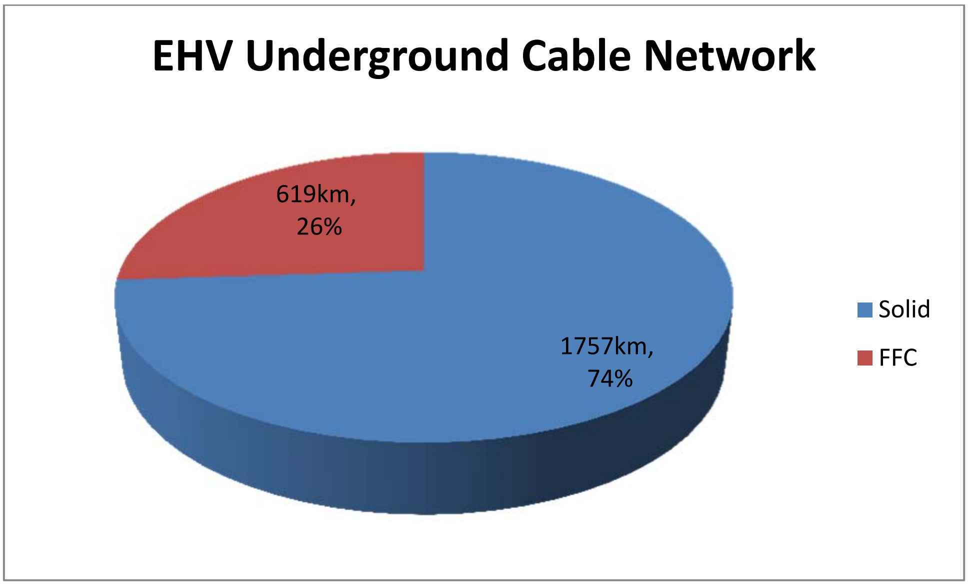


Figure 4 – EHV underground cable by type

Source: RIGs 2012 Table V5

2.1 Fluid-Filled Cables

Of the fluid filled cable network, 76% of the cables are at EHV and 24% of the cables are at 132kV. Figure 5 shows the breakdown of fluid-filled cable by voltage.

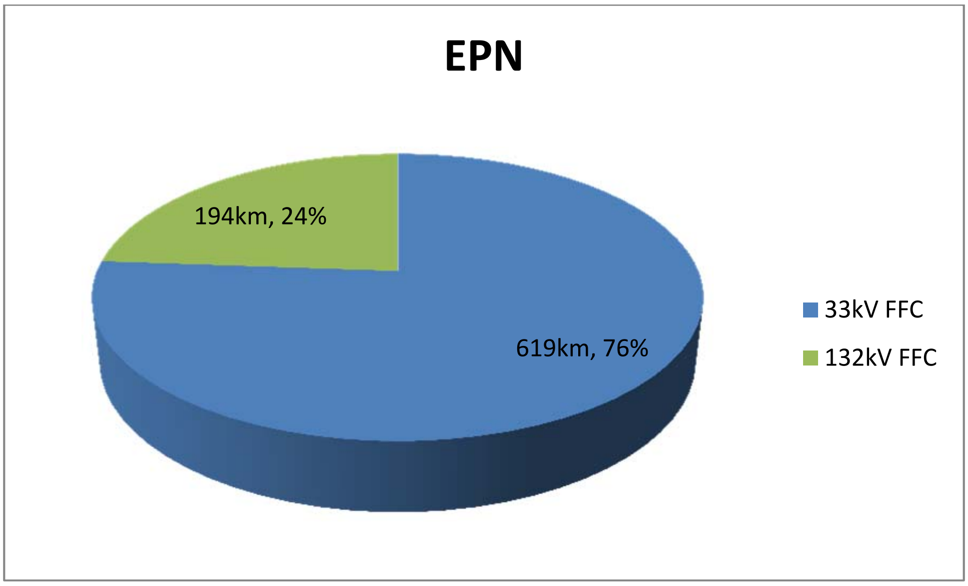


Figure 5 – Population of underground Fluid-Filled Cable (FFC) by voltage

Source: RIGs 2012 Table V5

The average age of the fluid-filled cable network is 53 years. The oldest 10% of these assets has an average age of approximately 77 years.

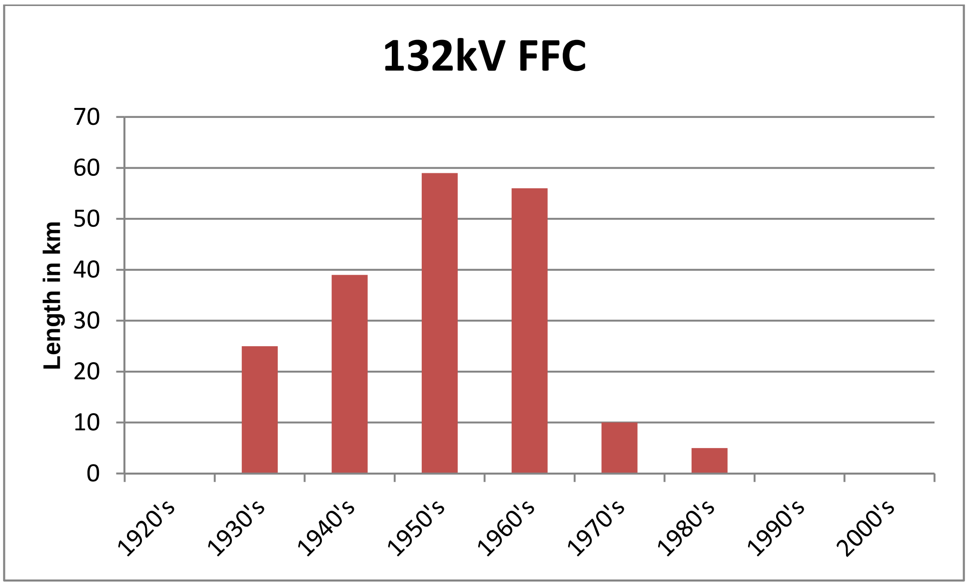


Figure 6 – Age profile of 132kV FFC cable

Source: RIGs 2012 Table V5

The average age of the 132kV fluid-filled cable network is 58 years.

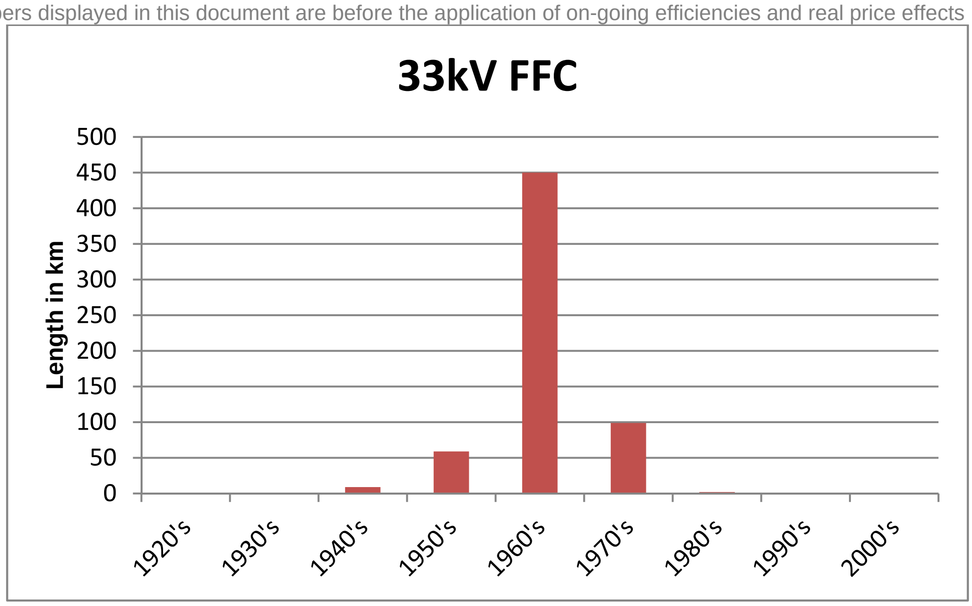


Figure 7 – Age profile of 33kV FFC Cable

Source: RIGs 2012 Table V5

The average age of the EHV fluid-filled cable network is 48 years.

Reference NAMP lines:

The fluid filled cable replacement provisions for ED1 are listed under following NAMP lines:

NAMP line	Description
1.29.01	Fluid Filled Cable Replacement (EHV)
1.29.02	Fluid Filled Cable Replacement (132kV)

Table 5 – NAMP reference

Reference RIGs code:

The corresponding RIGs lines are shown in Table 6:

RIGs tab	Line (additions)	Line (removals)	Description
CV3	63	191	33kV UG cable (oil)
CV3	93	221	132kV UG cable (oil)

Table 6 – RIGs categories

2.2 Solid Cables

There are a number of different types of solid cables in operation in the EPN region. These types are Paper Insulated Lead Covered Cable (PILC), Paper Insulated Corrugated Aluminium Sheath Cable (PICAS), Cross-Linked Polyethylene Cable (XLPE) and Waveform cable. Solid cables are operated at all voltage levels.The breakdown is shown in figure 8.

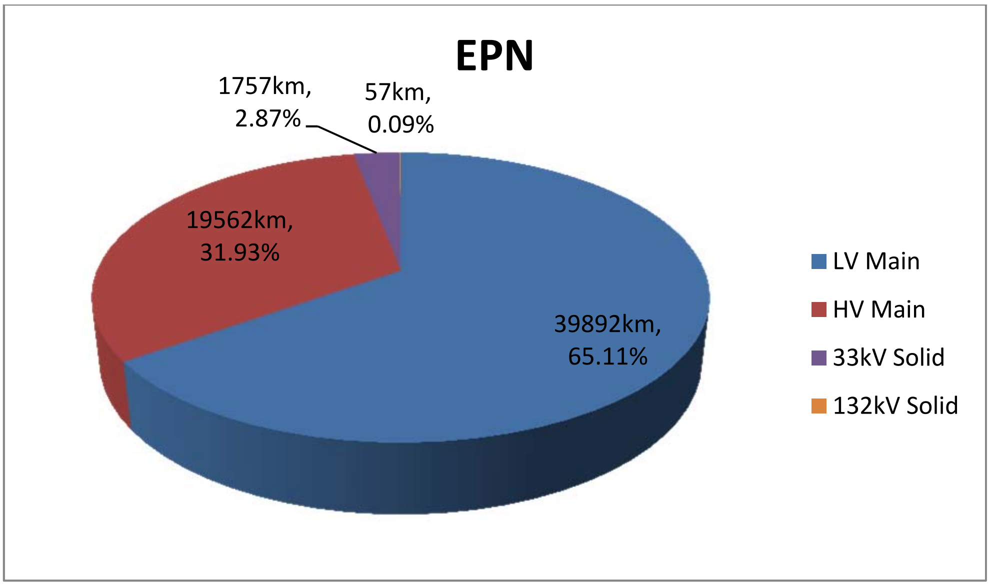


Figure 8 – Population of underground solid cable by voltage

Source: RIGs 2012 Table V5

Solid cables are now installed rather than fluid-filled cables or gas cables at higher voltages. At lower voltages, solid cables are always installed.

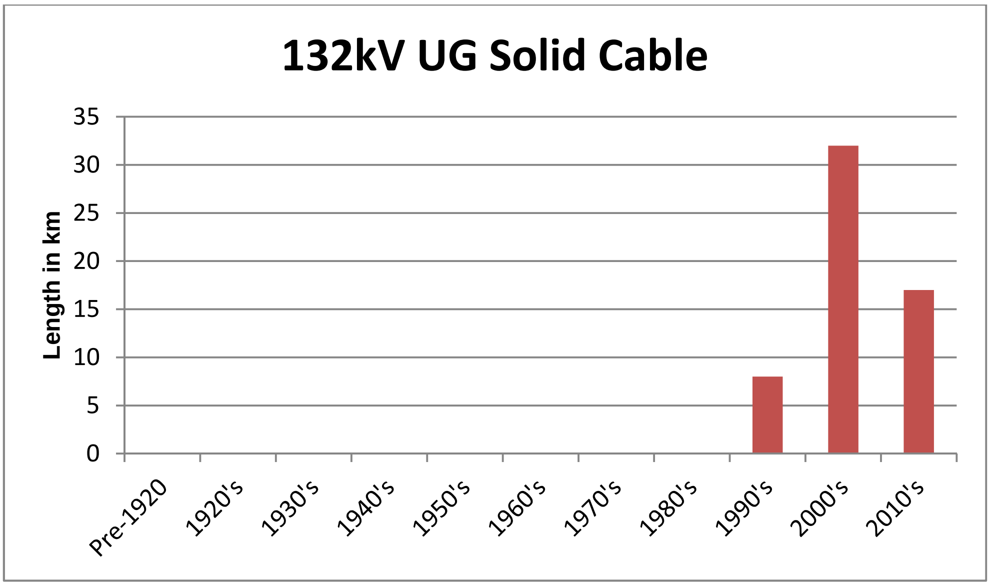


Figure 9 – Age profile of 132kV underground solid cable

Source: RIGs 2012 Table V5

The average age of the 132kV solid cable network is 8 years.

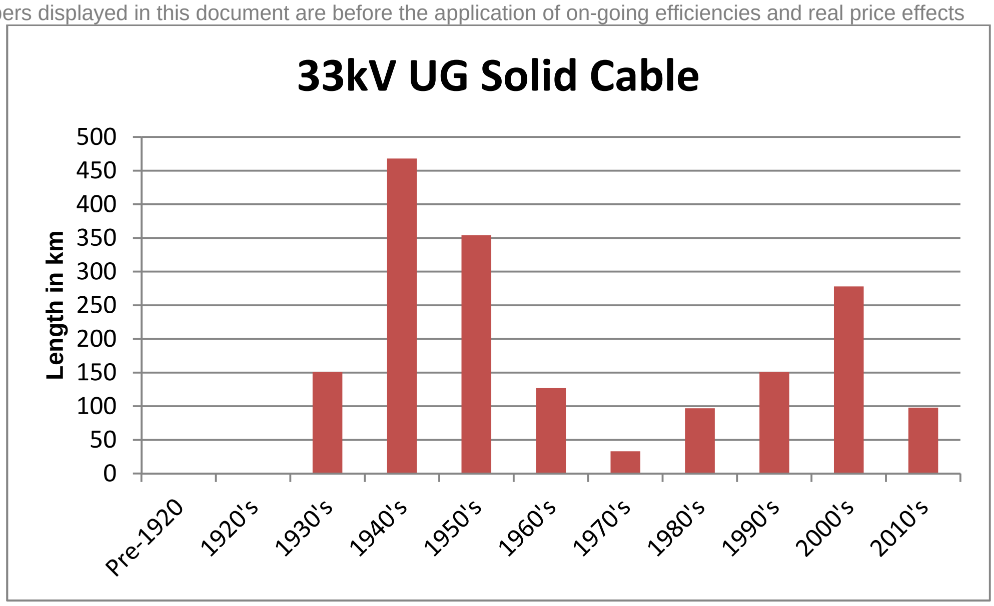


Figure 10 – Age profile of 33kV underground solid cable

Source: RIGs 2012 Table V5

The average age of the EHV solid cable network is 46 years.

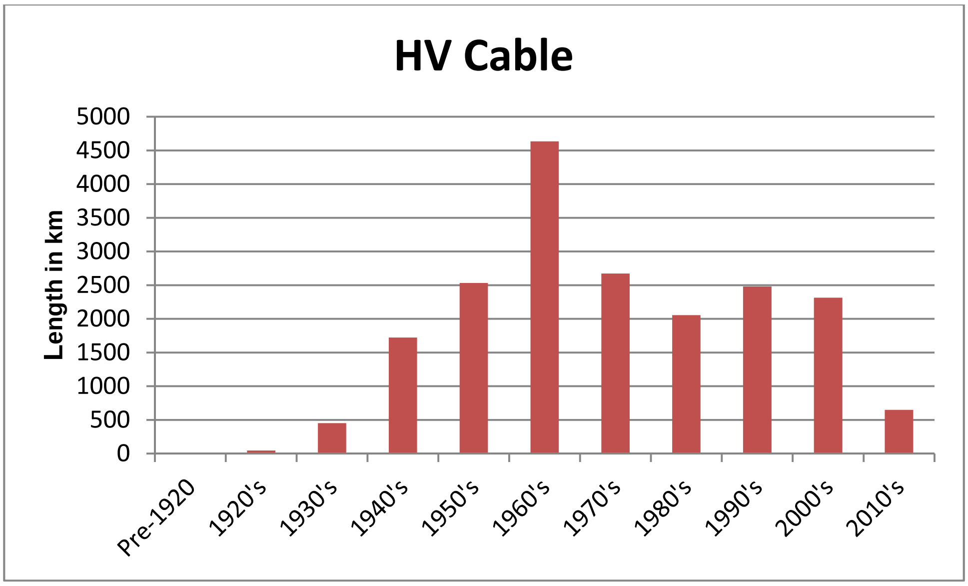


Figure 11 – Age profile of HV underground solid cable

Source: RIGs 2012 Table V5

The average age of the HV solid cable network is 39 years.

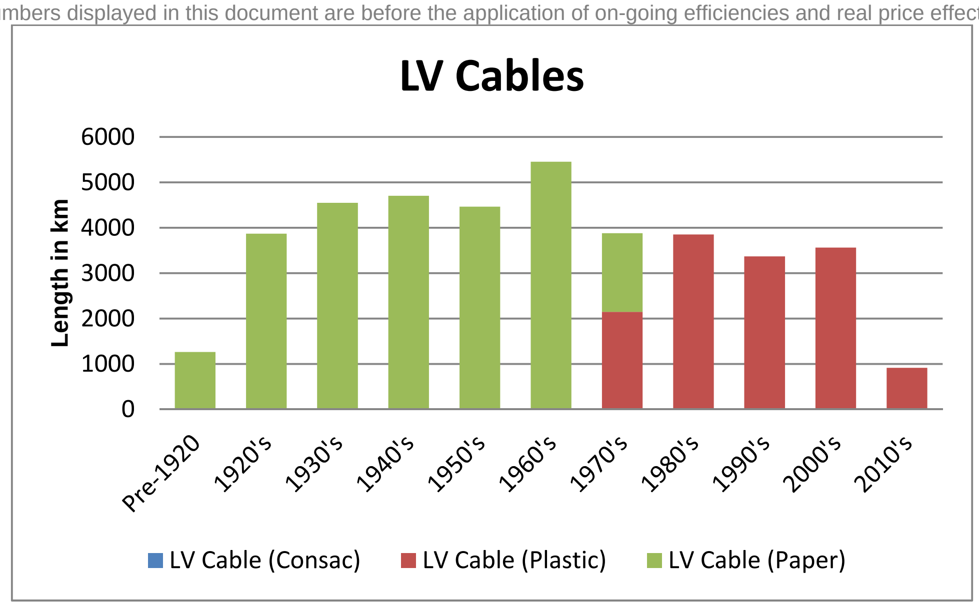


Figure 12 – Age profile of LV underground solid cable

Source: RIGs 2012 Table V5

The average age of the LV solid cable network is 42 years.

Reference NAMP lines:

The solid cable replacement provisions for ED1 are listed under following NAMP lines:

NAMP line	Description
1.07.90	Solid Cable Replacement (EHV)
1.07.02	Solid Cable Replacement (132kV)
1.18.01	HV Cable Replacement
1.18.03	LV Cable Replacement

Table 7 – NAMP lines

Reference RIGs code:

The corresponding RIGs lines are shown in Table 8:

RIGs tab	Line (additions)	Line (removals)	Description
CV3	009	137	LV Main (UG Consac)
CV3	010	138	LV Main (UG Plastic)
CV3	011	139	LV Main (UG Paper)
CV3	029	157	6.6/11kV UG Cable
CV3	062	190	33kV UG Cable (Non-Pressurised)
CV3	092	220	132kV UG Cable (Non-Pressurised)

Table 8 – RIGs categories

3.0 Investment Drivers

The high-level investment drivers for underground cables are detailed in EDP 00-0009, *Asset Lifecycle Strategy Underground Cables*. The principal drivers for the replacement of underground cables are safety, network security, public safety, environment, condition and compliance with relevant legislation. The industry code of practice governing fluid-filled cables is ENA Engineering Technical Report 135 – *Guidance on the operation and maintenance of Fluid-Filled Cables*.

3.1 Investment Drivers For Fluid-Filled Cables

3.1.1 Fluid-filled cable types and known issues

Fluid-filled cables are constructed with either a lead sheath or an aluminium sheath. Both types of cables have known failure mechanisms.

Lead sheath cables suffer from crystallisation of the sheath, which results in it becoming porous and discharging cable fluid into the environment. This cause has been documented in ENA ETR135. When lead crystallisation occurs, it usually does so along large sections or the whole of a circuit. As a consequence, the replacement of short section lengths will not alleviate this problem. Lead sheath crystallisation results in the rapid deterioration of the integrity of the cable, which cannot be managed through repeated fault repairs.

Once lead sheath crystallisation is discovered and a repair deemed not possible or unsuccessful, the replacement of a hydraulic section will be considered initially. It is, however, sometimes necessary for the whole circuit to be replaced if the condition is similar throughout the circuit length.

Aluminium sheath cables suffer primarily from cable fluid leaks at the joint plumbs. These can often be refurbished or repaired in order to rectify leaks, although replacement of cable sections or circuits are still necessary. Tape deterioration also has an impact on the strength of the sheath that ultimately will result in fluid leakage

Fluid-filled cables under high load conditions will subject the sheath to adverse thermo-mechanical forces, resulting in higher fluid leakage rates, particularly in the winter. Leaks can be difficult to repair as outage constraints and adverse weather often make repairs challenging to achieve during this period. Conversely, in more favourable operational conditions, cables are often leaking much less, making leak location more challenging.

Figure 13 – Crystallised lead sheath

Figure 14 – Aluminium joint

3.1.2 Cable fluid leakage

Cable fluid leakage is used in the ARP model to assist in the calculation of the overall Health Index of the fluid-filled cable population.

Fluid-filled top-up data published by Ofgem shows that EPN contributes 16% of fluid top-ups nationally, which, on a per-kilometre basis, is around the national average.

Using the ARP model to calculate the predicted HI4 and HI5 cable sections at the end of the ED1 period, the predicted leakage rates with and without investment have been calculated – refer to Figure 15.

This shows that the implementation of the proposed investment plan will maintain leakage rates at roughly the same level throughout the ED1 period. The leakage rate with intervention prediction includes a 2.5% year-on-year reduction in leakage due to enhanced leak-location techniques such as the

PFT tracer and an increased focus on leak repairs. Without intervention, the cable leakage rates are predicted to increase by 31% over the ED1 period.

