SP Energy Networks 2015–2023 Business Plan

Updated March 2014

Annex

132kV Overhead Lines Strategy

SP Energy Networks

March 2014

SP ENERGY NETWORKS

132kV Overhead Lines Strategy

March 2014

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17th March 2014	1.0	Alyn Jones	First Issue

1. Scope

This annex covers our strategy for managing our existing 132kV overhead line distribution network on the SPM network. It aims to address the current volume of assets at or approaching end of life, through an optimum level of investment, delivered through the continuation of a prioritised and project specific approach spanning DPCR5, RIIO-ED1 & RIIO-ED2.

2. Table of Linkages

This strategy supports our ED1 Business Plan. For ease of navigation, the following table links this strategy to other relevant parts of our plan.

Document	Chapter / Section
SP Energy Networks Business Plan 2015-2023	Chapter C6 – Expenditure e. Non Load Related Investment l. Cost efficiency and benchmarking
SP Energy Networks Business Plan 2015-2023 Annexes	Annex C6 – Expenditure Supplementary Annex – SPEN
SP Energy Networks Business Plan 2015-2023 Annexes	Annex C6 – Cost Benefit Analysis – SPEN No. 48 - 132kV Tower Lines
SP Energy Networks Business Plan 2015-2023 Annexes	Annex C6 – 132kV Overhead Lines Heat Maps – SPEN

3. Executive summary

The SP Energy Networks (SPEN) strategy for our existing 132kV overhead line distribution network on the SPM network aims to address the current volume of assets at or approaching end of life, through an optimum level of investment, delivered through the continuation of a prioritised and project specific approach spanning DPCR5, RIIO ED1 & RIIO ED2.

This is necessary to effectively manage an increasing business risk, ensure cost-efficient investment and continue the long term sustainability and resilience of this key SPM and GB asset.

Our investment plan in RIIO-ED1 involves £91.40 million of non-load related investment associated with the targeted replacement of conductors, insulators and fittings, and the refurbishment of steel towers which are at or approaching end of life.

The investment plan has been developed utilising our Asset Risk Management policies and procedures, together with modelling tools which reflect the nationally agreed Network Output Measures methodology

Scottish Power Energy Networks own, operate, and manage steel tower supported overhead lines on our Transmission Network in Scotland (SPT) and our Distribution Network in England and Wales (SPM). We have developed and utilise as common set of Asset Management Policies, Procedures and Standards across this asset class, to ensure the consistent use of best practice and standards throughout.

Our RIIO ED1 plan for the 132kV overhead lines in SPM is therefore based on the application of these policies, in line with our successful RIIO T1 submission for SPT.

The tables below illustrate our planned Asset Replacement and Asset refurbishment investment during RIIO-ED1.

Asset Replacement Expenditure	RIIO-ED1			
	Total (£m)		Per Annum (£m)	
	SPD	SPM	SPD	SPM
132kV OHL (Pole Line) Conductor	-	6.1	-	0.8
132kV Pole	-	5.4	-	0.7
132kv OHL (Tower Line) Conductor	-	28.9	-	3.6
132kV Fittings	-	15.5	-	1.9
132kV UG Cable (Non Pressurised)*	-	3.0	-	0.4
Total	**-**	**58.8**	**-**	**7.4**

*132kV UG Cable (non pressurised) value only covers 132kV OHL related investment

Asset Refurbishment Expenditure	RIIO-ED1			
	Total (£m)		Per Annum (£m)	
	SPD	SPM	SPD	SPM
132kV Tower	-	8.0	-	1.0
132kV Tower Painting	-	8.3	-	1.0
132kV Tower Foundation	-	16.2	-	2.0
Total	**-**	**32.6**	**-**	**4.1**

4. 132kV Overhead Line Asset Strategy

132kV Overhead Lines equates to £95.67m expenditure within our 132kV non-load investment programme in RIIO ED1.

Our plan over the three price review periods DPRC5, RIIO ED1 & RIIO ED2 is to address circa 837km circuit length of the remaining population of 1950/60s ACSR conductor on the 132kV network. In DPRC5 we will have replaced 139 circuit km of conductor, with work in progress to complete a further 28km, equating 167km, in RIIO-ED1 we plan to replace 412km, with the remaining 257km planned for RIIO-ED2, to manage this end of life risk.

As explained below we have prioritised the order in which we will undertake this work programme using our Asset Health Ranking score and by wherever possible combining the work in conjunction with other asset modernisation programmes such as 132kV substation replacement or reinforcement projects, to aide efficient delivery and optimise network security.

The 132kV overhead network is the backbone of the SPM network, its function historically has been to move large volumes of power from the intake positions from the National Grid to our bulk supply points nearer load centres. This remains the case however it now serves the increasing requirement to connect large renewable generators, both on and off shore, to the network.

Our RIIO-ED1 strategy is to invest in this asset and deliver improved resilience and reliability of this strategic asset for the next 4 or 5 decades.

On completion of this investment strategy we will have significantly improved asset health of, and therefore de-risked, the SPM 132kV overhead line network as no conductor will be HI5 (i.e. end of its electrical life) due to age or condition by the end of RIIO ED2.

In RIIO-ED1 we will also be modernising 33kV steel tower overhead lines in both SPD and SPM, many of the challenges are similar to those described within this annex, and a brief summary of our 33kV Steel Tower overhead line replacement and refurbishment plan is provided in Appendix 8

4.1. Overhead Line Asset Investment Process

To identify & prioritise our investment requirements we use the following key factors:

Condition (1)

- *Towers, foundations, phase conductors, earth conductor and insulators are assessed visually by means of a helicopter patrol condition based assessment, on a ten year cyclical programme. As detailed in Asset-01-021*[1] .

- *Conductor is sample tested utilising Cormon 2testing techniques*

Asset Health (2)

- *For overhead line towers, insulators and fittings this is primarily based on helicopter condition based assessments categorised using the 1-5 health index methodology.*

- *For conductor we utilise cormon data, where available, and conductor age as a proxy for condition as visual inspection alone is insufficient to detect the early onset of internal corrosion to the steel core of the conductor*

Heat Map (3**)**

- *The Health Indices populate the system heat map which is subsequently utilised to develop the first planning iteration Asset Management Investment Plan, taking account of any age based modelling for long term context.*

From this heat map asset interventions are applied over appropriate time periods to manage the risk, (in accordance with our Asset inspection and Condition Assessment Policy ASSET-01-021

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[1] ASSET-01-021 - Asset Inspection and Condition Assessment Policy

[2] Cormon testing is a non-destructive testing method for determining the condition of overhead power conductors. A remotely controlled device is passed along the ACSR conductor and measures the integrity of the galvanizing layer on the steel core strands. Loss of galvanizing is a precursor to the onset of galvanic corrosion between the steel and aluminium cores of ACSR and provides an early warning of the potential need to replace the conductor – **Teledyne Cormon**

Figure 1- Overhead Line Asset Investment Process[3]

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[3] The process map is taken from our 132- 400 kV OHL Investment Policy document **OHL_01-014** for illustration purposes only.

4.2. Overhead Line Asset Base

The asset base for the overhead line area comprises of:

Table 1 – forecast asset base end of D5

	Conductor (Circuit km)	Towers (Volume)
132kV	1332	2,568

5. 132kV Steel Tower Overhead Line Investment Strategy

The investment strategy for 132kV steel tower overhead lines is to replace those assets assessed as at, or approaching end of life, utilising asset condition information and conductor age as a proxy for condition, using the most cost effective delivery techniques' and processes.

Aluminium conductor with galvanised steel reinforced core (ACSR) has been utilised on high voltage overhead lines for over 80 years. The design of this type of conductor, with its differing metallic elements, is susceptible to galvanic corrosion between the strands which is heavily influenced by the weather and pollutants in the atmosphere (attacking the galvanising on the steel core). The majority of the 132kV distribution overhead network was constructed from the 1930's through to the 1970's using "Lynx" 175 sq mm Aluminium Conductor Steel Reinforced (ACSR) phase conductor, with the bulk of the network constructed in the 1950's & 60's.

To address this aging asset SPEN has built or rebuilt 40% of its 132kV overhead line network in the last 20 years, however the age profile of our asset base results in us now needing to address an up-turn in the asset moderisation requirements.

ACSR conductor is generally expected to have a mean asset life of circa 54 years[4][5] and is therefore at or approaching end of life (Asset Health 4 or 5) and is now considered to require replacement.