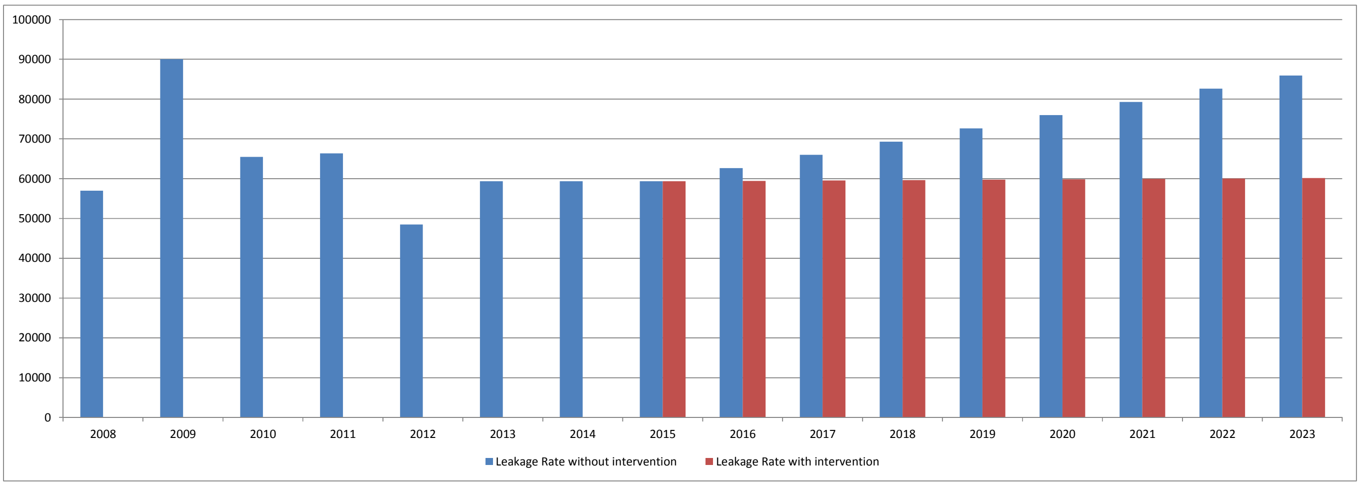


Figure 15 – Fluid-filled cable leakage with and without intervention

Source: ARP July model

3.1.3 Condition

Condition assessments of the fluid cable population are made whenever possible, e.g. after a fault or cable repair. The condition assessments enable the identification of issues such as a crystallised lead sheath and are used in conjunction with fluid top-up records to prioritise investment.

Should crystallised lead be discovered during a fault repair, the length of cable replaced will usually be increased to remove the length containing crystallised lead sheath.

3.1.4 Compliance with industry best practice

ENA Engineering Technical Report 135 (*Guidance for the operation and management of fluid cables*) forms the basis on the actions being taken by UK Power Networks to address the risks posed through the operation of fluid-filled cables. It is stated in the Operating Code that licencees “will take all reasonably practicable steps to prevent pollution of controlled waters, taking advice from the Environment Agency as required”.

UK Power Networks implements ETR 135 through its own policy, EDP 08 306 *Leak Management Strategy for Fluid-Filled Cables*.

Pollution risk is monitored through UK Power Networks policy HSS 01 009 *Environmental Management of Fluid-Filled Cables*.

3.1.5 Environmental risk

Compliance with environmental legislation is a key investment driver for fluid-filled cables. As per the Guidance on the National Operating Code for the Management of the Fluid-Filled Cable system, produced by Energy Network Association (ENA) and Environment Agency (EA), the responsibilities of Network operators are, in sensitive areas, to:

- determine the length of cable passing through the area
- report all leaks above 40 litres per month as soon as confirmed (this is the limit of leak detection/location)
- prioritise leak location and repairs in consultation with the Agency.

And in non-sensitive areas to:

- report all leaks above 100 litres per month during office hours once confirmed
- put repairs in hand without delay
- put repairs in hand within two months for leaks below 100 litres per month (subject to the practical thresholds of leak location).

The Environment Agency defines an area of environmental sensitivity as an area within 50 metres of a watercourse, a major aquifer with high or intermediate vulnerability or where groundwater is close to the surface (10 metres) or a Source Protection Zone (SPZ) around groundwater abstractions. The ARP uses environmental sensitivity data in the prioritisation of cable replacement.

3.2 Investment Drivers for Solid Cables

The investment drivers for the replacement of solid cables are based primarily on a case-by-case condition assessment of faulted cable sections. It is UK Power Networks policy to collect cable samples for assessment after a cable fault, as specified in EDS 02-0043, *Solid Cable Non-Load Related Repair and Refurbishment*..

In addition, partial discharge mapping is used at HV to identify circuits on raised activity levels and any potential failure risk, although this in isolation would not be sufficient an investment driver for the replacement of a cable without further condition assessment taking place.

3.3 Cable Fault Rates

The graphs show fault rates for cables by voltage level, but it is not possible to separate out different cable types from the data. Overall cable fault rates are relatively stable at all voltages.

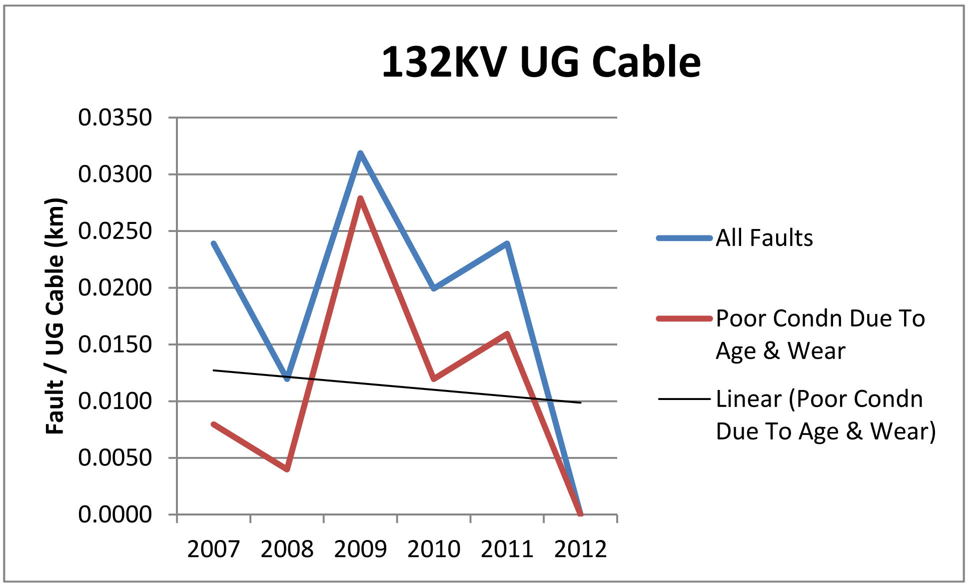


Figure 16 – Fault trends of 132kV underground cable

Source: UKPN Faults Cube

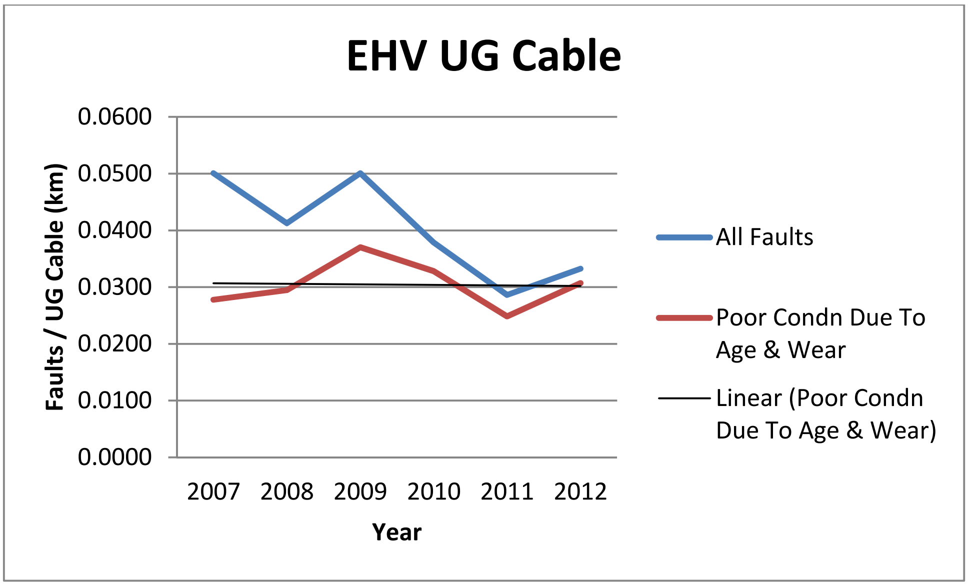


Figure 17 – Fault trends of EHV underground cable

Source: UKPN Faults Cube

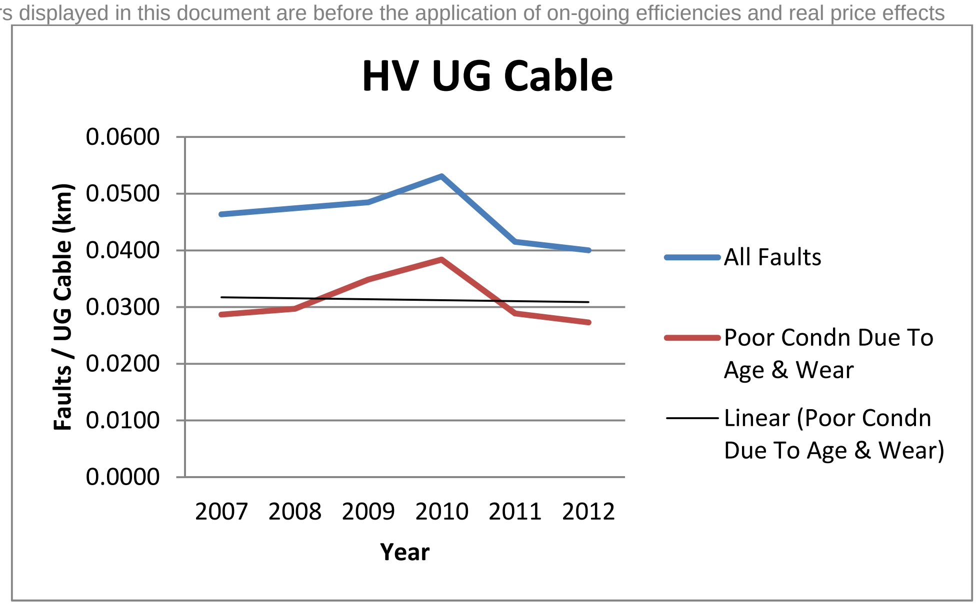


Figure 18 – Fault trends of HV underground cable

Source: UKPN Faults Cube

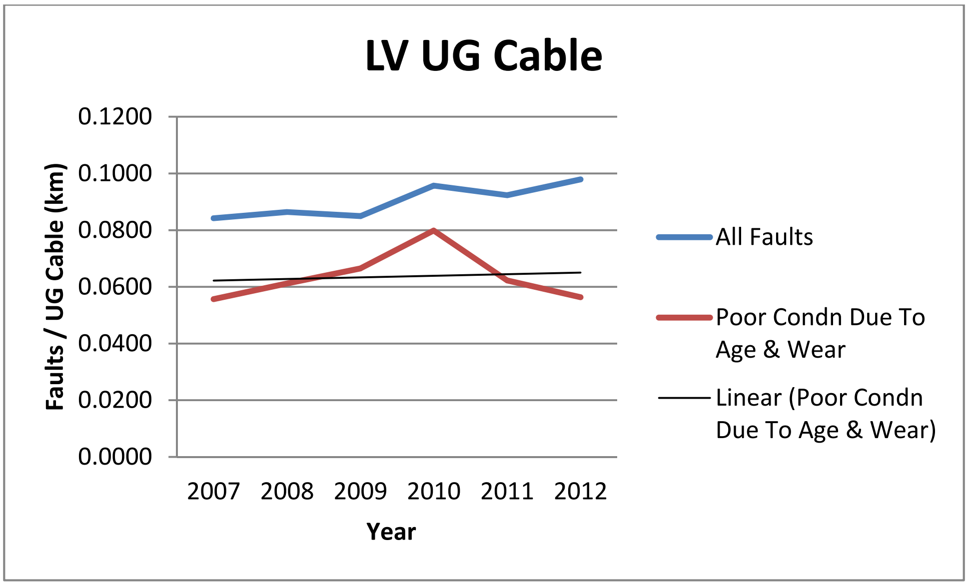


Figure 19 – Fault trends of LV underground cable

Source: UKPN Faults Cube

4.0 Asset Assessment

4.1 Health Assessment of Fluid-Filled Cables (FFC)

An innovative asset health modelling tool, the Asset Risk and Prioritisation (ARP) model, has been developed for several asset categories, including fluid-filled cables for all voltages. The methodology behind the modelling is the same for all asset categories, but the fluid-filled cable model has been tailored specifically to utilise the historical oil leak data.

4.1.1 Calculation of HI

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

4.1.2 Condition information

The initial age-based health index is modified by incorporating condition-assessment measurements, as well as a history of oil leaks and defects. The details of each of these factors are discussed below.

Condition factors – The fluid-filled cables model includes a number of condition points, such as oversheath condition, bedding condition, screen condition, conductor condition, armour condition, metallic sheath condition, insulation condition and paper condition.

Field engineers are requested to provide condition data when repairing cables. However, this is a relatively recent initiative, so at present no comprehensive sets of condition data are available. Available data is entered into the model and set up as such that each condition point is assigned a score of 1 or 4 and then translated to a condition factor.

Oil-leak history – The critical issue for fluid-filled cables is the condition of the fluid containment system. The leak history of each section is a useful proxy for this and the model includes oil leaks for up to five years. The annual oil loss per section is then estimated as the weighted average of the actual oil loss figures over the past five years.

Defect history – The rate of occurrence of defects can be considered as an indication of both the condition of an asset and the likelihood of future defects or failure. At present, the model has no defect parameters defined, but this is a facility that could be used in the future.

Final Health Index – An overall factor value is derived for each cable section and is the highest of the following three factors:

- condition
- oil leakage history
- fault history.

An interim final Health Index is calculated for each section. This is the product of the overall factor value and the initial age-related Health Index.

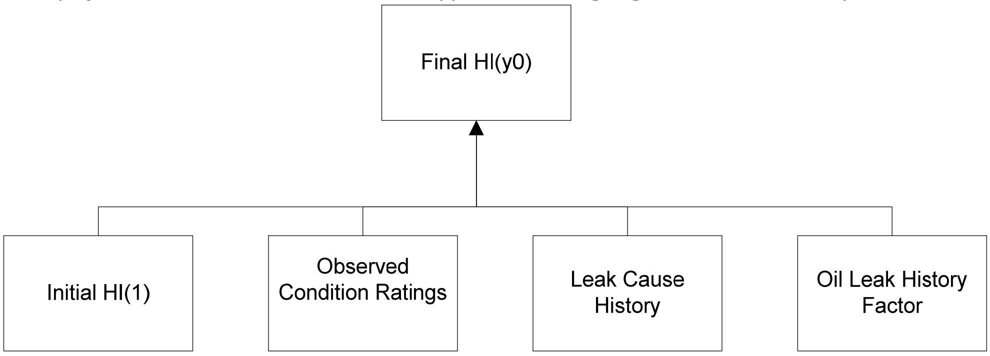


Figure 20 – Flowchart showing calculation of Health Index from ARP model

4.2 Asset Criticality

The ARP model can also be used to calculate the criticality of a particular hydraulic section of the FFC asset. This is then output in the form of 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 *Commentary Document 15: Model Overview*.

In the FFC ARP model, there are five main areas considered when calculating the criticality of an asset: network performance, safety, operational expenditure, capital expenditure and environment. A number of key factors are considered in each of these areas.

This area of the model is still in its infancy and in the process of being further developed.

4.3 Network Risk

The network risk in monetary terms can also be calculated in the ARP model. This is done using the probability of failure, the criticality and the consequence of failure. The probability of failure is calculated using the current Health Index of the item of FFC, and the criticality is calculated as described in the previous section. The consequence of failure is the average cost to either repair or replace the section of cables following one of failure modes.

This area of the model is still in its infancy and in the process of being further developed.

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, which provides details of every non-compliance, allowing 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.

4.6 Data Completeness

The completeness, accuracy and timeliness of the data used in the ARP model are routinely checked. The results for the data used in the fluid-filled cable model are given in Table 9.

Area	Result
Completeness	87.9%
Accuracy	Not available
Timeliness	Not available

Table 9 – Data CAT scores

Source: Decision Lab report "CAT Scoring" 8th February 2013
* Not available: quality standards are under review

The completeness score is a combination of fluid filled name plate data and pumping information in asset register. The completeness of any data used in the network risk section, such as customer numbers, is also used in the overall completeness score.

The accuracy and timeliness scores are a measure of how reliable and correct the condition data stored in Ellipse is. This analysis has not been completed because condition data is not collected for fluid-filled cables.

4.7 Health Assessment of Solid Cables

Individual solid cables are not assessed for health on a planned basis. However, UK Power Networks has a policy to collect cable samples for assessment as specified in EDS 02-0043, *Solid Cable Non-Load Related Repair and Refurbishment*. As part of the policy, field engineers provide relevant samples for condition assessment. Over time, this will enable a fuller picture of the health of solid cables to be built up for used as a future investment driver. Figure 21 shows the snapshot of the CADERA (Cable Analysis Database By ERA) consisting of assessment results.

Results show that the main failure mode is due to the drying out of the impregnate, especially for cables installed on slopes. Oil migration in insulation papers also appears to play a significant role in the premature ageing of solid cables.

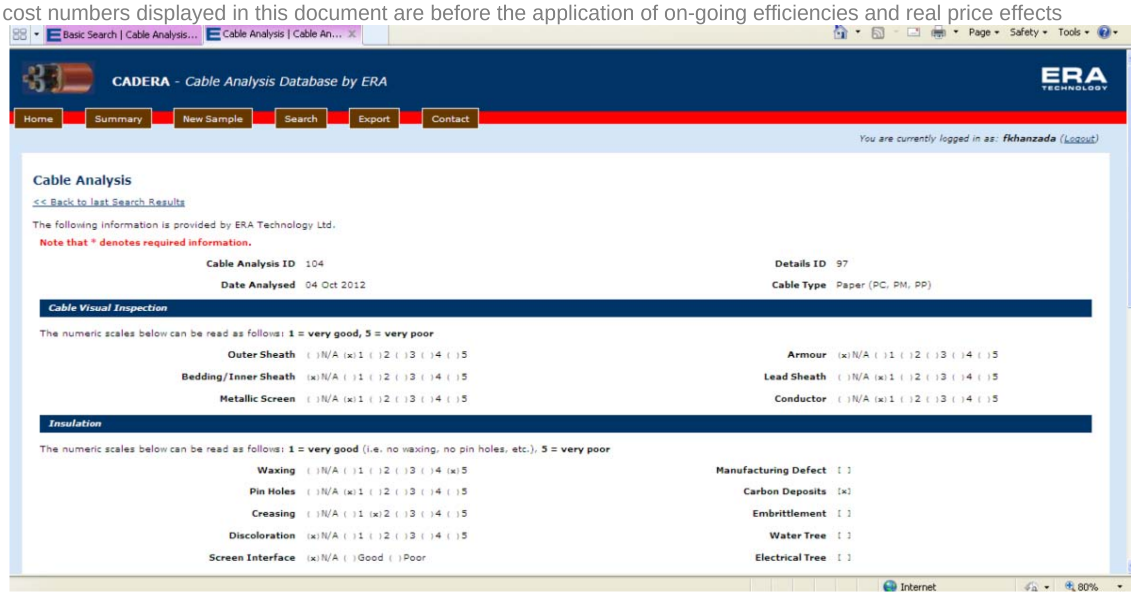


Figure 21 Snapshot of the cable analysis database

5.0 Intervention Policies

5.1 Intervention Options

5.1.1 Interventions for Fluid-Filled Cables

Interventions on fluid-filled cables consist of the replacement of a complete circuit, the replacement of a hydraulic section or leak repair. The type of intervention used is driven by application of the investment drivers highlighted in Section 3.

If possible, a leak repair is carried out. However, if crystallised lead is discovered, consideration will be given to the replacement of a hydraulic section or possibly the circuit, depending on leak-rate history and the extent of the sheath degradation.

5.1.2 Interventions for Solid Cables

Interventions on solid cables consist of either a cable repair or the replacement of faulted cable sections. A reactive replacement of cable may also be considered if cable in poor condition is discovered during other work. This decision is usually based on a condition assessment by a field engineer in consultation with Asset Management as required.

6.0 Innovation

UK Power Networks has undertaken several initiatives to explore various innovative solutions in order to improve the performance of the underground cable network.

6.1 Fluid-Filled Cables

6.1.1 Online pressure monitoring

Using pressure transducers to monitor fluid-filled cable operating pressures remotely offers the potential for a more holistic approach to maintenance and inspection based on real-time condition against the current regime of periodic-based scheduled tasks. The topping up of fluid reservoirs could be done based on trends rather than planned ‘milk runs’. This equipment is in the process of installation and is expected to be complete by end of DPCR5.

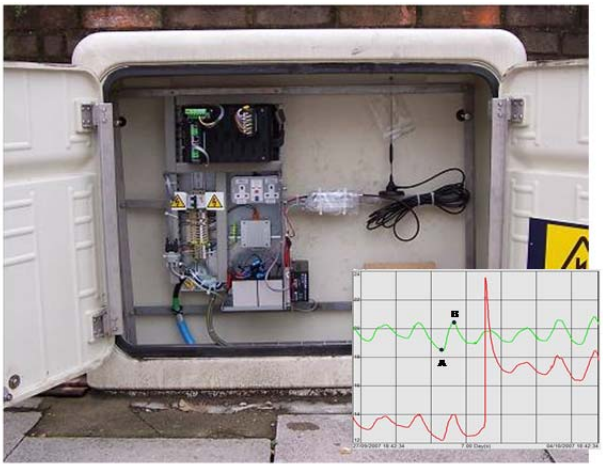


Figure 22 Online pressure monitoring system

6.1.2 PFT leak location

In order to offset the long-term leakage from fluid-filled cables, an innovative solution has been developed and deployed. A minute amount of Perflurocarbon Tracer (PFT) is added to the cable fluid. PFT introduced in this way is vented to the atmosphere at the point where a leak in the cable is present, where it can be detected using highly sensitive mobile equipment. This method greatly improves performance in the detection and resolution of leaking cable incidents, reducing the cost of work, outage time and environmental impact.

Figure 23 – PFT leak location system

6.1.3 FFC self-healing

This project will identify, develop and assess self-repairing systems for fluid-filled cable sheath, such that damage to the sheath will self heal, avoiding oil leakage and a subsequent environmental clean-up.

This is an IFI project currently at the R&D stage. Phase 1 is due to be completed in January 2015 and is an exercise to identify potentially suitable additives. Depending on the success of this phase, there would potentially be subsequent laboratory and field trial phases.

6.2 Solid Cables

6.2.1 Innovative design of 132kV and 66kV solid cables

Design modifications are being explored to reduce the cost of the 132kV and 66kV solid cables by eliminating copper and reducing insulation thickness without comprising the integrity and quality of the cables.

This is a UK Power Networks lead initiative in conjunction with cable manufacturers.

6.2.2 Innovative design of 33kV and 11kV solid cables

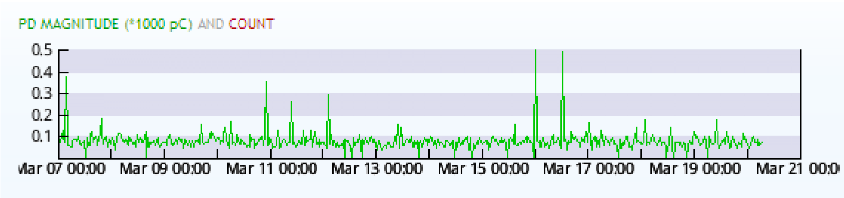
Design modifications being developed will remove all copper. The reduction in cost is still to be determined, but will likely be in the region of 10 to 20%, and the cables will be less susceptible to theft.

This is a UK Power Networks lead initiative in conjunction with cable manufacturers.

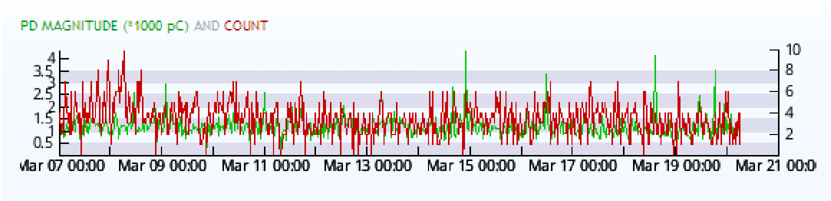
6.2.3 Partial discharge monitoring system on HV cable network

The use of partial discharge (PD) measurement is a well-known method of checking the condition of electrical insulation. Over the past 10 years, UK Power Networks has been actively involved in the development of online partial discharge monitoring and mapping techniques. Opportunities to improve the existing technology have been identified. This project has developed equipment to continuously monitor PD activity in 11kV underground cables. Further work is in progress in order to improve algorithms for early fault detection.

Figure 24 shows typical screen shots from the online PD monitoring system showing activity on 11kV cables at Canvey Primary substation.



Canvey Primary Methane No1 cable PD – showing very low levels of activity



Canvey Primary East Crescent cable PD – showing slightly raised levels of activity

Figure 24 – Partial discharge activity of 11kV cables at Canvey Primary substation (EPN)

7.0 Expenditure Requirements for Underground Cables

7.1 Method

7.1.1 Fluid-filled cables

An overview of the method used to construct the ED1 plan is shown in Figure 25. This programme has been produced with the assistance of the Asset Replacement Prioritisation (ARP) model.

1. Cable sections with a Health Index of HI4 and HI5 were identified by the ARP tool.
2. Internal Stakeholders such as Network Operations, Infrastructure Planning and Capital Programme were consulted on the identified cable sections.
3. Identified cable sections were prioritised based on the location sensitivity.
4. After the consultation process, schemes were raised for inclusion in the ED1 plan

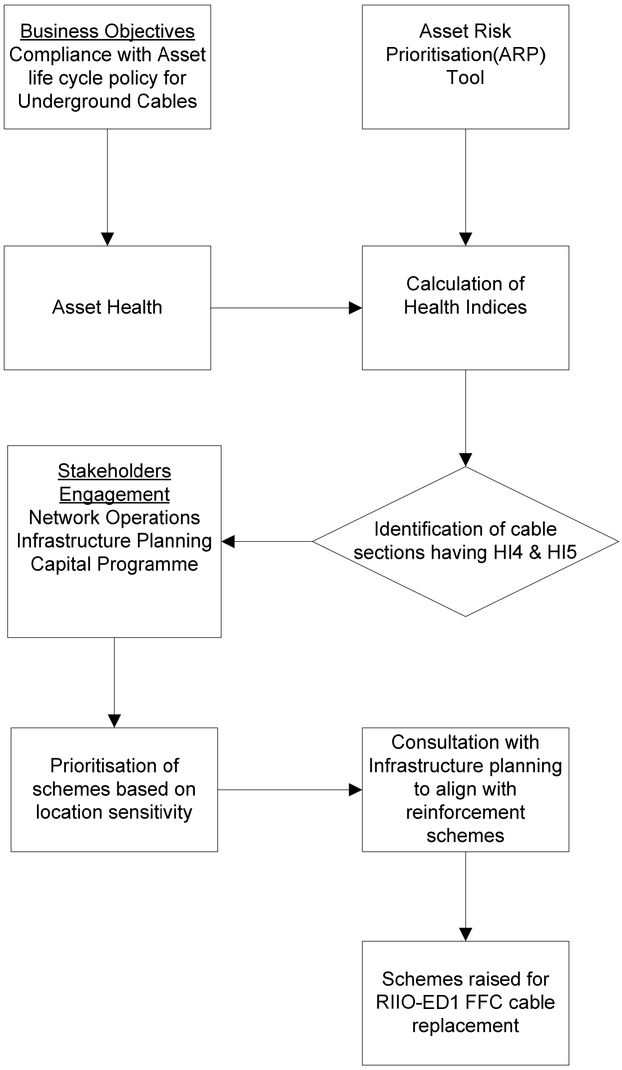


Figure 25 Construction of NLRE plan for FFC replacement

7.1.2 Solid cables

This programme is compiled on the basis of historical replacement levels. Post-fault analysis is carried out on historical faults. Solid cables are replaced with a modern XLPE cable, but only when their condition is found to be poor. Solid cable condition is not recorded in Ellipse, but partial discharge mapping can be used on short lengths of circuit where poor fault history is found.

The following process has been adopted for the ED1 solid cable replacement plan.

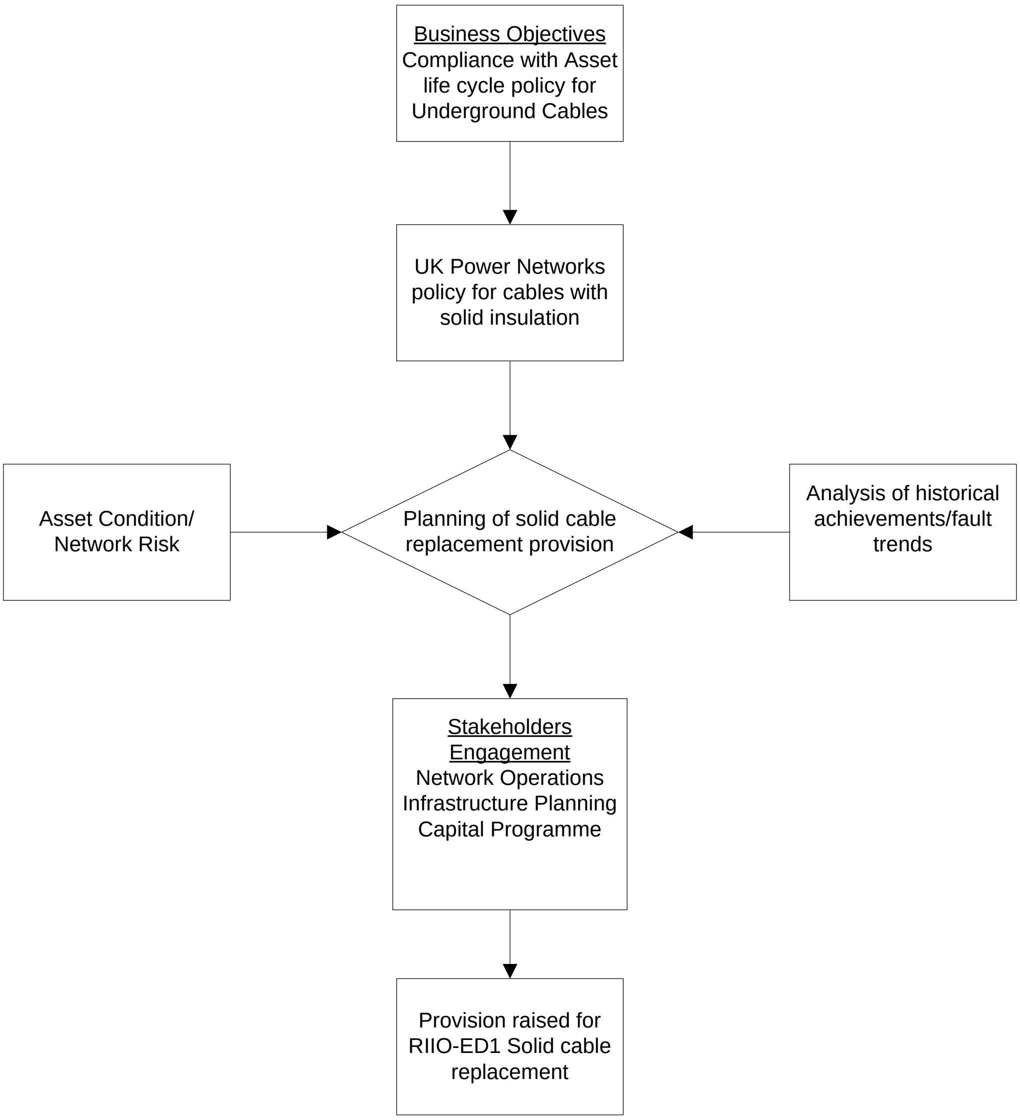


Figure 26 – Construction of NLRE plan for solid cable replacement

7.2 Constructing the Plan

7.2.1 Fluid-filled cables

Intervention volumes – The business objective throughout the planning process for ED1 was to invest at a level that will maintain leakage rates at roughly the same level throughout the ED1 period. To achieve this, the ARP model was used to determine the HI profiles for 132kV and 33kV FFC cable sections at the end of DPCR5 and at the end of ED1 to project how the number of HI4s and HI5s would increase without investment.

The graphs in Figure 27 and Figure 28 show how the lengths of HI4 and HI5 fluid-filled cable is projected to change over the remaining period of DPCR5 and ED1, both with and without investment.

HI profiles:

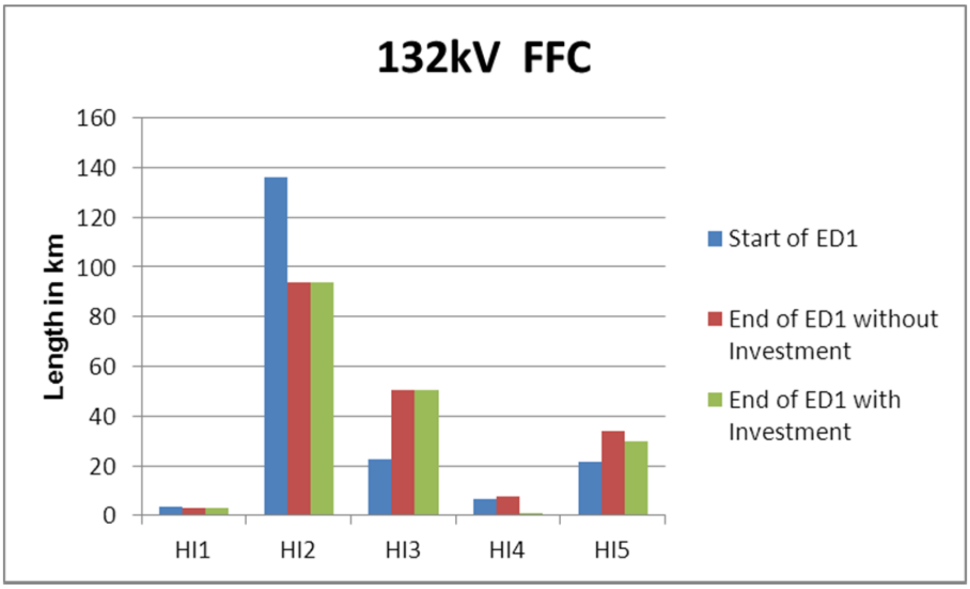


Figure 27 – HI profiles of 132kV fluid-filled cables (FFC)

Source: ARP Model W_FFC_25Jul2012_March 2014 submission

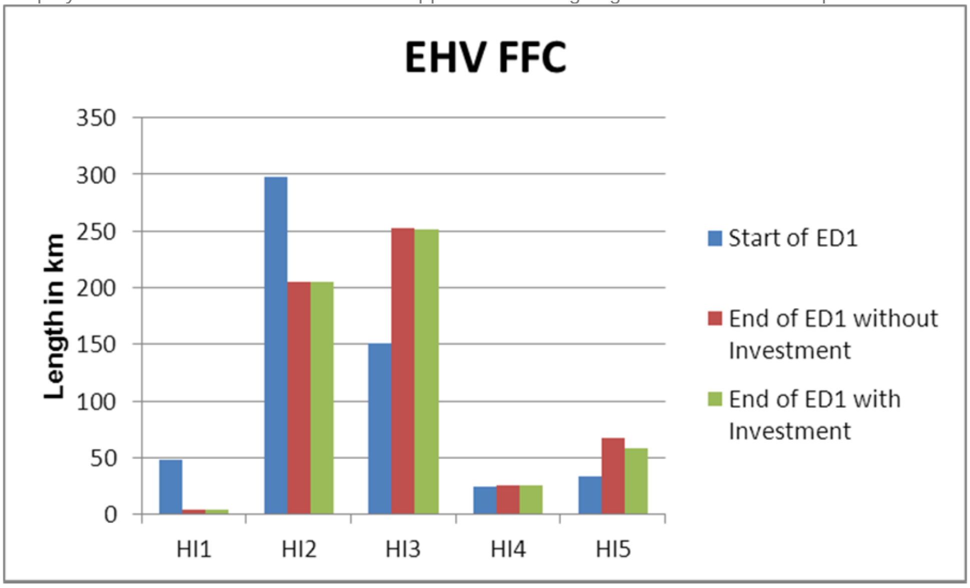


Figure 28 – HI profiles of EHV fluid-filled cables (FFC)

Source: ARP Model W_FFC_25Jul2012_March 2014 submission

Intervention types – Interventions on fluid-filled cables consist of the replacement of a complete circuit, the replacement of a hydraulic section or leak repair. The type of intervention used is driven by application of the investment drivers highlighted in Section 3.

If possible, a leak repair is carried out. However if crystallised lead is discovered then consideration will be given to the replacement of a hydraulic section or possibly the circuit depending on leak-rate history and the extent of the sheath degradation.

7.2.2 Solid cables

Intervention volumes – The business objective throughout the planning process for ED1 solid cable replacement plans was to use historical replacement trends to inform the future replacement programme.

HIs are not calculated for solid cables and hence HI graphs are not available.

Intervention types – Interventions on solid cables consist of either a cable repair or the replacement of faulted cable sections. A reactive replacement of cable may also be considered if the cable in poor condition is discovered during other work or a circuit with an unacceptably high fault rate is identified

.

7.3 Additional Considerations

The Network Asset Management Plan (NAMP) has been used to ensure that the proposed underground cable projects are not duplicated in the Non-Load Related Expenditure and Load Related plans.

Stakeholder engagement was an important part of the process to finalise the ED1 plan. Network Operations, Infrastructure Planning and Capital Programme were consulted through formal peer review sessions and various informal discussions during the construction of ED1 plan.

7.4 Asset Volumes and Expenditure

7.4.1 132kV fluid-filled cables

In total, there are 11.40 kilometres of 132kV fluid-filled cables proposed for intervention during ED1. This represents 5.9% of the installed population of 132kV FFC in EPN. The ED2 figures shown in the graph below have been derived on the basis of assumption that similar rate of ED1 investment will continue in ED2. Further work will be done in ED1 to explore additional intervention options that can be used to extend asset life.

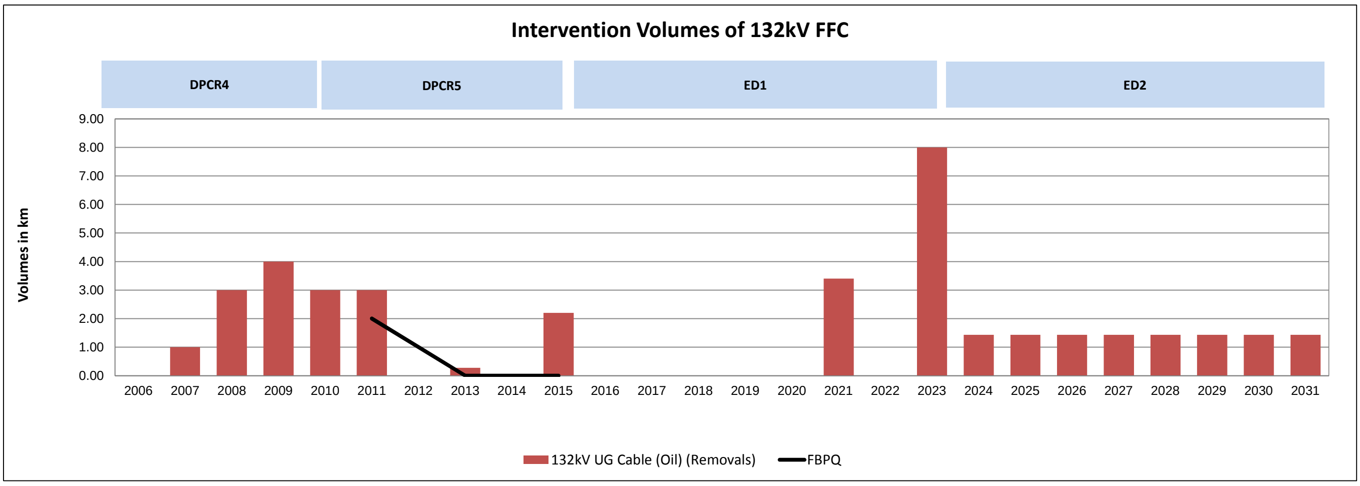


Figure 29 – Intervention volumes of 132kV fluid-filled cables

Sources:
DPCR4 & DPCR5 FBPQ - Table NL3 (DPCR5 FBPQ)
DPCR5 (First three years) - 2013/2014 RIGS CV3 table
DPCR5 (Last Two years) - 2013/2014 RIGS CV3 table
ED1 - 2013/2014 RIGS CV3 table
ED2 - Similar rate of investment in ED1 assumed

The estimated cost of the proposed investment plan in ED1 is £15.17 m.

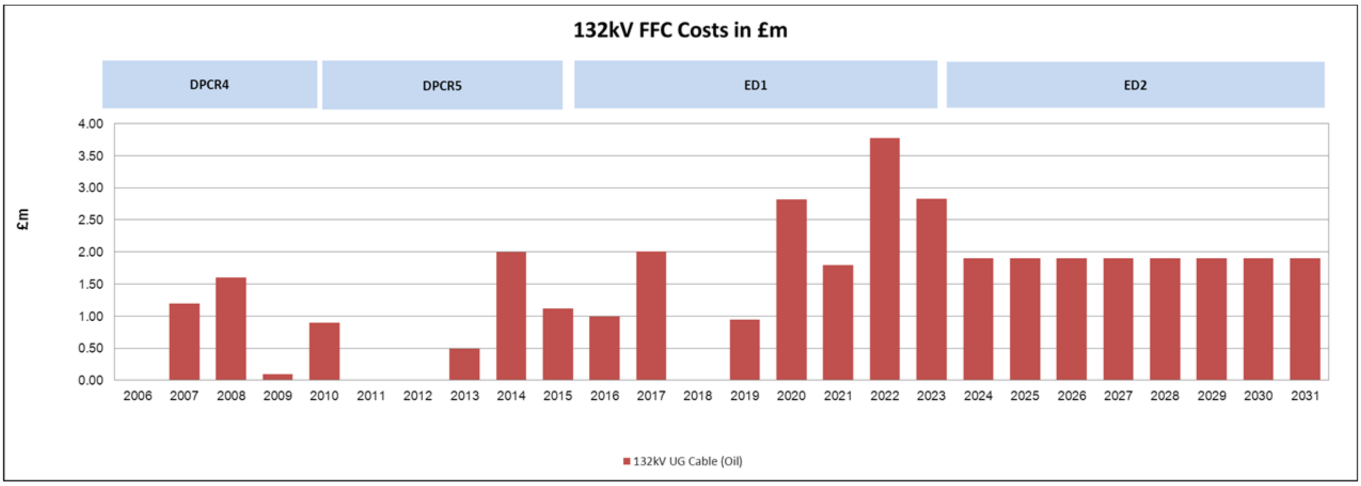


Figure 30 – Intervention cost of 132kV fluid-filled cables

Sources:
DPCR4 - Table NL1 (DPCR5 FBPQ)
DPCR5 (First three years) - 2013/2014 RIGS CV3 table
DPCR5 (Last Two years) – 14thJune NAMP (Table JLI)
ED1 – 19th February NAMP 2014 (Table J Less Indirect)
ED2 - Average from ED1 costs

7.4.2 EHV fluid filled cables

In total, there are 11.60 kilometres of EHV hydraulic sections proposed for intervention during ED1, which represents 1.9% of the installed population of EHV FFC in EPN. The ED2 figures shown in the graph below have been derived on the basis of assumption that similar rate of ED1 investment will continue in ED2. Further work will be done in ED1 to explore additional intervention options that can be used to extend asset life.