We do not believe there to be an imminent risk of conductor failure in the short term under normal operating conditions, however as shown in our health index analysis, by 2023, based on our technical assumptions for degradation and the age of the conductor, we believe there to be a significant medium to long term risk of reactive condition based conductor failure if we do not intervene as detailed in our submission.

Figure 2, below illustrates the age profile of SPM 132kV overhead line conductor, as forecast at the end of our DPRC5 investment programme. The table shows three sectors:-

- *The initial build of the network and electrification from the 1930's to the early 1970's (we have previously invested to modernise the oldest of these assets)*

- *The period through the mid 70's to early nineties where network growth was relatively static with small scale asset replacement*

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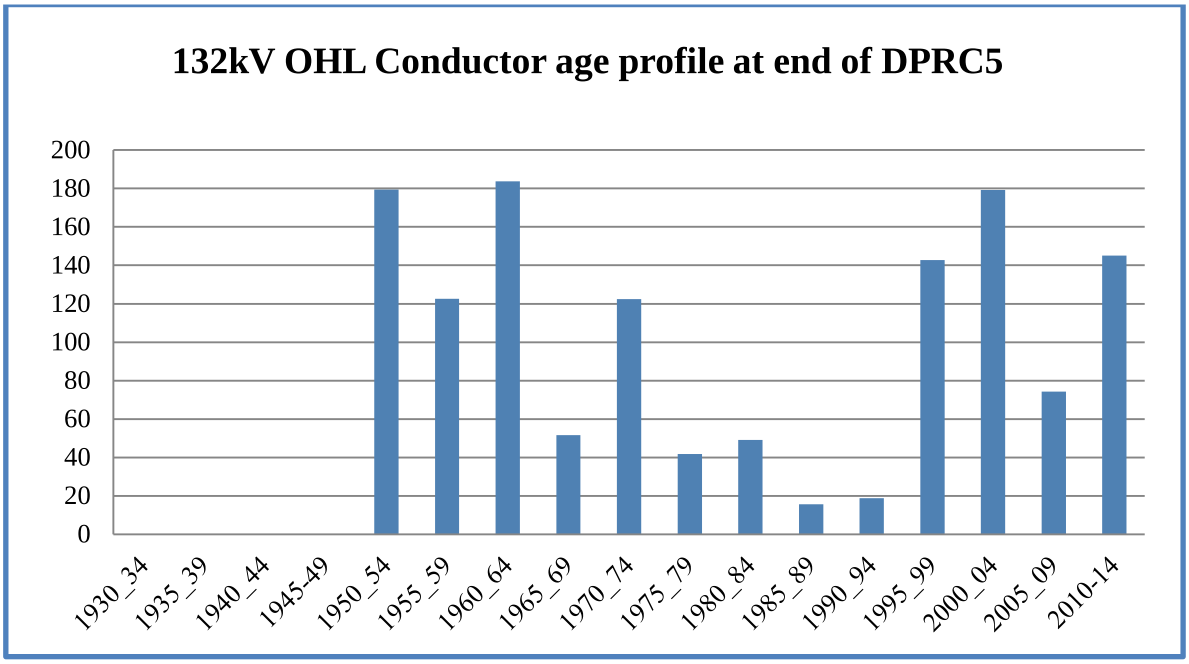
[4] Kema Report: PR1078 Rev D014, 6th July 2006, page 77. Mean Asset Life for Normal Environment **54 years**, standard deviation of **14**.

[5] Cigre Working Group: 37.27: Ageing of the System, Impact on Planning, Report 176, December 2000, page 7. Mean Asset Life for Normal Environment **52.5 years**, standard deviation of **7.5**.

- *The period from the mid-nineties to date; covering the initial asset replacement phase of the oldest sections of 132kV network, pre mid 1950's, together with network expansion due to connection of renewable energy schemes and necessary network reinforcement*

Figure 2 – 132kV conductor age profile



The table clearly shows that despite the investment in the last couple of decades or so, there remains a considerable volume of 132kV conductor from the 1950's & 60's that is now at, or approaching end of life.

Application of the process identified in section 4.1 above, gives the following results.