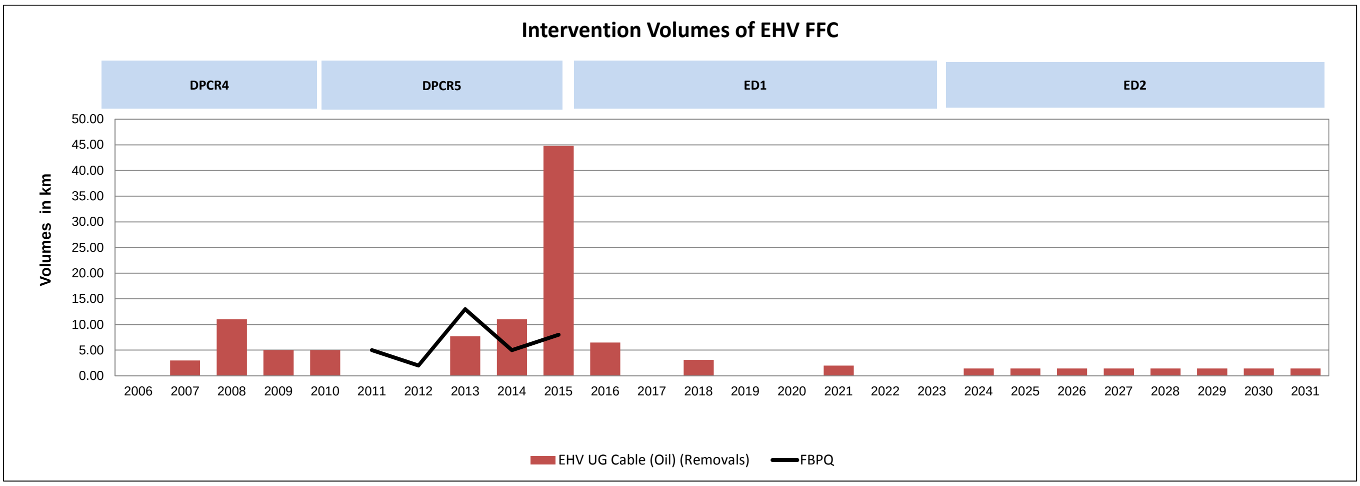


Figure 31– Intervention volumes of EHV fluid-filled cables

Sources:
DPCR4 & DPCR5 FBPQ - Table NL3 (DPCR5 FBPQ)
DPCR5 (First three years) - 2013/2014 RIGS CV3 table
DPCR5 (Last Two years) - 2013/2014 RIGS CV3 table
ED1 - 2013/2014 RIGS CV3 table
ED2 - Similar rate of investment in ED1 assumed

The estimated cost of the proposed investment plan in ED1 is £3.54m.

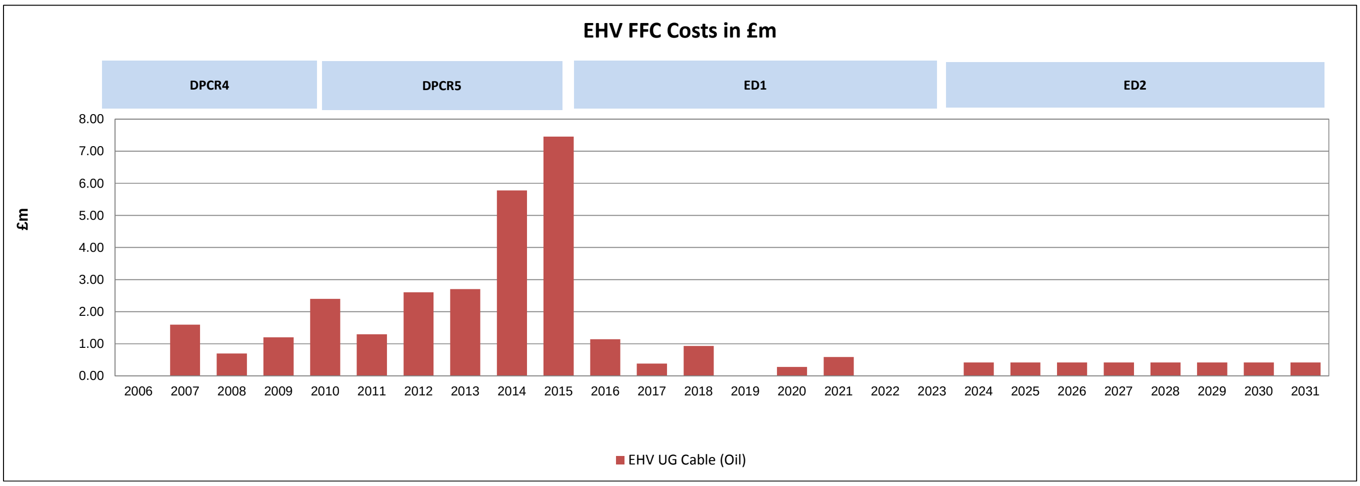


Figure 32 – Intervention cost of EHV fluid-filled cables

Sources:
DPCR4 - Table NL1 (DPCR5 FBPQ)
DPCR5 (First three years) - 2013/2014 RIGS CV3 table
DPCR5 (Last Two years) – 14thJune NAMP (Table JLI)
ED1 – 19th February NAMP 2014 (Table J Less Indirect)
ED2 - Average from ED1 costs

7.4.3 132kV solid cables

In total, there are 2 kilometres of 132kV solid cable proposed for intervention during ED1. This represents 3.5% of the installed population in EPN. The ED2 figures shown in the graph below have been derived on the basis of assumption that similar rate of ED1 investment will continue in ED2.

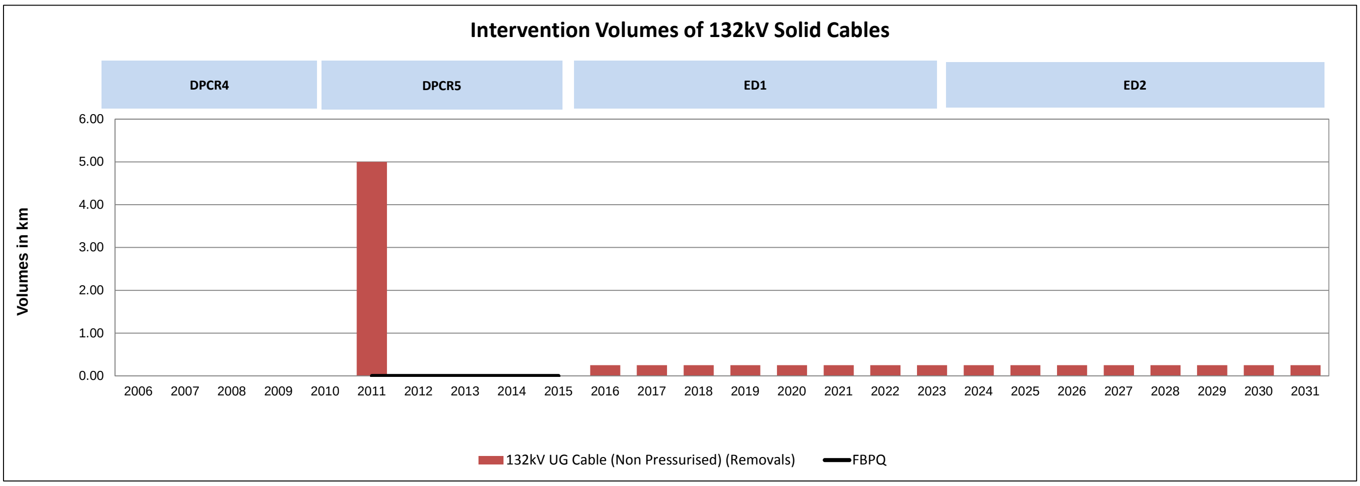


Figure 33 – Intervention volumes of 132kV solid cables

Sources:
DPCR4 & DPCR5 FBPQ - Table NL3 (DPCR5 FBPQ)
DPCR5 (First three years) - 2013/2014 RIGS CV3 table
DPCR5 (Last Two years) - 2013/2014 RIGS CV3 table
ED1 - 2013/2014 RIGS CV3 table
ED2 - Similar rate of investment in ED1 assumed

The estimated cost of the proposed investment plan in ED1 is £2.0m.

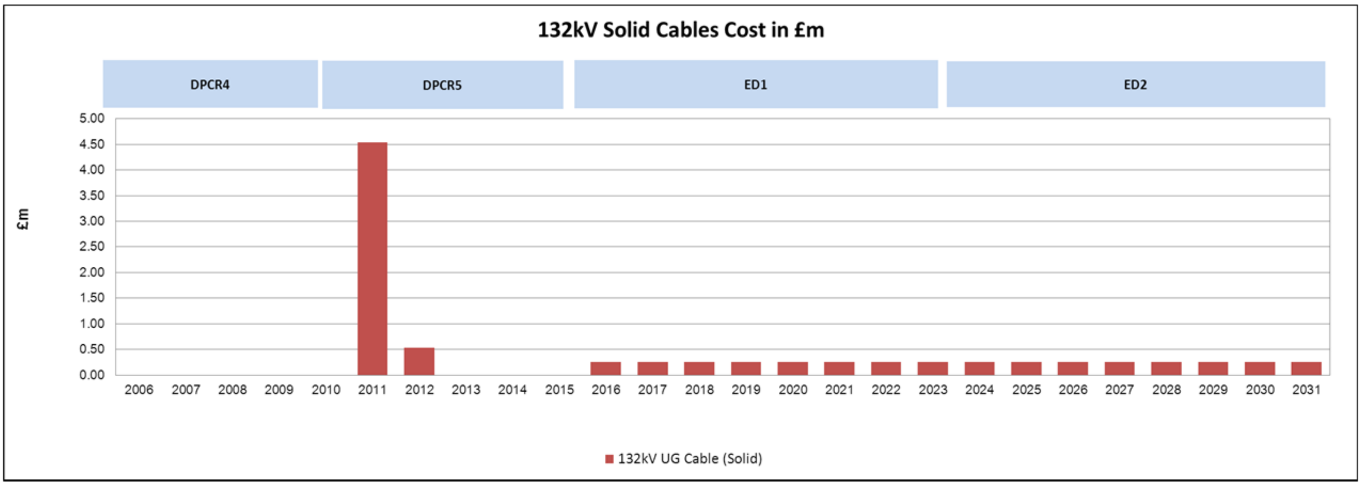


Figure 34 – Intervention cost of 132kV solid cables

Sources:
DPCR4 - Table NL1 (DPCR5 FBPQ)
DPCR5 (First three years) - 2013/2014 RIGS CV3 table
DPCR5 (Last Two years) – 14thJune NAMP (Table JLI)
ED1 – 19th February NAMP 2014 (Table J Less Indirect)
ED2 - Average from ED1 costs

7.4.4 EHV solid cables

In total, there are 24.64 kilometres of EHV solid cable proposed for intervention during ED1. This represents 1.4% of the installed population in EPN. The ED2 figures shown in the graph below have been derived on the basis of assumption that similar rate of ED1 investment will continue in ED2.

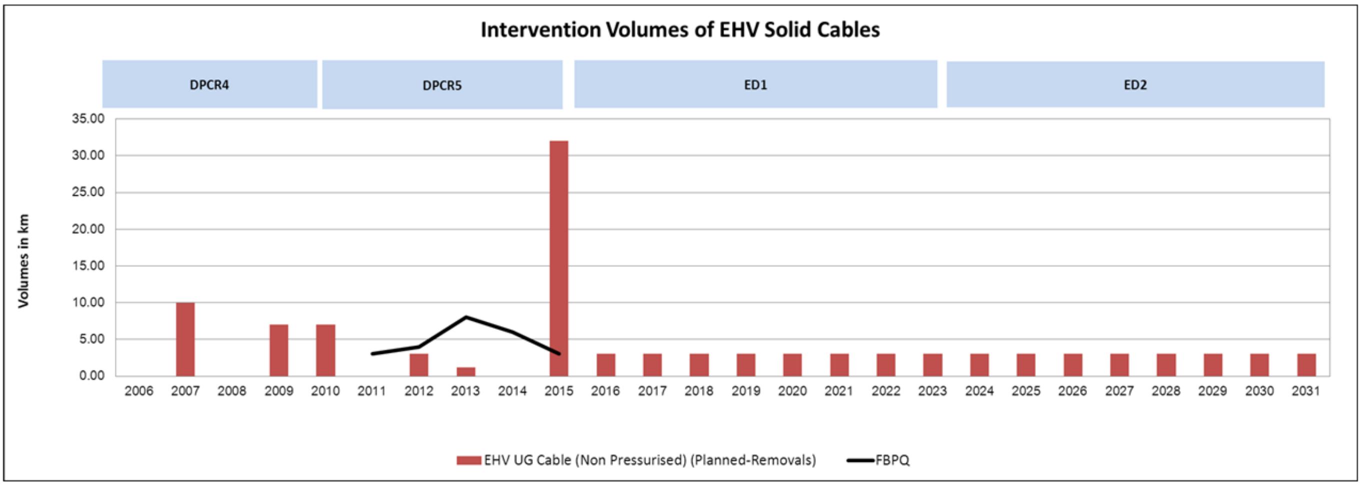


Figure 35 – Intervention volumes of EHV solid cables

Sources:
DPCR4 & DPCR5 FBPQ - Table NL3 (DPCR5 FBPQ)
DPCR5 (First three years) - 2013/2014 RIGS CV3 table
DPCR5 (Last Two years) - 2013/2014 RIGS CV3 table
ED1 - 2013/2014 RIGS CV3 table
ED2 - Similar rate of investment in ED1 assumed

The estimated cost of the proposed investment plan in ED1 is £7.44m.

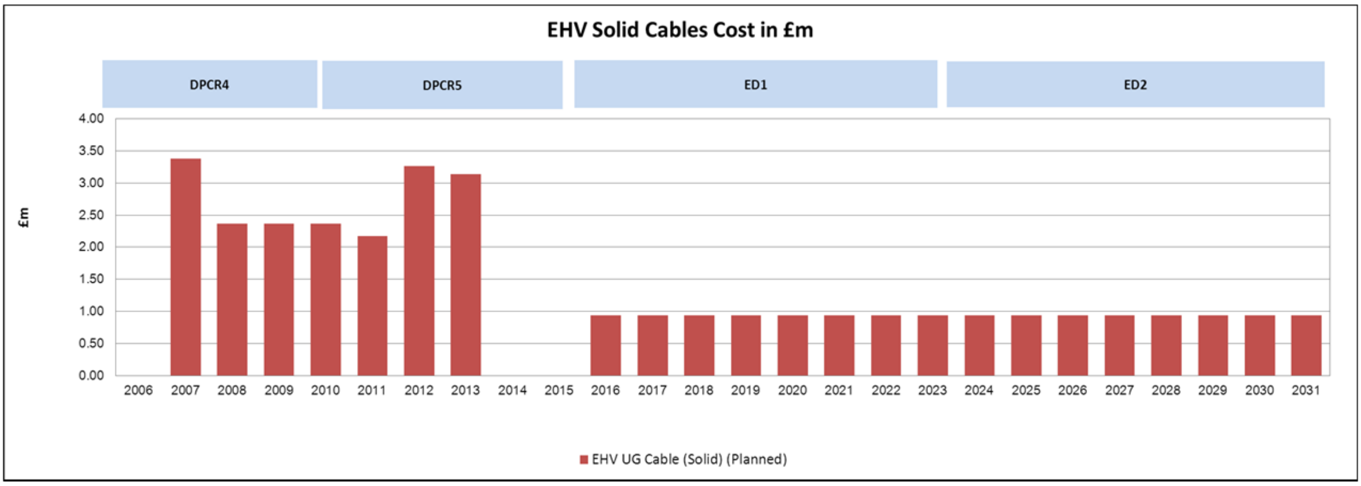


Figure 36 – Intervention cost of EHV solid cables

DPCR4 - Table NL1 (DPCR5 FBPQ)
DPCR5 (First three years) - 2013/2014 RIGS CV3 table
DPCR5 (Last Two years) – 14thJune NAMP (Table JLI)
ED1 – 19th February NAMP 2014 (Table J Less Indirect)
ED2 - Average from ED1 costs

7.4.5 HV solid cables

In total, there are 48 kilometres of HV solid cable proposed for intervention during ED1. This represents 0.2% of the installed population in EPN. The ED1 figures in the graph below also include volumes for undergrdounding 11kV overheadline as a result of quality of supply (QOS) driven work.The ED2 figures shown in the chart below have been derived on the basis of assumption that similar rate of ED1 investment will continue in ED2.

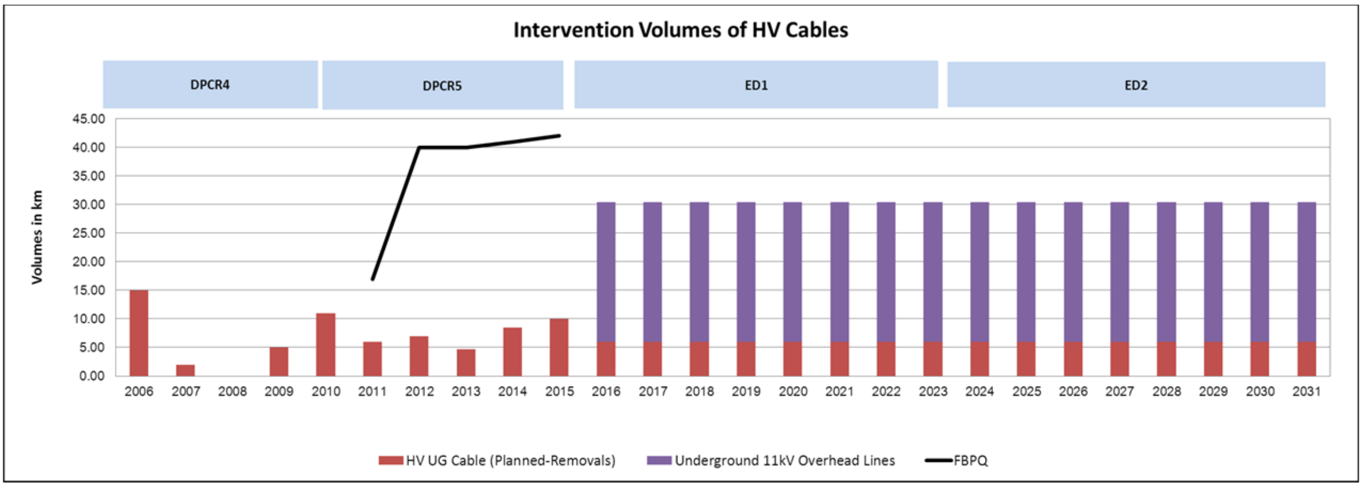


Figure 37 – Intervention volume of HV solid cables

Sources:
DPCR4 & DPCR5 FBPQ - Table NL3 (DPCR5 FBPQ)
DPCR5 (First three years) - 2013/2014 RIGS CV3 table
DPCR5 (Last Two years) - 2013/2014 RIGS CV3 table
ED1 - 2013/2014 RIGS CV3 table
ED2 - Similar rate of investment in ED1 assumed

The estimated cost of the proposed investment plan in ED1 is £15.84m.

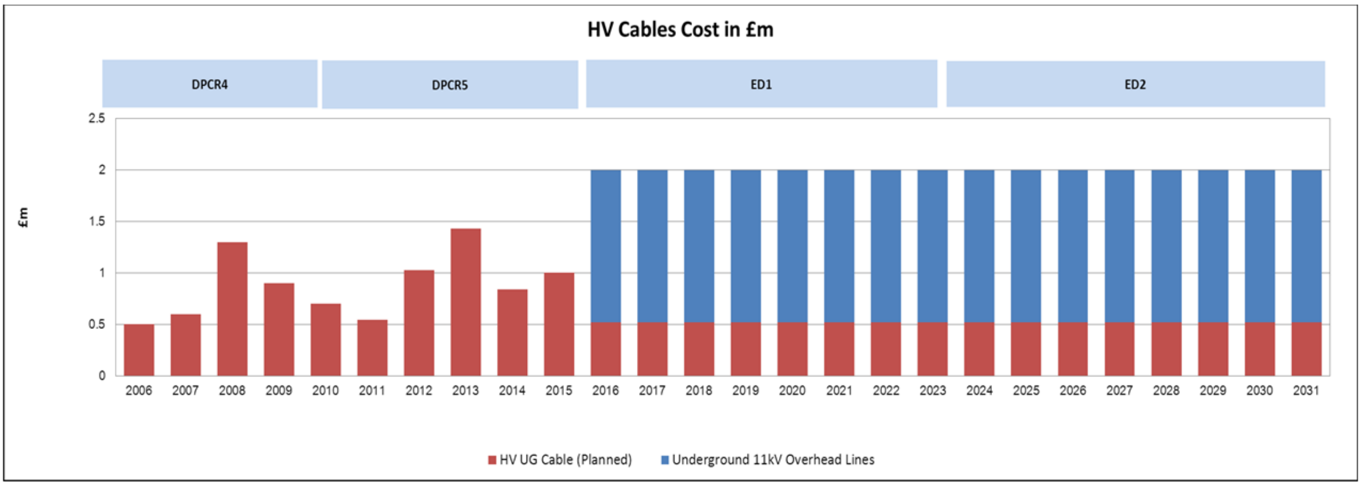


Figure 38 – Intervention cost of HV solid cables

Sources:
DPCR4 - Table NL1 (DPCR5 FBPQ)
DPCR5 (First three years) - 2013/2014 RIGS CV3 table
DPCR5 (Last Two years) – 14thJune NAMP (Table JLI)
ED1 – 19th February NAMP 2014 (Table J Less Indirect)
ED2 - Average from ED1 costs

7.4.6 LV solid cables

In total, there are 32 kilometres of LV solid cable proposed for intervention during ED1. This represents 0.2% of the installed population in EPN. The ED2 figures shown in the graph below have been derived on the basis of assumption that similar rate of ED1 investment will continue in ED2.

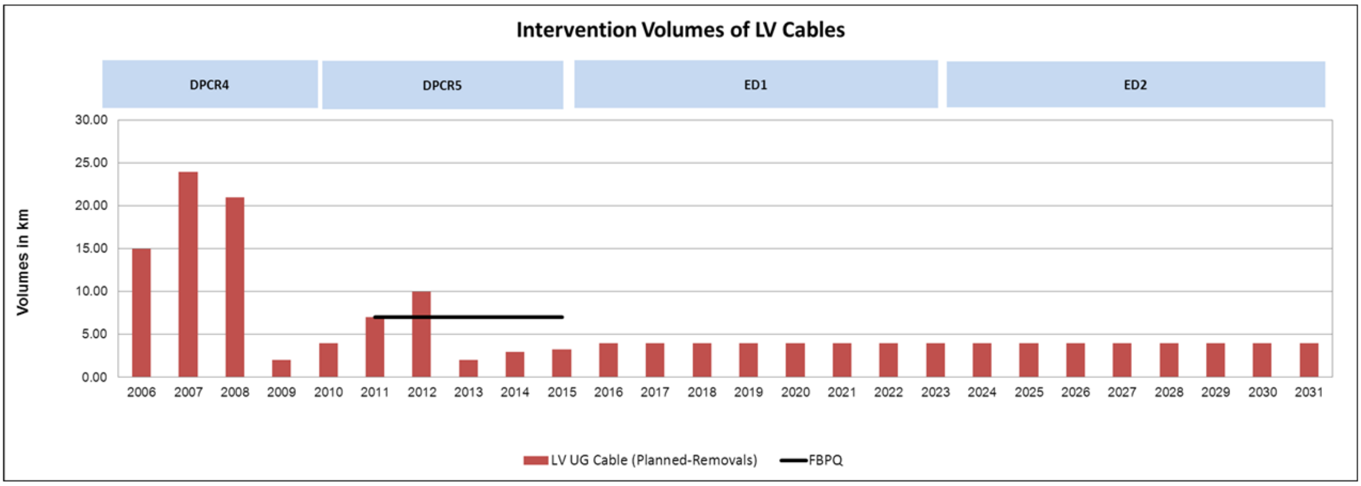


Figure 39 – Intervention volume of LV solid cables

Sources:
DPCR4 & DPCR5 FBPQ - Table NL3 (DPCR5 FBPQ)
DPCR5 (First three years) - 2013/2014 RIGS CV3 table
DPCR5 (Last Two years) - 2013/2014 RIGS CV3 table
ED1 - 2013/2014 RIGS CV3 table
ED2 - Similar rate of investment in ED1 assumed

The estimated cost of the proposed investment plan in ED1 is £3.36m.

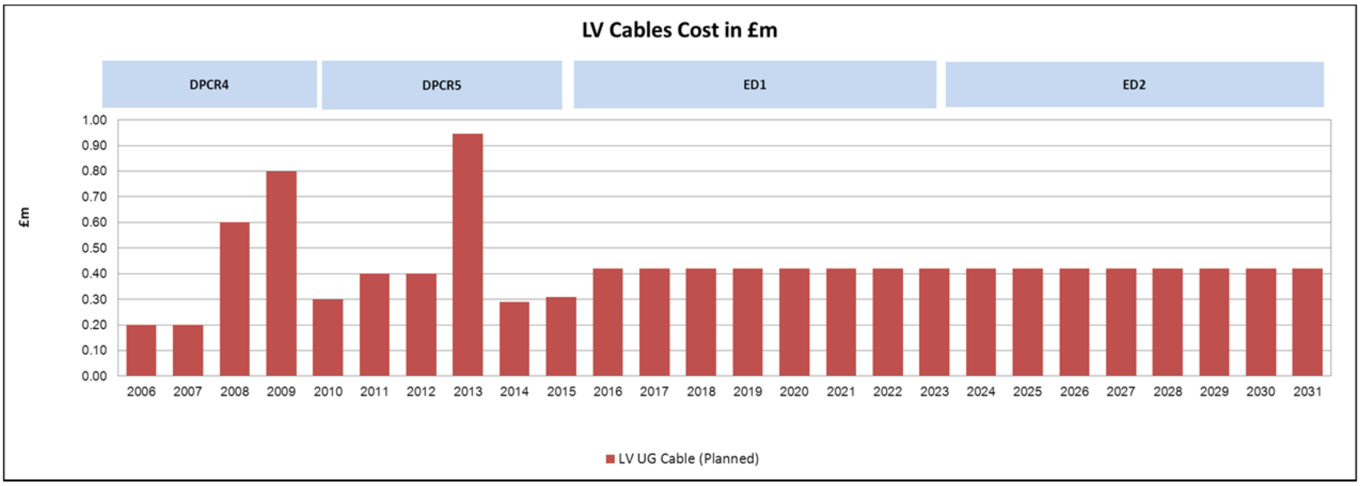


Figure 40 – Intervention cost of LV solid cables

Sources:
DPCR4 - Table NL1 (DPCR5 FBPQ)
DPCR5 (First three years) - 2013/2014 RIGS CV3 table
DPCR5 (Last Two years) – 14thJune NAMP (Table JLI)
ED1 – 19th February NAMP 2014 (Table J Less Indirect)
ED2 - Average from ED1 costs

7.4.7 FFC joints and ancillary equipment

Intervention volumes								
Description	**15/16**	**16/17**	**17/18**	**18/19**	**19/20**	**20/21**	**21/22**	**22/23**
Replace aluminium cable joint plumbs	21	21	21	21	21	21	21	21
Install remote pressure-monitoring equipment	7	7	7	7	7	7	7	7
Replace pressurised cables ancillary equipment (tanks, gauges, etc)	21	21	21	21	21	21	21	21

Table 10 – Intervention volumes of joints and ancillary equipment

Intervention cost in £m								
Description	**15/16**	**16/17**	**17/18**	**18/19**	**19/20**	**20/21**	**21/22**	**22/23**
Replace aluminium cable joint plumbs	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.17
Install remote pressure-monitoring equipment	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Replace pressurised cables ancillary equipment (tanks, gauges, etc)	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45

Table 11 – Intervention cost of joints and ancillary equipment in £m

7.5 Commentary

7.5.1 Fluid-filled cables

As previously discussed in the Investment Drivers Section 3, EPN has a leakage rate per kilometre of installed fluid-filled cable that is around the national average.

The hydraulic sections and circuits identified for replacement in ED1 with the assistance of the ARP model represent 2.8% of the total fluid-filled cable population in EPN – and yet were responsible for 15% of the fluid leakage during the period 2008 to 2012.

The health indices are calculated using the ARP model and are based primarily on age and leakage history of the hydraulic circuit. These identified circuits were than investigated in detail based on the available condition information that is gathered when available during fault repairs.

7.5.2 Solid cables

The replacement of solid cables is decided on a case-by-case condition assessment of faulted sections. Named schemes are not identified in advance and the planned provision is based primarily on historical levels of activity in each of the voltage level areas, as can been seen in the graphs in Section 7.4.3 to 7.4.6. This is considered to be a prudent approach in line with decreasing or flat fault rate.

7.6 Sensitivity Analysis and Plan Validation

An independent report has been carried out by Decision Lab to understand how the Health Index profile of assets may change if the average asset life does not turn out as predicted. The full results are shown in Appendix 6.

Average life change	**2015** percentage HI profile				
	HI1	HI2	HI3	HI4	HI5
-4	21.3	57.5	15.5	4.8	1.0
-2	21.3	60.9	13.0	3.9	1.0
-1	21.3	60.9	15.0	1.4	1.0
0	21.3	60.9	15.0	2.9	0.0
1	21.7	60.4	15.0	2.9	0.0
2	21.7	61.8	13.5	2.9	0.0
4	29.0	55.1	13.5	2.9	0.0

Average life change	**2023** percentage HI profile				
	HI1	HI2	HI3	HI4	HI5
-4	1.4	52.2	37.7	2.9	5.8
-2	1.4	61.8	28.0	3.9	4.8
-1	1.4	64.7	25.1	3.9	4.8
0	19.8	46.4	25.1	3.9	4.8
1	19.8	46.4	25.1	3.9	4.8
2	20.8	46.4	23.7	3.9	4.8
4	20.8	54.1	16.4	5.8	2.9

Table 12 – Results of sensitivity analysis 132kV

Average life change	**2015** percentage HI profile				
	HI1	HI2	HI3	HI4	HI5
-4	0.0	67.8	28.4	3.0	0.8
-2	0.0	71.1	25.7	2.8	0.3
-1	0.0	72.5	24.2	2.8	0.3
0	0.0	76.1	21.8	1.7	0.3
1	0.0	76.5	21.7	1.6	0.3
2	0.0	76.8	21.7	1.3	0.3
4	0.2	77.9	20.6	1.1	0.3

Average life change	**2023** percentage HI profile				
	HI1	HI2	HI3	HI4	HI5
-4	0.0	31.7	57.9	5.8	4.7
-2	0.0	47.7	42.5	6.4	3.5
-1	0.0	51.6	38.6	6.8	2.8
0	0.0	51.6	40.0	5.5	2.8
1	0.0	58.1	34.2	5.3	2.4
2	0.0	59.3	33.4	5.0	2.2
4	0.0	61.4	32.7	4.7	1.3

Table 13 – Results of sensitivity analysis of EHV FFC

In Tables 12 and 13, each average asset life change of years +/- 1, 2 and 4 are represented as a percentage of the current population. With each change in average asset life, there is a subsequent movement in the percentage of population in each Health Index. An average asset life at 0 represents the current population split within each Health Index with intervention strategies applied. Figures for the start of ED1 (2015) and the end of ED1 (2023) are given.

These tables show the percentage population movements over the eight-year period and the impact any change in average asset life will have on the asset group's HI profile.

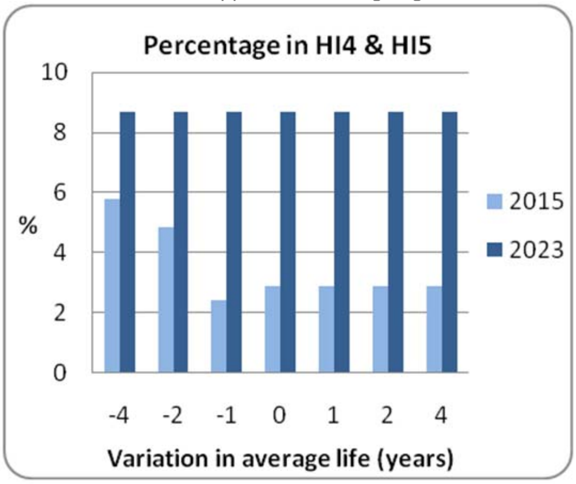


Figure 41– Effect of average asset life variation on volumes of HI4 and HI5 of 132kV FFC

Figure 41 represents the summed HI4s and HI5s as a percentage of the population, showing the change at each average asset life iteration comparing 2015 and 2023. In 2015, if average asset life is four years longer, the proportion of HI4 and HI5 assets will be unchanged at 2.9%; but if four years shorter, the proportion will increase to 5.9%. In 2023, the proportion of HI4 and HI5 assets will be 8.7% and this will be unchanged if average asset life varies by up to four years.

It is concluded from the above observations that the ED1 replacement plan for EPN 132kV UG Cable (Oil) is quite insensitive to a variation in average asset life of up to four years.

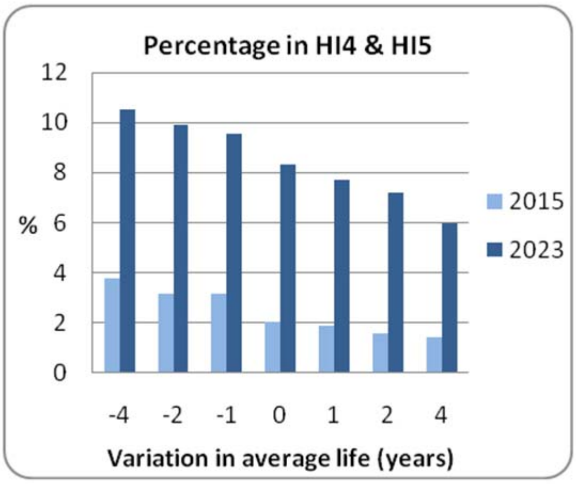


Figure 42 – Effect of average asset life variation on volumes of HI4 and HI5 of EHV FFC

Figure 42 represents the summed HI4s and HI5s as a percentage of the population, showing the change at each average asset life iteration, comparing 2015 and 2023. In 2015, if average asset life is four years longer, the proportion of HI4 and HI5 assets will reduce from 2.0% to 1.4%; but if four years shorter, it will increase to 3.8%. In 2023, if average asset life is four years longer, the proportion of HI4 and HI5 assets will reduce from 8.3% to 6.0%; but if four years shorter, it will increase to 10.5%.

It is concluded from the above observations that the ED1 replacement plan for EPN EHV UG Cable (Oil) is mildly sensitive to a variation in average asset life of up to four years.

7.7 Model testing

The ARP model had undergone rigorous testing to ensure it met the defined requirements prior to acceptance. There were four distinct subsets to the testing process: algorithm testing, software testing, data flow testing and user and methodology testing. Each test is designed to capture potential errors in specific parts of the system. The completion of all tests provides assurance that a thorough evaluation has been carried out to ensure correctness and validity of the outputs.

7.71 Algorithm testing

The ARP model comprises a set of algorithms implemented within the database code. The tester in a spreadsheet mimics each algorithm, with the results compared with those of the ARP algorithm for a given set of test data inputs. The test data comprised data within normal expected ranges, low-value numbers, high-value numbers, floating point numbers, integers, negative numbers and unpopulated values. In order to pass the test, all results from the ARP algorithm are required to match the spreadsheet calculation.

7.7.2 Software testing

A number of new software functions used in the model required testing to ensure they performed correctly. A test script was created to identify the functional requirement, the method to carry out the function and the expected outcome. In order to pass the test, the achieved outcome had to match the expected outcome.

7.7.3 Data-flow testing

Data-flow testing was carried out to ensure that data presented in the ARP upload files passes into the model correctly. Data counts from the ARP model upload files were compared to data successfully uploaded to the model. To pass the test, counts of the data had to match within specified tolerances.

7.7.4 User and methodology testing

The aim of the user and methodology testing is to ensure that the models are fit for purpose. A test script has been created to check that displays operate correctly and that outputs respond appropriately to changes in calibration settings.

7.8 Network Risk

Tables 14,15,16 and 17 illustrate the estimated asset health and criticality of the assets in EPN at the beginning and end of RIIO-ED1 with interventions.

Asset Category	Criticality	Units	Estimated Asset Health and Criticality Profile 2015					2015
			Asset Health					
			HI1	HI2	HI3	HI4	HI5	
132kV FFC	Low	circuit km	0	23	3	1	3	30
	Average	circuit km	1	49	8	2	8	68
	High	circuit km	1	30	5	2	5	43
	Very high	circuit km	1	34	6	2	6	49

Table 14 – Estimated Asset Health and Criticality Profile 2015

Asset Category	Criticality	Units	Estimated Asset Health and Criticality Profile 2023					2023
			Asset Health					
			HI1	HI2	HI3	HI4	HI5	
132kV FFC	Low	circuit km	0	16	8	1	5	30
	Average	circuit km	1	34	18	0	12	65
	High	circuit km	1	20	12	0	4	37
	Very high	circuit km	1	24	13	0	9	47

Table 15 – Estimated Asset Health and Criticality Profile 2023

Asset Category	Criticality	Units	Estimated Asset Health and Criticality Profile 2015					2015
			Asset Health					
			HI1	HI2	HI3	HI4	HI5	
EHV FFC	Low	circuit km	24	149	75	12	17	277
	Average	circuit km	17	106	54	10	12	199
	High	circuit km	6	37	19	3	4	69
	Very high	circuit km	1	6	3	0	1	11

Table 16 – Estimated Asset Health and Criticality Profile 2015

Asset Category	Criticality	Units	Estimated Asset Health and Criticality Profile 2023					2023
			Asset Health					
			HI1	HI2	HI3	HI4	HI5	
EHV FFC	Low	circuit km	2	102	126	13	34	277
	Average	circuit km	2	72	91	9	23	197
	High	circuit km	0	27	29	3	2	60
	Very high	circuit km	0	4	5	1	0	10

Table 17 – Estimated Asset Health and Criticality Profile 2023

Source: 21st February 20144 ED1 Business Plan Data Tables

8.0 Deliverability

An appropriate use of both internal and external resources will be necessary to successfully deliver the plan. Consultation with internal stakeholders responsible for the delivery of the plan was taken at an early stage and will continue throughout the process.

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Appendices

Appendix 1 – Age Profiles

Fluid-filled cables (FFC)

The age profiles of 132kV FFC cables are shown in Figure 43.

1920's	1930's	1940's	1950's	1960's	1970's	1980's	1990's	2000's
0	25	39	59	56	10	5	0	0

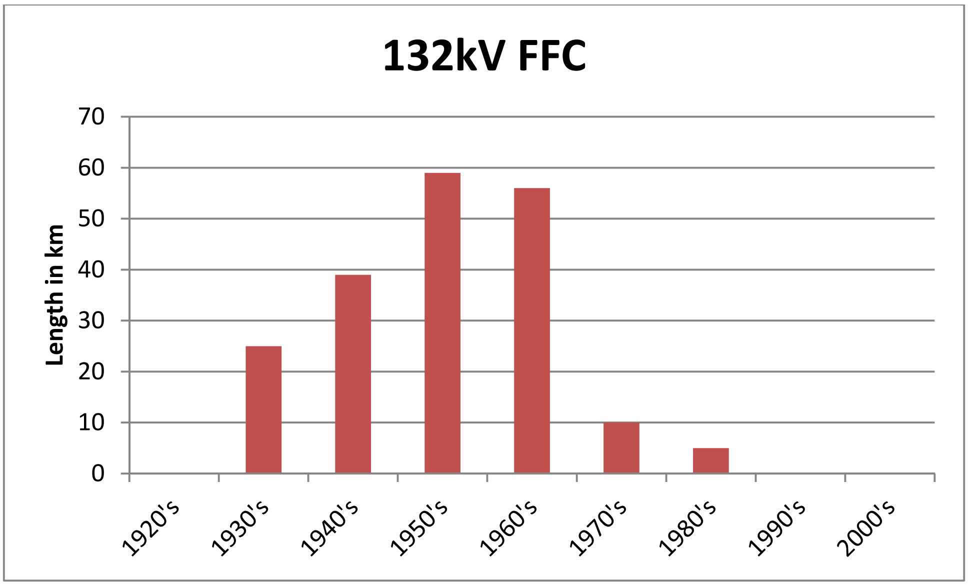


Figure 43 – Age profile of 132kV FFC

The age profiles of 33kV FFC cables are shown in Figure 44.

1920's	1930's	1940's	1950's	1960's	1970's	1980's	1990's	2000's
0	0	9	59	450	99	2	0	0

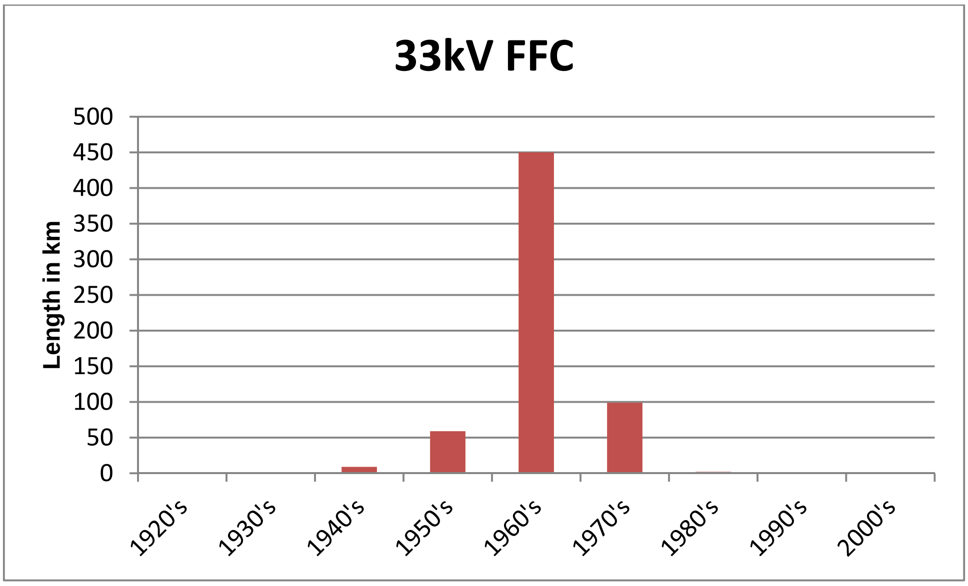


Figure 44 – Age profile of 33kV FFC

Solid cables

The age profiles of 132kV solid cables are shown in Figure 45.

Pre-1920	1920's	1930's	1940's	1950's	1960's	1970's	1980's	1990's	2000's	2010's
0	0	0	0	0	0	0	0	8	32	17

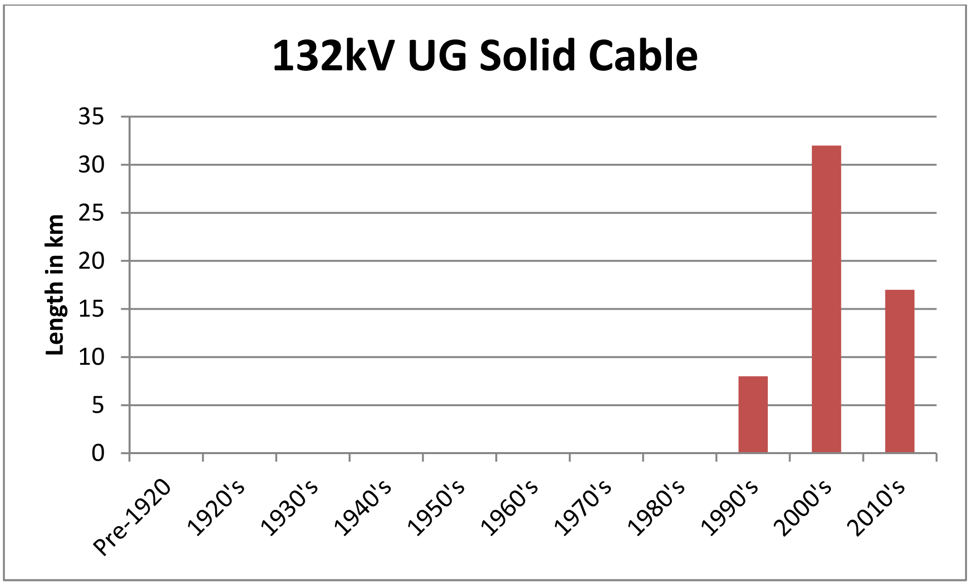


Figure 45 – Age profile of 132kV underground solid cable

The age profiles of 33kV solid cables are shown in Figure 46.

Pre-1920	1920's	1930's	1940's	1950's	1960's	1970's	1980's	1990's	2000's	2010's
0	0	151	468	354	127	33	97	151	278	98

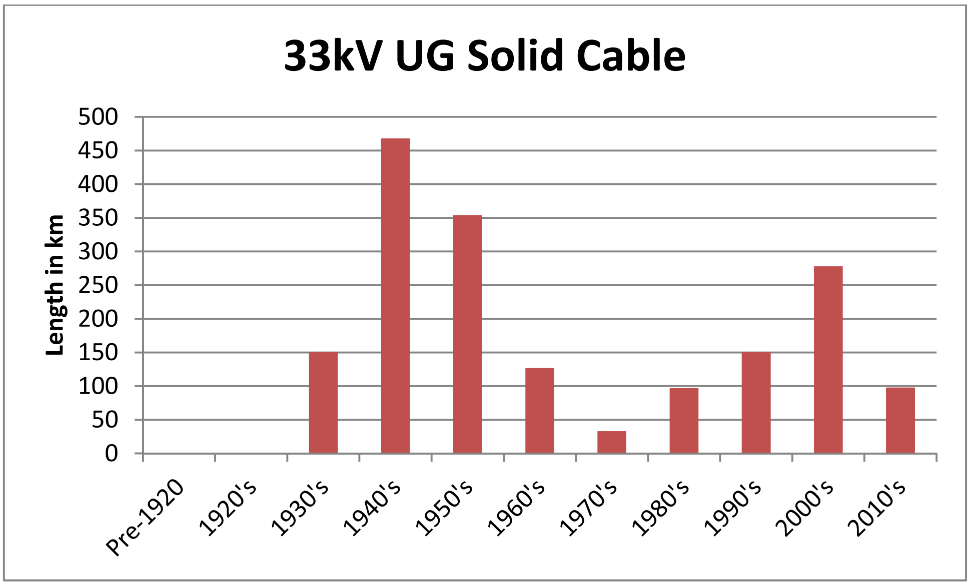


Figure 46 – Age profile of 33kV underground solid cable

The age profiles of HV solid cables are shown in Figure 47.