- *At the end of our DPRC 5 investment programme 375 circuit km (28%) of the asset base will be older than 54 years*
- *If we do not intervene, we predict that this will move to 537circuit km (40%) of the asset base being older than 54 years and therefore at or close to end of life at the end of ED1.*

The age distribution of our 132kV overhead line conductor reflects the large population of conductor which was installed in the 1950/60's and is at or exceeding 54[6] years age. These assets will develop towards end of economic replacement and electrical end of life in RIIO-ED1, and this issue is discussed in further detail in section 6 below.

Our ongoing strategy to manage this issue is to:-

- *DPRC5 - significantly reduce HI-5 conductor based on both age and in poorest condition.*
- *RIIO ED1 - replace HI5 conductor based on age and condition, as of end of DPRC5 and target 50% of conductor that will become HI5 within ED1.*
- *RIIO ED2 - replace HI5 conductor based on age and condition, at end of ED1 and 100% of conductor that will become HI5 within ED2*

[6] Kema Report: PR1078 Rev D014, 6th July 2006, page 77. Mean Asset Life for Normal Environment **54 years**, standard deviation of **14**

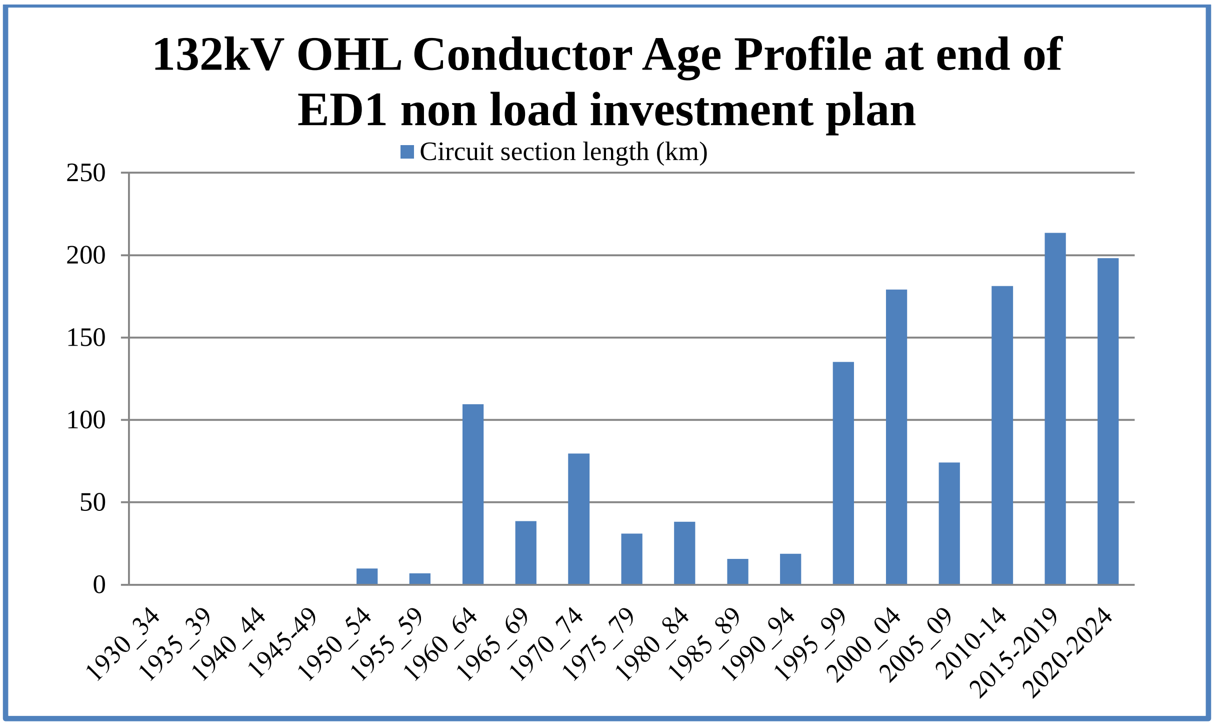
- *RIIO ED3 - replace conductor that will become HI5 within ED3*

This equates to the requirement to replace 669circuit km of 132kV conductor over two RIIO price review periods, with 61% being replaced in RIIO ED1 and 39% being replaced in RIIO-ED2

The application of this strategy will result in an improved Asset Age profile and Health indices at the end of RIIO ED1 in Figure 3 and Figure 4 below, based on the planned investments in RIIO-ED1, and assumed investment throughout RIO-ED2 & ED3 in line with the SPEN asset management strategy