Pre-1920	1920's	1930's	1940's	1950's	1960's	1970's	1980's	1990's	2000's	2010's
0	46	453	1722	2534	4634	2673	2055	2481	2315	649

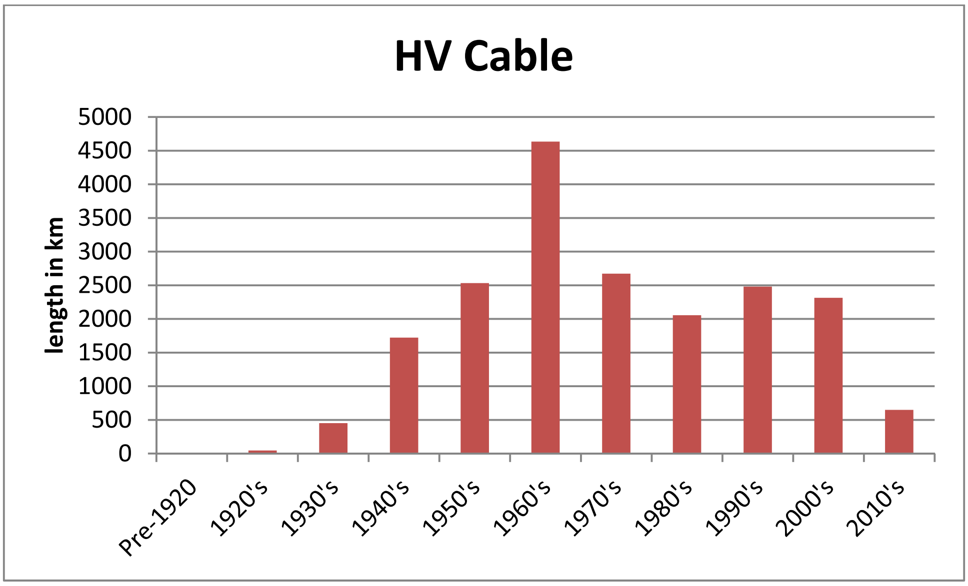


Figure 47 – Age profile of HV underground solid cable

The age profiles of LV solid cables are shown in Figure 48

Pre-1920	1920's	1930's	1940's	1950's	1960's	1970's	1980's	1990's	2000's	2010's
1266	3871	4549	4705	4464	5454	3880	3854	3370	3564	915

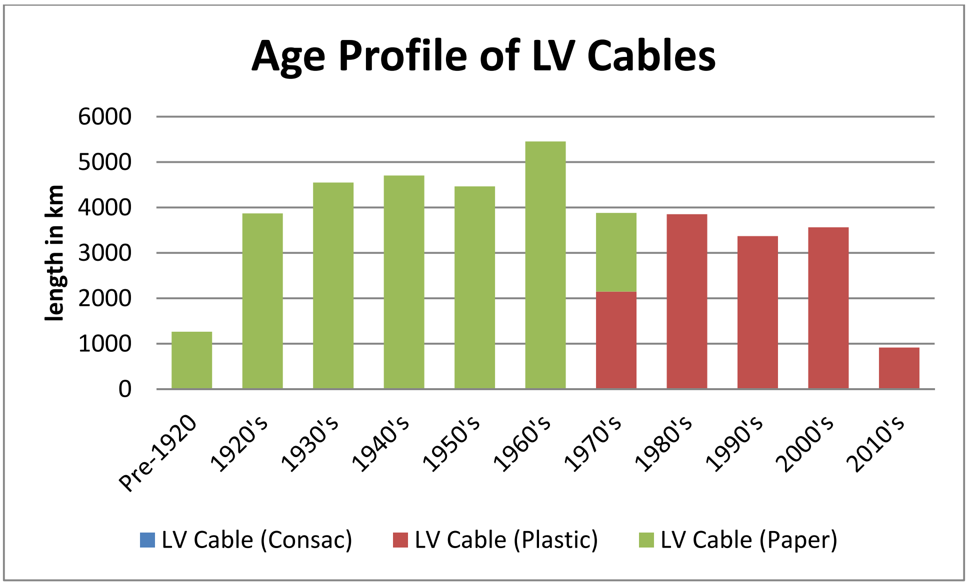


Figure 48 – Age profile of LV underground solid cable

Appendix 2 – HI Profiles

Fluid-filled cables (FFC)

132kV	HI1	HI2	HI3	HI4	HI5
Start of ED1	3	136	22	7	22
End of ED1 without Investment	3	94	51	8	34
End of ED1 with Investment	3	94	51	1	30

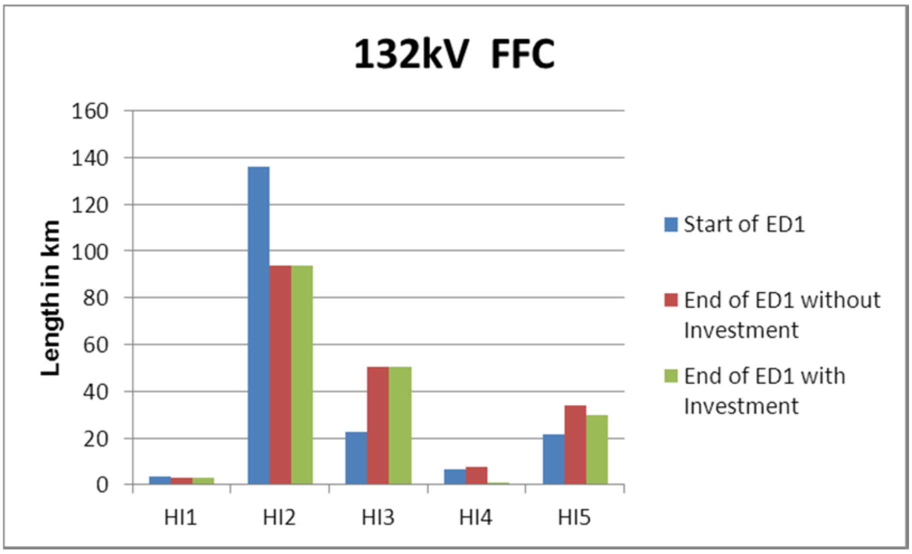


Figure 49 – HI profile for 132kV fluid-filled cable

Source: ARP Model W_FFC_25Jul2012_March 2014 submission

EHV	HI1	HI2	HI3	HI4	HI5
Start of ED1	48	298	151	25	34
End of ED1 without Investment	4	205	253	26	68
End of ED1 with Investment	4	205	251	26	59

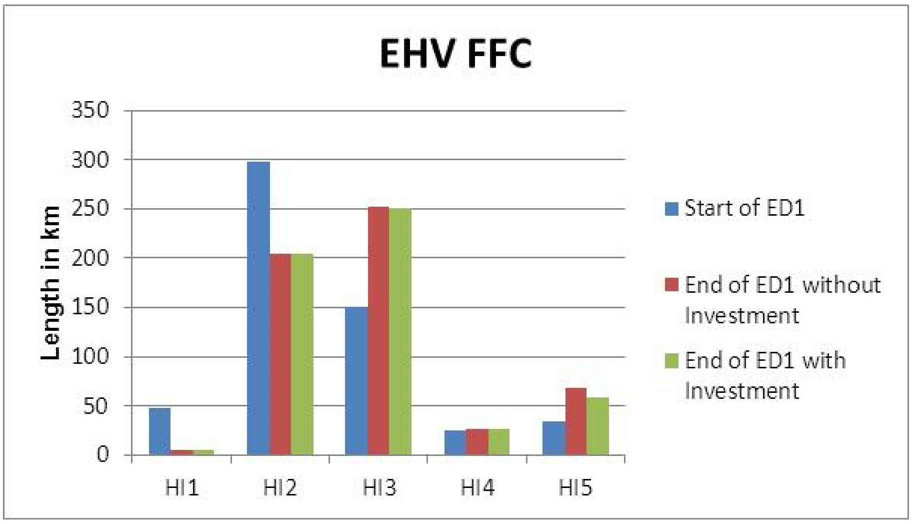


Figure 50 – HI profile for EHV fluid-filled cables

Source: ARP Model W_FFC_25Jul2012_March 2014 submission

Appendix 3 – Fault Data

132KV UG Cable	2007	2008	2009	2010	2011	2012
All Faults	0.0239	0.0120	0.0319	0.0199	0.0239	0.0000
Poor Condn Due To Age & Wear	0.0080	0.0040	0.0279	0.0120	0.0159	0.0000

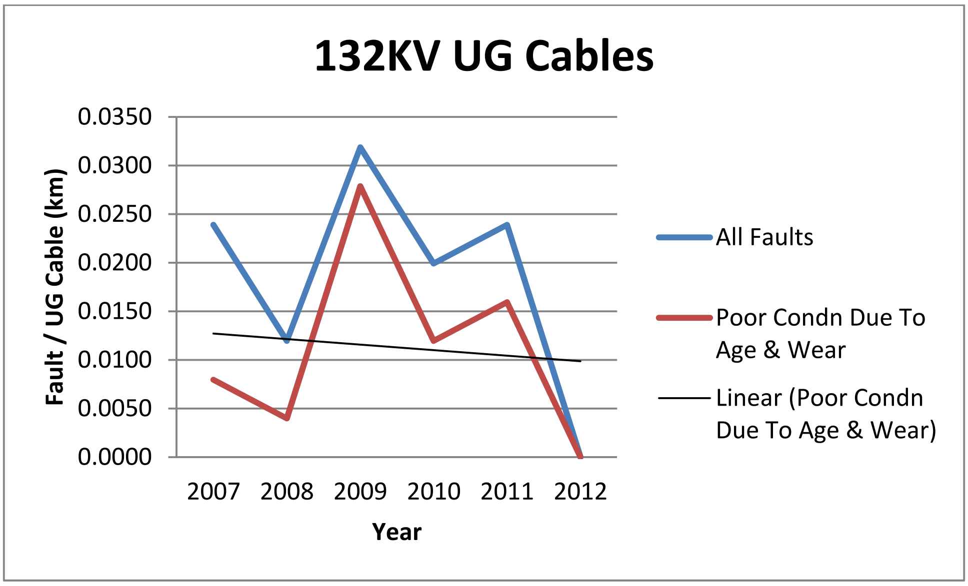


Figure 51 – Fault trends of 132kV underground cable

EHV UG Cable	2007	2008	2009	2010	2011	2012
All Faults	0.0501	0.0412	0.0501	0.0379	0.0286	0.0332
Poor Condn Due To Age & Wear	0.0278	0.0295	0.0370	0.0328	0.0248	0.0307

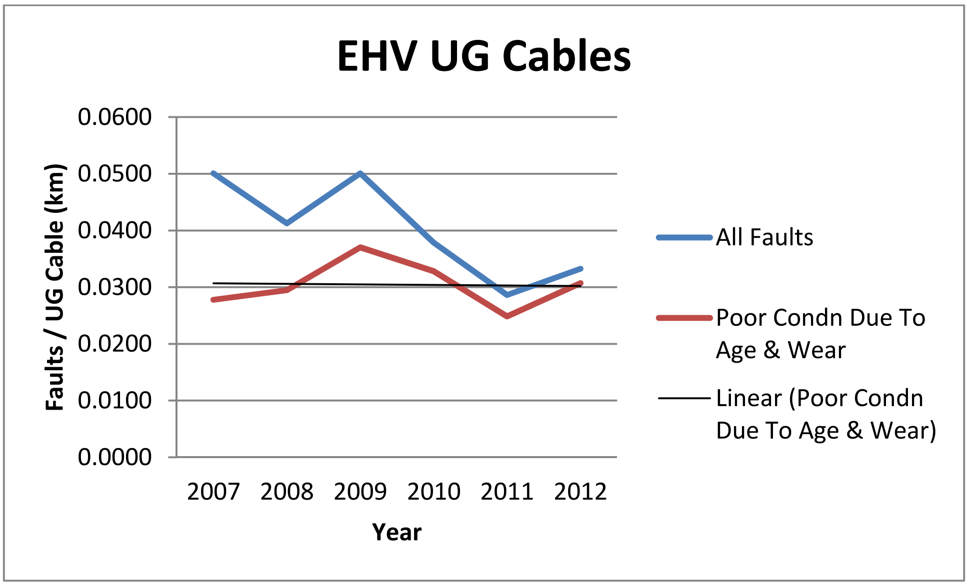


Figure 52 – Fault trends of EHV underground cable

HV UG Cable	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
All Faults	0.0464	0.0474	0.0485	0.0531	0.0415	0.0400
Poor Condn Due To Age & Wear	0.0287	0.0297	0.0349	0.0384	0.0289	0.0273

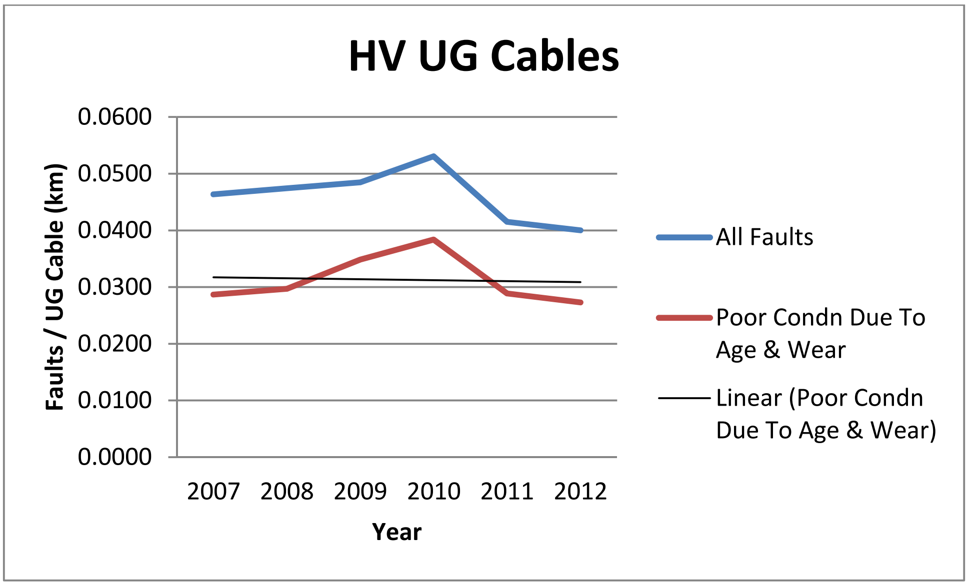


Figure 53 – Fault trends of HV underground cable

LV UG Cable	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
All Faults	0.0842	0.0864	0.0850	0.0957	0.0923	0.0979
Poor Condn Due To Age & Wear	0.0557	0.0612	0.0665	0.0799	0.0622	0.0563

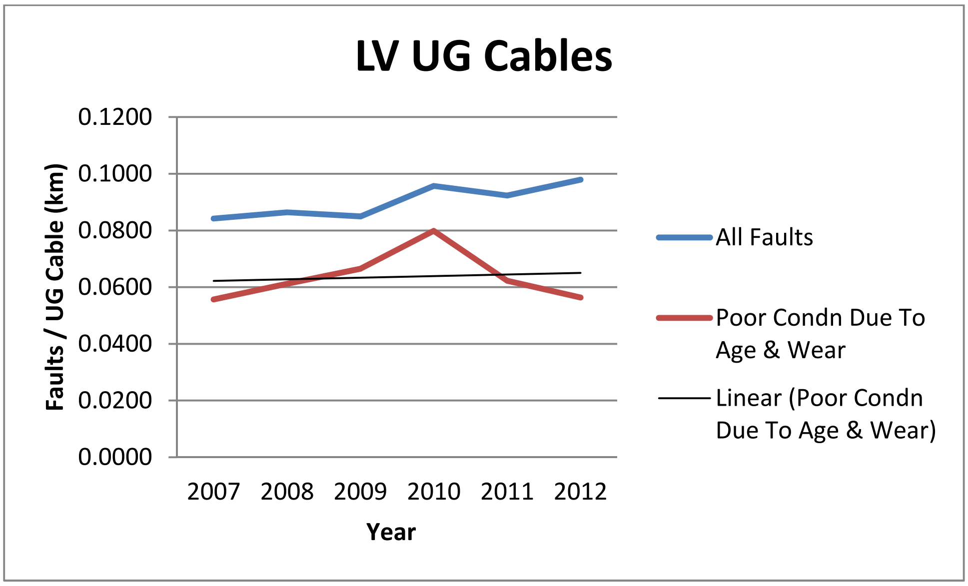


Figure 54 – Fault trends of LV underground cable

Source: UKPN Faults Cube

Appendix 4 – WLC Case Studies

Whole life cost description	132kV Fluid Filled Cable
Starting assumption (same for all scenarios)	It is assumed the 132kV Fluid Filled Cable is 60 years old at the beginning of the scenario, that the current replacement cost is £1.3M per km and that it has an average useful operating life of 80 years. The average life used for a solid cable is 100 years.

Scenario 1	End of life of a 132 kV Fluid Filled Cable with a replacement Solid Cable purchased at 70 years
Assumptions specific to this scenario	60 year old fluid filled cable requiring £1k of inspection and maintenance activity per annum per km

Description of costs/(income) items	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Year 20	Year 21	Year 22	Year 23	Year 24	Year 25	Year 26	Year 27	Year 28	Year 29	Year 30	Totals
Notional purchase cost of a 60 year fluid filled cable (1km) (i.e.: 20 years remaining service life)	300																														300
Annual inspection & maintenance costs of initial fluid filled cable	1	1	1	1	1	1	1	1	1	1																					10
Purchase of replacement cable in year 10 (Solid Cable Installed)										1,200																					1,200
Annual inspection & maintenance costs of replacement cable (which will be solid)																															0
Residual value of replacement solid cable at end of scenario (i.e.: 80 years remaining life)																														-1,040	-1,040
Net cash flow	301	1	1	1	1	1	1	1	1	1201	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-1040	470

Discount rate: Select 6.85%	6.85%
Discounted whole life cost	764

Scenario 2	End of life of a 132 kV Fluid Filled Cable with a replacement Solid Cable purchased at end of life
Assumptions specific to this scenario	60 year old fluid filled cable requiring £1k of inspection and maintenance activity per annum per km

Description of costs/(income) items	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10	Year 11	Year 12	Year 13	Year 14	Year 15	Year 16	Year 17	Year 18	Year 19	Year 20	Year 21	Year 22	Year 23	Year 24	Year 25	Year 26	Year 27	Year 28	Year 29	Year 30	Totals
Notional purchase cost of a 60 year old fluid filled cable (i.e.: 20 years remaining service life)	300																														300
Annual inspection & maintenance costs of initial fluid filled cable	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1											20
Purchase of replacement cable in year 20 (Solid Cable Installed)																				1,200											1,200
Annual inspection & maintenance costs of replacement cable (which will be solid)																															0
(blank)																															0
(blank)																															0
Residual value of replacement solid cable at end of scenario (i.e.: 90 years remaining life)																														-1,040	-1,040
Net cash flow	301	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1201	0	0	0	0	0	0	0	0	0	-1040	480

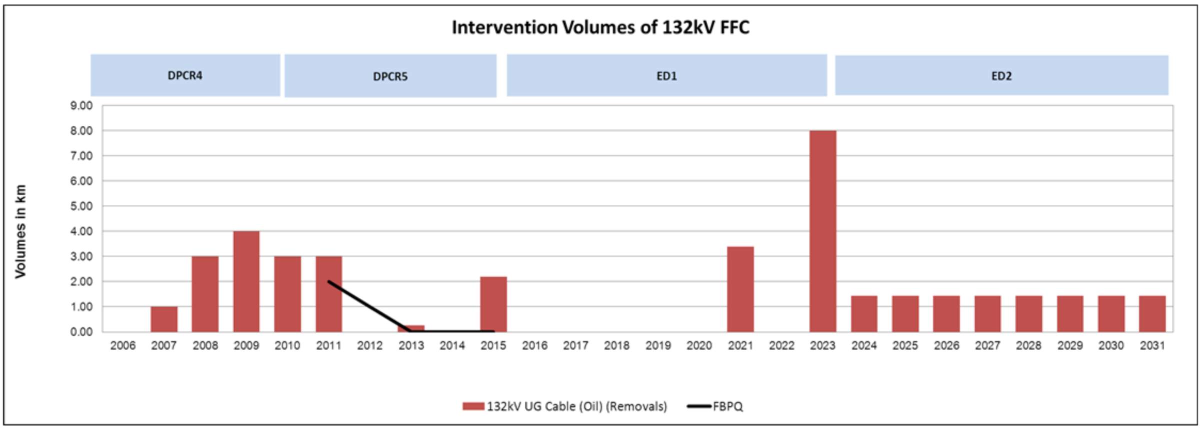
Discount rate: Select 6.85%	6.85%
Discounted whole life cost	468

Appendix 5 – NLRE Expenditure Plan

132kV fluid-filled cables volumes

Volumes	DPCR4 (FBPQ)					DPCR5 (Actual and Forecast from RIgs)				
Year end	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
132kV UG Cable (Oil) FBPQ (Removals only)						2.00	1.00	0.00	0.00	0.00
132kV UG Cable (Oil) (Removals)	0.00	1.00	3.00	4.00	3.00	3.00	0.00	0.27	0.00	2.20

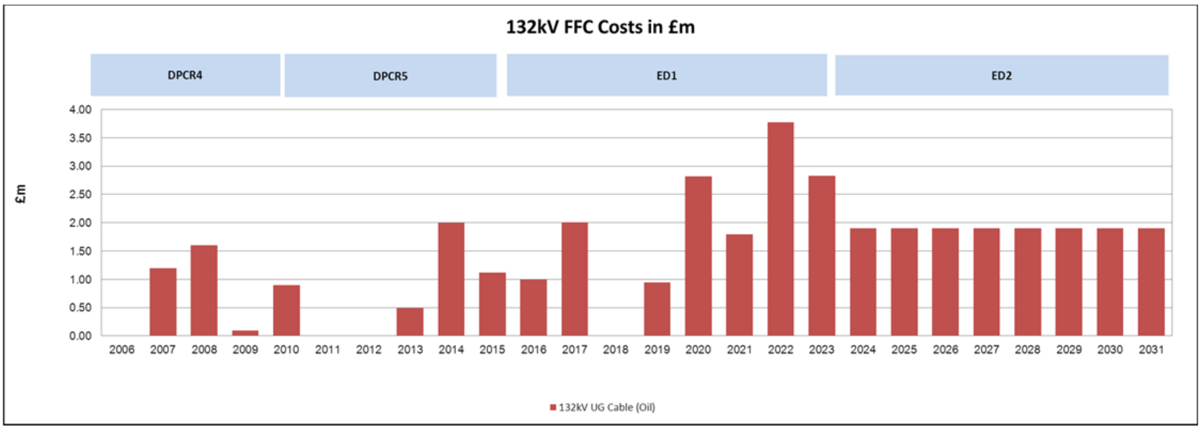
Volumes	ED1 Plan								ED2 Plan							
Year end	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
132kV UG Cable (Oil) FBPQ (Removals only)																
132kV UG Cable (Oil) (Removals)	0.00	0.00	0.00	0.00	0.00	3.40	0.00	8.00	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43