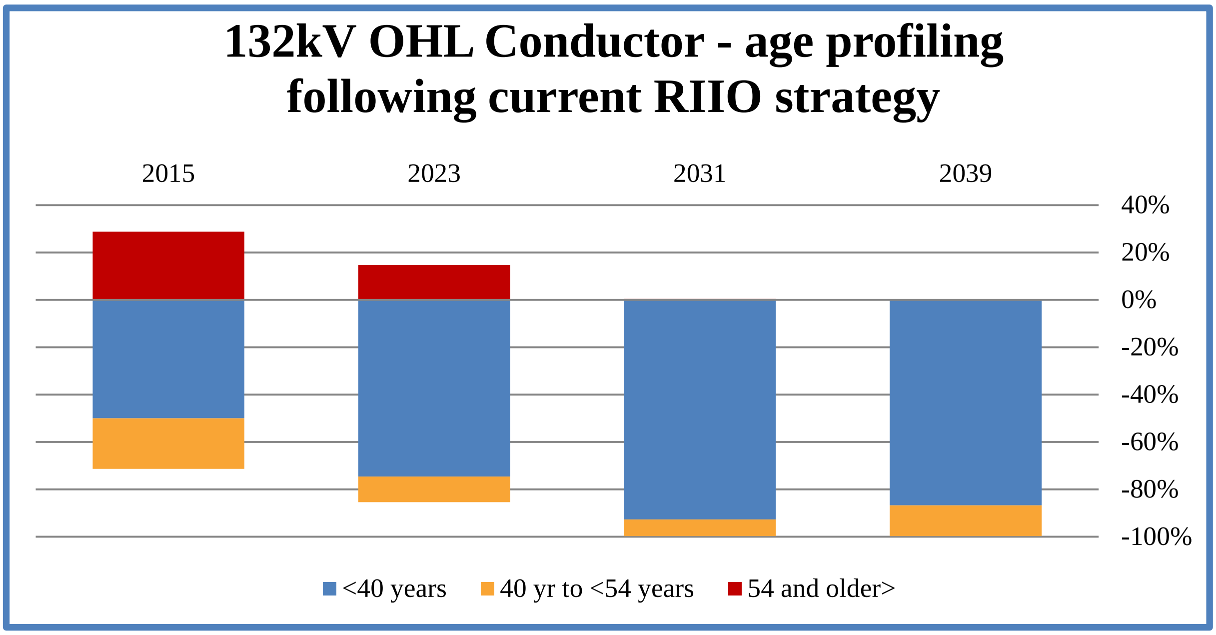
Small sections of HI3 conductor is included in the above totals to complete entire routes utilising the same conductor, removing jointing issues between dissimilar conductor and conductor fittings and gaining benefit from the enhanced rating offered by 200mm^2 poplar conductor

Figure 3: OHL Conductor age profile at end of ED1 with Intervention



The pre 1960 assets not progressed in our ED1 programme are currently subject to wayleave termination negotiations on the Q route, or form part of the 4ZC 400kV route on North Wales upon which SPM have conductors strung on NGC towers, and are currently subject to an modification application from NGC. Asset replacement on these two routes has therefore been deferred until ED2, pending the outcome of the 'necessary wayleave hearings' and a formal design being submitted by NGC. I&M and condition monitoring will continue in line with Asset inspection and Condition Assessment Policy ASSET-01-021, with intervention on a reactive basis if and when appropriate.

Figure 4: 132kV age profile improvement delivered by investment plan over ED1/ED2