132kV fluid-filled cables cost:

Investment £'m	DPCR4 (FBPQ)					DPCR5 (Actual and Forecast from RIgs)				
Year end	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
132kV UG Cable (Oil)	0.00	1.20	1.60	0.10	0.90	0.00	0.00	0.49	2.00	1.12

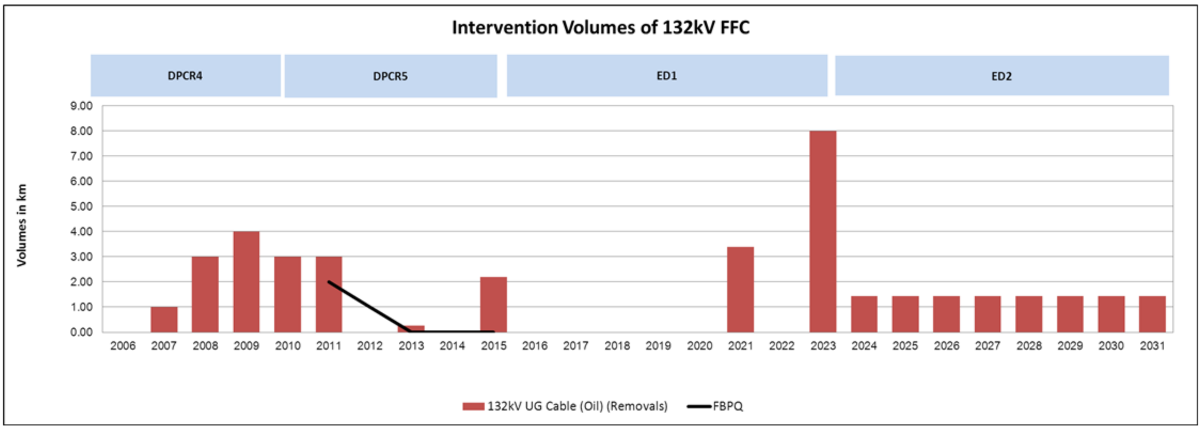
Investment £'m	ED1 Plan								ED2 Plan							
Year end	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
132kV UG Cable (Oil)	0.99	2.01	0.00	0.95	2.82	1.80	3.77	2.83	1.90	1.90	1.90	1.90	1.90	1.90	1.90	1.90



EHV fluid-filled cables volumes:

Volumes	DPCR4 (FBPQ)					DPCR5 (Actual and Forecast from RIgs)				
Year end	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
132kV UG Cable (Oil) FBPQ (Removals only)						2.00	1.00	0.00	0.00	0.00
132kV UG Cable (Oil) (Removals)	0.00	1.00	3.00	4.00	3.00	3.00	0.00	0.27	0.00	2.20

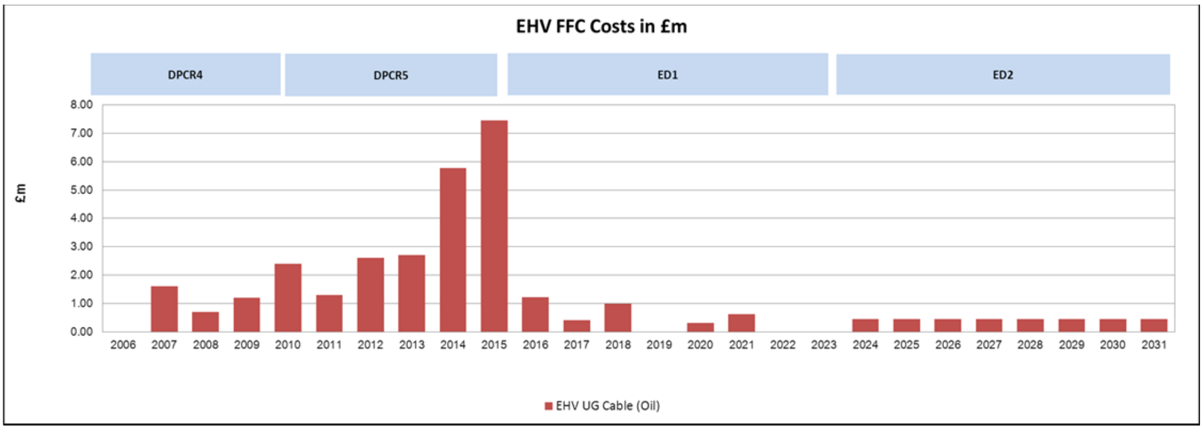
Volumes	ED1 Plan								ED2 Plan							
Year end	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
132kV UG Cable (Oil) FBPQ (Removals only)																
132kV UG Cable (Oil) (Removals)	0.00	0.00	0.00	0.00	0.00	3.40	0.00	8.00	1.43	1.43	1.43	1.43	1.43	1.43	1.43	1.43



EHV fluid-filled cables cost:

Investment £'m	DPCR4 (FBPQ)					DPCR5 (Actual and Forecast from RIgs)				
Year end	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
EHV UG Cable (Oil)		1.60	0.70	1.20	2.40	1.30	2.60	2.70	5.78	7.46

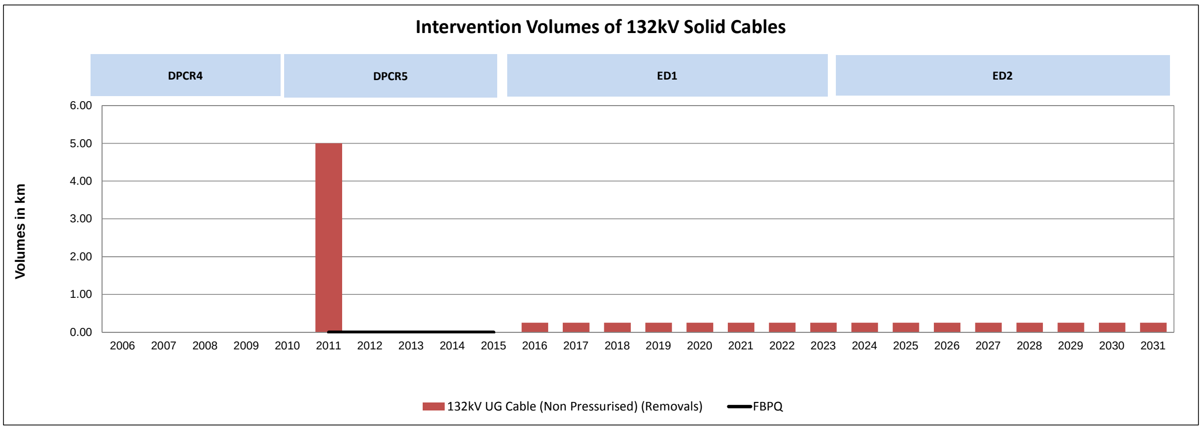
Investment £'m	ED1 Plan								ED2 Plan							
Year end	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
EHV UG Cable (Oil)	1.21	0.40	0.99	0.00	0.30	0.63	0.00	0.00	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44



132kV solid cables volumes:

Volumes	DPCR4 (FBPQ)					DPCR5 (Actual and Forecast from RIgs)				
Year end	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
132kV UG Cable (Non Pressurised) FBPQ (Removals only)						0.00	0.00	0.00	0.00	0.00
132kV UG Cable (Non Pressurised) (Removals)	0.00	0.00	0.00	0.00	0.00	5.00	0.00	0.00	0.00	0.00

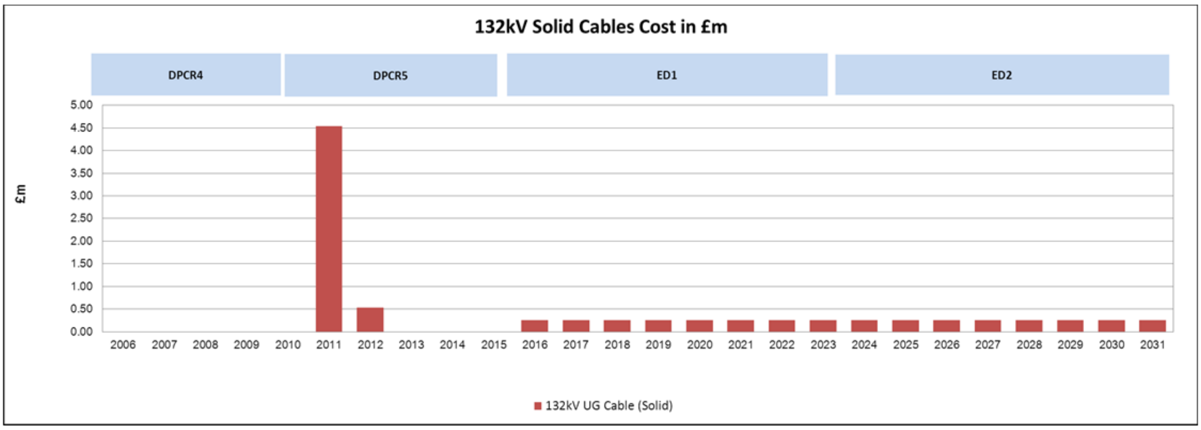
Volumes	ED1 Plan								ED2 Plan							
Year end	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
132kV UG Cable (Non Pressurised) FBPQ (Removals only)																
132kV UG Cable (Non Pressurised) (Removals)	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25



132kV solid cables cost:

Investment £'m	DPCR4 (FBPQ)					DPCR5 (Actual and Forecast from RIgs)				
Year end	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
132kV UG Cable (Solid)						4.54	0.53	0.00	0.00	0.00

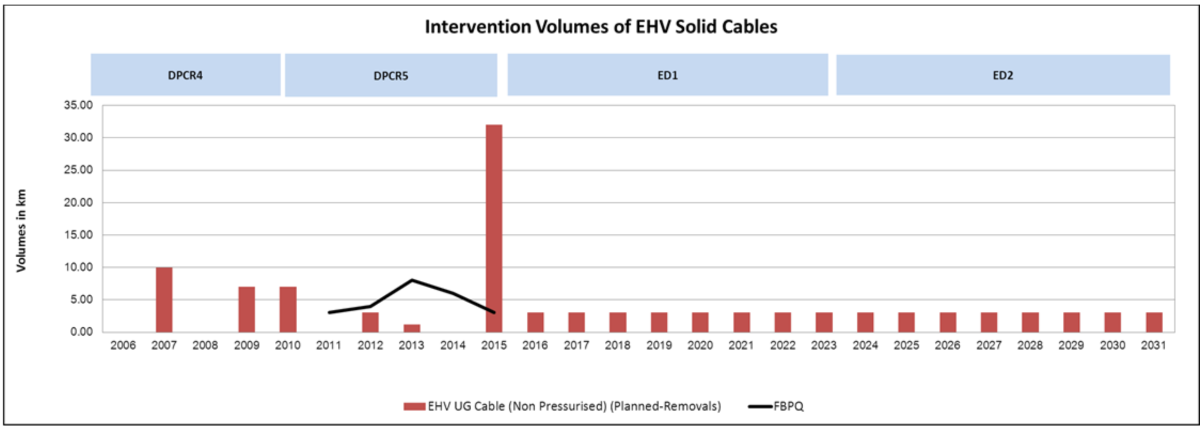
Investment £'m	ED1 Plan								ED2 Plan							
Year end	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
132kV UG Cable (Solid)	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25



EHV solid cables volumes:

Volumes	DPCR4 (FBPQ)					DPCR5 (Actual and Forecast from RIgs)				
Year end	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
EHV UG Cable (Non Pressurised) FBPQ (Removals only)						3.00	4.00	8.00	6.00	3.00
EHV UG Cable (Non Pressurised) (Planned-Removals)	0.00	10.00	0.00	7.00	7.00	0.00	3.00	1.18	0.00	32.00

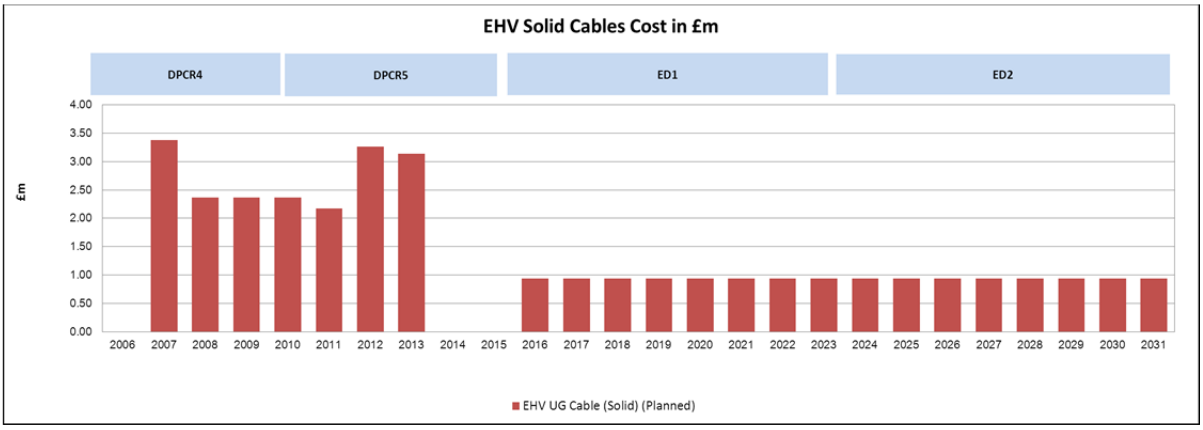
Volumes	ED1 Plan								ED2 Plan							
Year end	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
EHV UG Cable (Non Pressurised) FBPQ (Removals only)																
EHV UG Cable (Non Pressurised) (Planned-Removals)	3.08	3.08	3.08	3.08	3.08	3.08	3.08	3.08	3.08	3.08	3.08	3.08	3.08	3.08	3.08	3.08



EHV solid cables cost:

Investment £'m	DPCR4 (FBPQ)					DPCR5 (Actual and Forecast from RIgs)				
Year end	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
EHV UG Cable (Solid) (Planned)		3.38	2.37	2.37	2.37	2.18	3.26	3.14	0.00	0.00

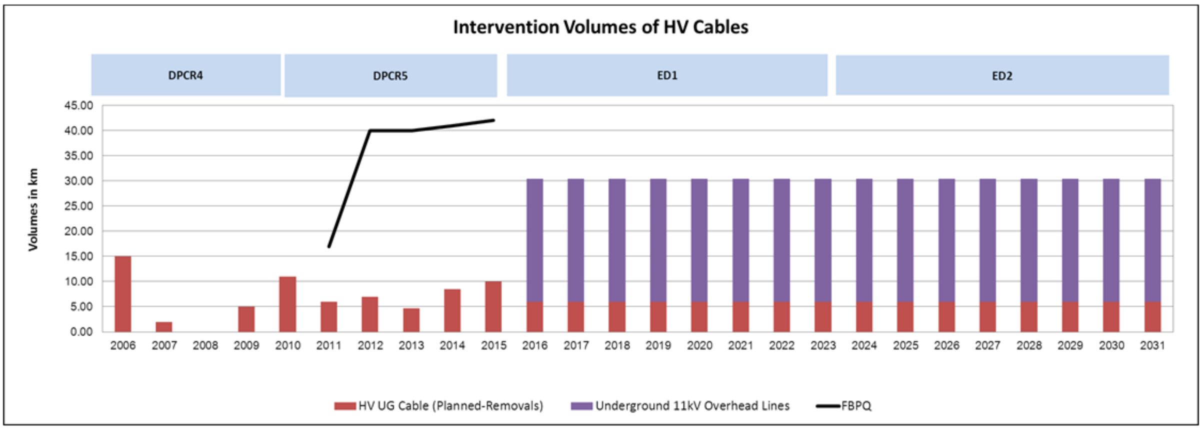
Investment £'m	ED1 Plan								ED2 Plan							
Year end	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
EHV UG Cable (Solid) (Planned)	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93



HV solid cables volumes:

Volumes	DPCR4 (FBPQ)					DPCR5 (Actual and Forecast from RIgs)				
Year end	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
HV UG Cable FBPQ (Removals only)						17	40	40	41	42
HV UG Cable (Planned-Removals)	15.00	2.00	0.00	5.00	11.00	6.00	7.00	4.64	8.45	10.04
Underground 11kV Overhead Lines										

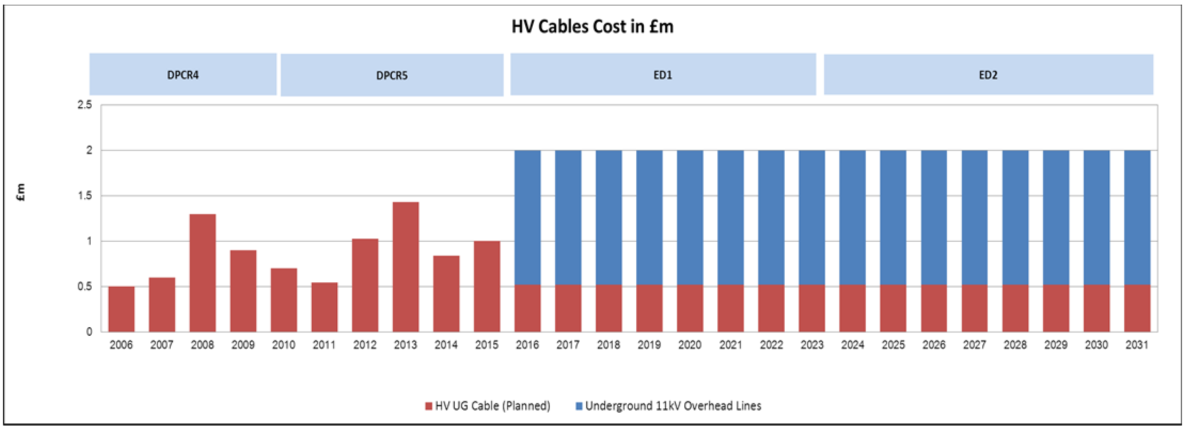
Volumes	ED1 Plan								ED2 Plan							
Year end	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
HV UG Cable FBPQ (Removals only)																
HV UG Cable (Planned-Removals)	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00
Underground 11kV Overhead Lines	24.40	24.40	24.40	24.40	24.40	24.40	24.40	24.40	24.40	24.40	24.40	24.40	24.40	24.40	24.40	24.40



HV solid cables cost:

Investment £'m	DPCR4 (FBPQ)					DPCR5 (Actual and Forecast from RIgs)				
Year end	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
HV UG Cable (Planned)	0.5	0.6	1.3	0.9	0.7	0.54	1.02	1.43	0.84	1.00
Underground 11kV Overhea										

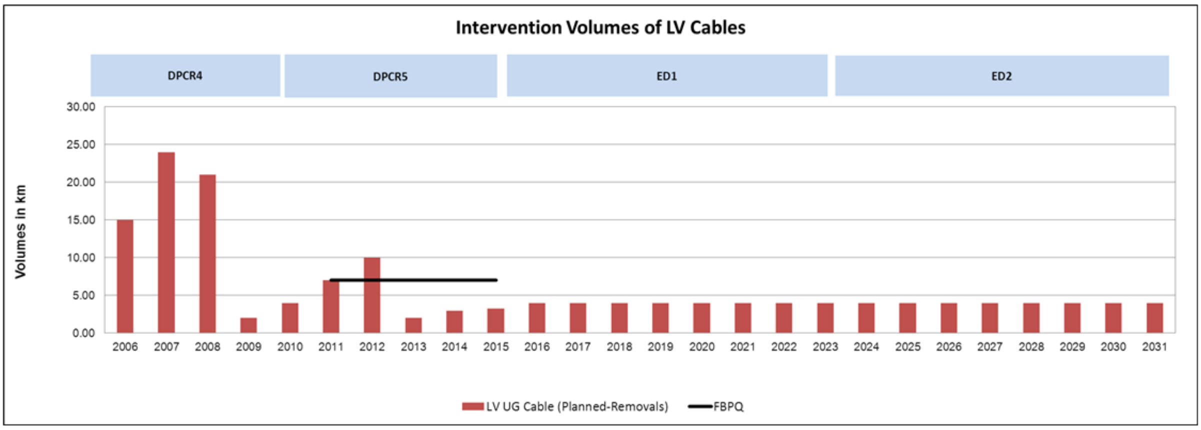
Investment £'m	ED1 Plan								ED2 Plan							
Year end	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
HV UG Cable (Planned)	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Underground 11kV Overhead Lines	1.48	1.48	1.48	1.48	1.48	1.48	1.48	1.48	1.48	1.48	1.48	1.48	1.48	1.48	1.48	1.48



LV solid cables volumes:

Volumes	DPCR4 (FBPQ)					DPCR5 (Actual and Forecast from RIgs)				
Year end	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
LV UG Cable FBPQ (Removals only)						7.00	7.00	7.00	7.00	7.00
LV UG Cable (Planned-Removals)	15.00	24.00	21.00	2.00	4.00	7.00	10.00	2.00	3.00	3.25

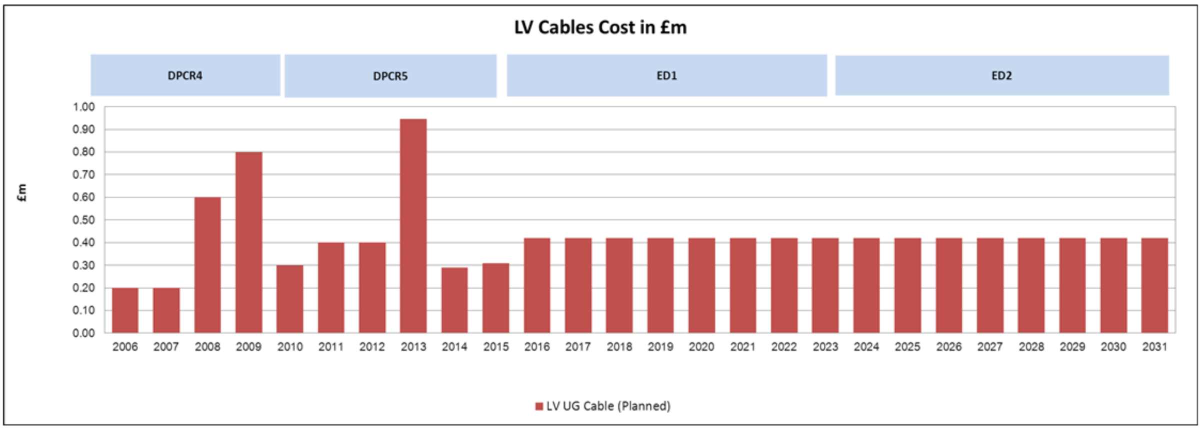
Volumes	ED1 Plan								ED2 Plan							
Year end	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
LV UG Cable FBPQ (Removals only)																
LV UG Cable (Planned-Removals)	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00



LV solid cables cost:

Investment £'m	DPCR4 (FBPQ)					DPCR5 (Actual and Forecast from RIgs)				
Year end	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
LV UG Cable (Planned)	0.20	0.20	0.60	0.80	0.30	0.40	0.40	0.95	0.29	0.31

Investment £'m	ED1 Plan								ED2 Plan							
Year end	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
LV UG Cable (Planned)	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42



FFC joints and ancillary equipment

Intervention volumes								
Description	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**
Replace aluminium cable joint plumbs	21	21	21	21	21	21	21	21
Install remote pressure-monitoring equipment	7	7	7	7	7	7	7	7
Replace pressurised cables and ancillary equipment (tanks, gauges, etc)	21	21	21	21	21	21	21	21

Intervention cost in £m								
Description	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**
Replace aluminium cable joint plumbs	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.17
Install remote pressure-monitoring equipment	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Replace pressurised cables and ancillary equipment (tanks, gauges, etc)	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45

Appendix 6 – Sensitivity Analysis

Sensitivity Analysis:

Asset Risk and Prioritisation Model for EPN 132kV UG Cable (Oil) (written by Decision Lab)

Introduction

This is a report on the sensitivity analysis conducted on the Asset Risk and Prioritisation (ARP) Model, developed by EA Technology and used to support the asset replacement and investment strategy for EPN 132kV UG Cable (Oil), which is included in the ED1 plan.

The objective is to understand how the Health Index profile of assets may change if the average asset life does not turn out as predicted.

An input to the ARP model is the starting asset population in each Health Index, which is different in each region. Therefore, sensitivity analysis has been done on a region-by-region basis.

The Asset Risk and Prioritisation Model

The ARP model uses database information about each individual asset, and models many parameters to predict the Health Index of each asset in the future. Significant parameters are age, location, loading and current average asset life.

Sensitivity Analysis

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

Standard average asset lives are used in the ARP model. These are 70, 80 and 85 years. In 2012, about 99% had a current average asset life of 80 years. This study covered the full population of EPN 132kV UG Cable (Oil).

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

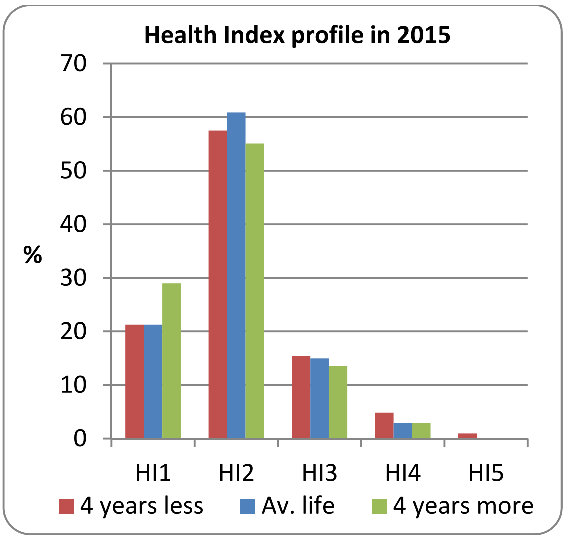
All results are shown below as the percentages of the population.

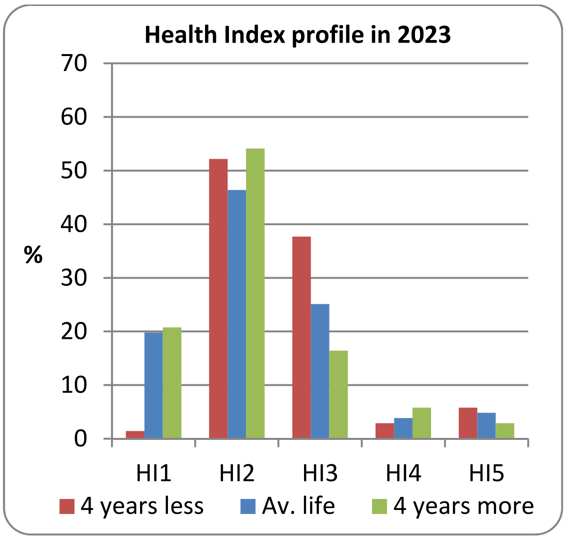
Average life change	2015 percentage HI profile				
	HI1	HI2	HI3	HI4	HI5
-4	21.3	57.5	15.5	4.8	1.0
-2	21.3	60.9	13.0	3.9	1.0
-1	21.3	60.9	15.0	1.4	1.0
0	21.3	60.9	15.0	2.9	0.0
1	21.7	60.4	15.0	2.9	0.0
2	21.7	61.8	13.5	2.9	0.0
4	29.0	55.1	13.5	2.9	0.0

Average life change	2023 percentage HI profile				
	HI1	HI2	HI3	HI4	HI5
-4	1.4	52.2	37.7	2.9	5.8
-2	1.4	61.8	28.0	3.9	4.8
-1	1.4	64.7	25.1	3.9	4.8
0	19.8	46.4	25.1	3.9	4.8
1	19.8	46.4	25.1	3.9	4.8
2	20.8	46.4	23.7	3.9	4.8
4	20.8	54.1	16.4	5.8	2.9

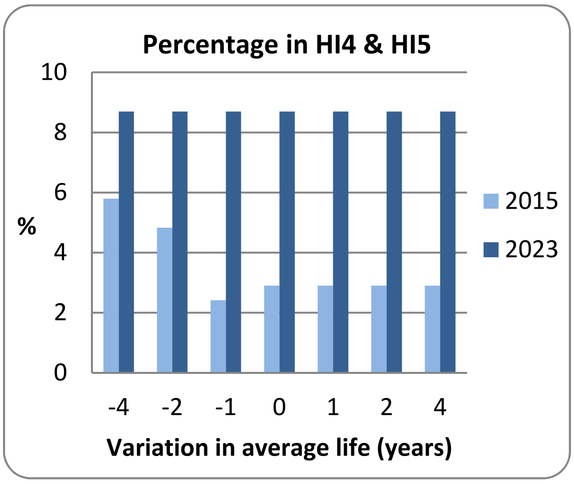
As the percentages above are rounded, the sum of a row may be 0.2% above or below 100%.

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





For all cases modelled, the sums of assets in Health Indices HI4 and HI5 are plotted below.



The results show:

- In 2015, if average asset life is four years longer, the proportion of HI4 and HI5 assets will be unchanged at 2.9%; but if four years shorter, the proportion will increase to 5.9%.
- In 2023, the proportion of HI4 and HI5 assets will be 8.7%; this will be unchanged if average asset life varies by up to four years.

Conclusion

The ED1 replacement plan for EPN 132kV UG Cable (Oil) is quite insensitive to a variation in average asset life of up to four years.

Sensitivity Analysis:

Asset Risk and Prioritisation Model for EPN EHV UG Cable (Oil) (written by Decision Lab)

Introduction

This is a report on the sensitivity analysis conducted on the Asset Risk and Prioritisation (ARP) Model, developed by EA Technology and used to support the asset replacement and investment strategy for EPN EHV UG Cable (Oil), which is included in the ED1 plan.

The objective is to understand how the Health Index profile of assets may change if the average asset life does not turn out as predicted.

An input to the ARP model is the starting asset population in each Health Index, which is different in each region. Therefore, sensitivity analysis has been done on a region-by-region basis.

The Asset Risk and Prioritisation Model

The ARP model uses database information about each individual asset and models many parameters to predict the Health Index of each asset in the future. Significant parameters are age, location, loading and current average asset life.

Sensitivity Analysis

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

Standard average asset lives are used in the ARP model. These are 70, 80, 85 and 95 years. In 2012, about 95% had a current average asset life of 80 years. This study covered the full population of EPN EHV UG Cable (Oil).

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

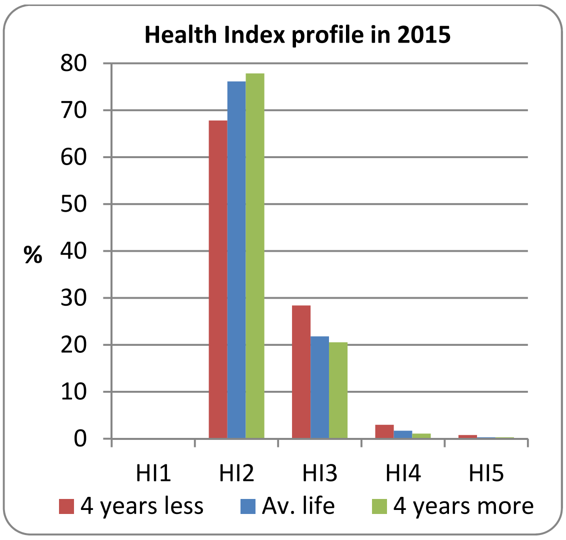
All results are shown below as the percentages of the population.

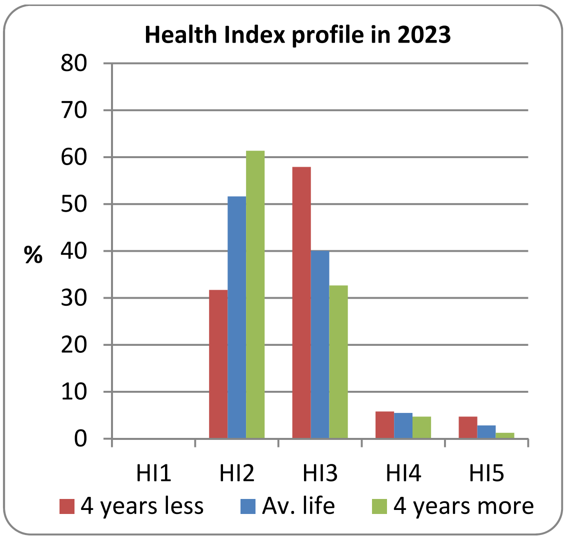
Average life change	**2015** percentage HI profile				
	HI1	HI2	HI3	HI4	HI5
-4	0.0	67.8	28.4	3.0	0.8
-2	0.0	71.1	25.7	2.8	0.3
-1	0.0	72.5	24.2	2.8	0.3
0	0.0	76.1	21.8	1.7	0.3
1	0.0	76.5	21.7	1.6	0.3
2	0.0	76.8	21.7	1.3	0.3
4	0.2	77.9	20.6	1.1	0.3

Average life change	**2023** percentage HI profile				
	HI1	HI2	HI3	HI4	HI5
-4	0.0	31.7	57.9	5.8	4.7
-2	0.0	47.7	42.5	6.4	3.5
-1	0.0	51.6	38.6	6.8	2.8
0	0.0	51.6	40.0	5.5	2.8
1	0.0	58.1	34.2	5.3	2.4
2	0.0	59.3	33.4	5.0	2.2
4	0.0	61.4	32.7	4.7	1.3

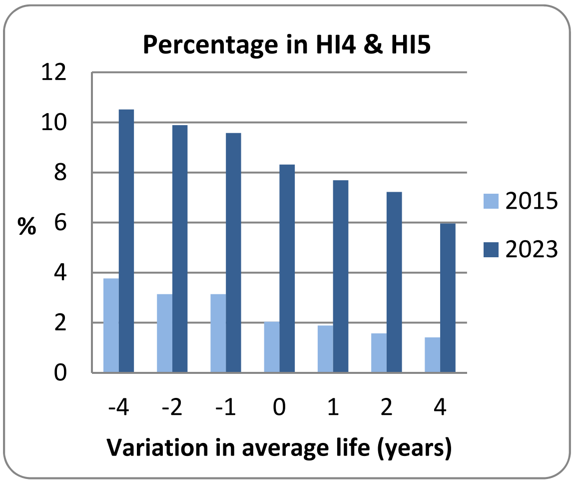
As the percentages above are rounded, the sum of a row may be 0.2% above or below 100%.

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





For all cases modelled, the sums of assets in Health Indices HI4 and HI5 are plotted below.



The results show:

- A variation in asset life will affect the proportions of HI4 and HI5 assets in 2015 and 2023.
- In 2015, if average asset life is four years longer, the proportion of HI4 and HI5 assets will reduce from 2.0% to 1.4%; but if four years shorter, it will increase to 3.8%.
- In 2023, if average asset life is four years longer, the proportion of HI4 and HI5 assets will reduce from 8.3% to 6.0%; but if four years shorter, it will increase to 10.5%.

Conclusion

The ED1 replacement plan for EPN EHV UG Cable (Oil) is mildly sensitive to a variation in average asset life of up to four years.

Appendix 7 – Named Schemes

Fluid-filled cable

Ref	Project ID	DNO	Description	Volume (km)	Cost (£m)
1.29.01.2976	2976	EPN	Gidea Pk/Noak Hill 33kV FFC Circuit – replace cables	5.5	0.85
1.29.01.7595	7595	EPN	Southend Grid / Fleethall Primary 33kV Fluid Filled Cables – 33kV FFC Replacement (Section 1-2 & Section 2-2)	2.0	0.93
1.29.01.7596	7596	EPN	Stanmore Grid / Kenton Primary 33kV Fluid Filled Cables – 33kV FFC Replacement (Section-2-4)	1.0	0.36
1.29.01.7597	7597	EPN	Tilbury Grid / Marshfoot Rd Primary 33kV Fluid Filled Cables – 33kV FFC Replacement (Section 2-1)	3.1	1.39
1.29.02.7598	7598	EPN	Wymondley Local / Letchworth Grid 132kV Fluid Filled Cables – 132kV FFC Replacement (Section-1-1 & Section 1-2)	7.9	7.55
1.29.02.7599	7599	EPN	Tottenham Grid / Hornsey Grid 132kV Fluid Filled Cables – 132kV FFC Replacement	3.4	4.61

Solid cable

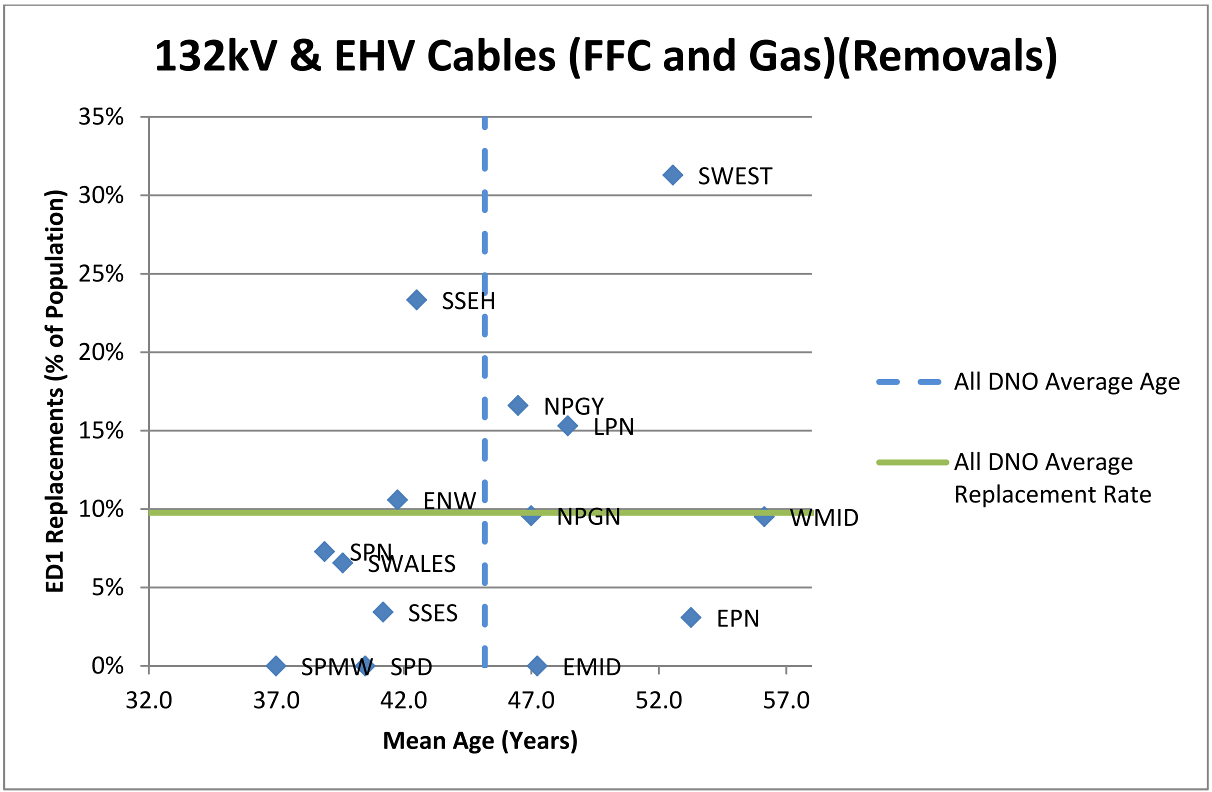
Ref	Project ID	DNO	Description	Volume (km)	Cost (£m)
1.07.02	5092	EPN	ED1 Replace 132kV solid cable provision – EPN	2	2.0
1.07.90	2723	EPN	ED1 Replace 33kV solid cable provision – EPN	24.67	7.44
1.18.01	9052	EPN	Replace HV Cable (Planned)	48	4.00
1.18.03	9127	EPN	Replace LV Cable (Planned)	32	3.36
1.32.09	8919	EPN	Underground 11kV Overhead Lines	195.20	11.84
1.07.02	5092	EPN	ED1 Replace 132kV solid cable provision – EPN	2	2.0

Appendix 8 – Output NAMP/ED1 Business Plan Data Tables

Outputs	Asset Stewardship report										RIG Table										
Investment destription	**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**
132kV FFC replacement	1.29.02	0.00	0.00	0.00	0.00	0.00	3.40	0.00	8.00	11.40	CV3	221	-	-	-	-	-	3.40	-	8.00	11.40
EHV FFC replacement	1.29.01	6.50	0.00	3.10	0.00	0.00	2.00	0.00	0.00	11.60	CV3	191	6.50	-	3.10	-	-	2.00	-	-	11.60
											CV3	194	-	-	-	-	-	-	-	-	0.00
132kV Gas replacement	1.07.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	CV3	222	-	-	-	-	-	-	-	-	0.00
EHV Gas replacement	1.07.90	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	CV3	192	-	-	-	-	-	-	-	-	0.00
											CV3	195	-	-	-	-	-	-	-	-	0.00
Replace 132kV solid cable	1.07.02	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	2.00	CV3	220	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	2.00
Replace EHV solid cable (planned)	1.07.01	3.08	3.08	3.08	3.08	3.08	3.08	3.08	3.08	24.67	CV3	190	3.08	3.08	3.08	3.08	3.08	3.08	3.08	3.08	24.67
											CV3	193	-	-	-	-	-	-	-	-	0.00
Replace HV cable (planned)	1.18.01	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	48.00	CV3	157	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	48.00
Underground 11kV Overhead Lines	1.32.09	24.40	24.40	24.40	24.40	24.40	24.40	24.40	24.40	195.20	CV3	151	24.40	24.40	24.40	24.40	24.40	24.40	24.40	24.40	195.20
Replace LV cable (planned)	1.18.03	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	32.00	CV3	137	-	-	-	-	-	-	-	-	0.00
											CV3	138	1.41	1.41	1.41	1.41	1.41	1.41	1.41	1.41	11.25
											CV3	139	2.59	2.59	2.59	2.59	2.59	2.59	2.59	2.59	20.75
Total		**44.23**	**37.73**	**40.83**	**37.73**	**37.73**	**43.13**	**37.73**	**45.73**	**324.87**			**44.23**	**37.73**	**40.83**	**37.73**	**37.73**	**43.13**	**37.73**	**45.73**	**324.87**

Source: 19th February 2014 NAMP Table O
21st February 2014 ED1 Business Plan Data Tables

Appendix 9 – Efficiency benchmarking with other DNO's



This graph shows EPN have below average level of investment. The business objective throughout the planning process for ED1 was to invest at a level that will maintain leakage rates at roughly the same level throughout the ED1 period

Appendix 10 – Material changes since the July 2013 ED1 submission

This document now only includes costs relevant to *asset replacement (CV3)* and. Unplanned replacements (NAMP lines 2.50) are now included in the *Inspection and Maintenance Asset Stewardship reports.*

There are no changes to our proposed fluid filled cables (FFC) investment at 132kV and EHV as the business objective throughout the planning process for ED1 was to invest at a level that will maintain leakage rates at roughly the same level throughout the ED1 period.

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
6.6/11kV UG Cable	Replace	Volume (Addition)	56	243.20	187.2	-
		Volume (Removals)	168	48	(120 no. of services)	-
		Investment (£m)	17.58	29.27	11.69	-
		UCI (£k)	314.0	120.4	(193.6)	-
33kV UG Cable (Non Pressurised)	Replace	Volume (Addition)	44.29	36.27	(8.02)	
		Volume (Removals)	24.67	24.67	0	
		Investment (£m)	13.07	12.09	(0.98)	
		UCI (£k)	295.1	333.4	38.3	

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

6.6/11kV UG Cable

The increase in 6.6/11kV solid cable addition volumes is due to the movement of activity from CV2 for the undergrounding of 11kV overhead lines as a result of Quality of Supply (QOS) driven work.

There was also a reduction in 6.6/11kV solid cable volumes due to removal of an 11kV OHL project which required the undergrounding 8km of OHL.The overall effect of these two changes is a net increase addition volumes.

Correction has been made in 6.6/11kV solid cable removal volumes as redundant HV services (no. of services) removal volumes were reported by mistake in the July 2013 ED1 submission.

33kV UG Cable (Non Pressurised)

The decrease in 33kV solid cable addition volumes is due to removal of a 33kV OHL project which required the undergrounding 8km of OHL.

Correction has been made in HV (planned) volumes as redundant HV services were reported by mistake in the July 2013 ED1 submission. This is the only change to the plans since the July 2013 ED1 submission.