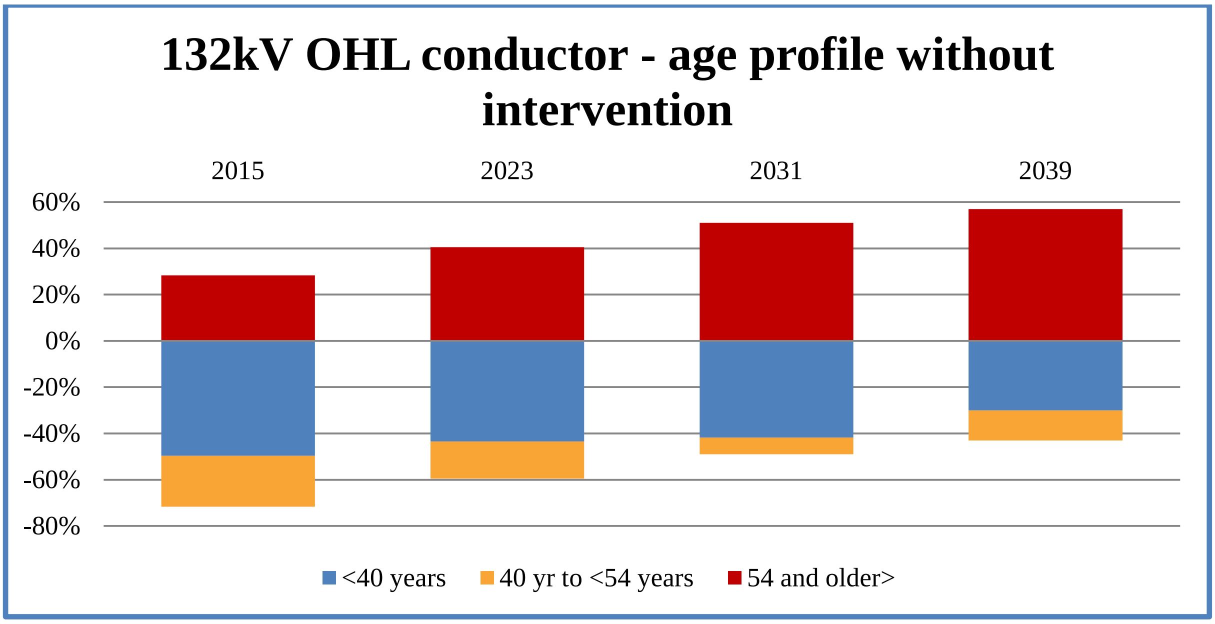
Whilst there is currently 28% of our conductor older than 54 years as we enter ED1, we do not believe there to be an imminent risk of conductor failure in the short term, however we believe there to be a significant medium to long term risk of reactive condition based conductor failure if we do not intervene as detailed in our submission. We also consider as discussed later that not intervening as per our submission, would result in increase in future replacement cost due the preferred and most economic option of full tension stringing technique being denied to us, this would both increase delivery timescales and cost, which is not in the best interests of system security or our customers.

During DPRC5 we increased our investment in 132kV overhead line conductor and developed our internal and external delivery capability. In doing so we will have replaced 139 circuit km of conductor, with work in progress to complete a further 28km based on age/condition, equating to167km or 34km per annum.

The age profile of our asset base results in us now needing to address an up-turn in requirements such that our investment plan in RIIO ED1 is for the replacement of 412km of conductor based on age/condition equal to 51.5 km per annum, and in RIIO-ED2 we plan to replace 257km of conductor equal to 32.5 km per annum.

Figure 5 below, illustrates by way of contrast the age profile of our 132kV overhead line conductor should we do not intervene, we would suggest that this is not an appropriate strategy to manage assets critical to the security of supply of our customers and stakeholders.

Figure 5: -132kV OHL conductor age profile without intervention throughout ED1/ED2



The details of which circuits are in each category are described in section 7 and 8 where our “heat map” of asset health issues shows the circuits in each category, and explains the rational of why each circuit is identified within each category.

5.1. Asset Replacement

Our policy for undertaking full rebuild is applicable when all components require replacement based on the ranked Condition Assessment Tables and Asset Life Expectancy and would be considered particularly appropriate if a significant number of support structures i.e. the steel towers and foundations have reached an end of life position. A rebuild will generally involve the replacement of all towers, foundations, phase conductors, earth wire, insulators, line fittings anti-climbing guards and any other ancillary equipment deemed necessary.

In our RIIO-ED1 programme the single circuit 132kV route between Legacy in North Wales and Crewe in Cheshire, built in 1958 (including the CT line connecting Marchwiel) has been identified for a full rebuild due to the poor condition of the steel work and sub-standard foundations. Therefore rather than refurbish the tower steelwork and replace all of the foundations as part of the conductor replacement programme, the line will be dismantled and rebuilt with a wood pole construction, as a less onerous and more cost effective option for a single circuit line.

5.2. Full Refurbishment

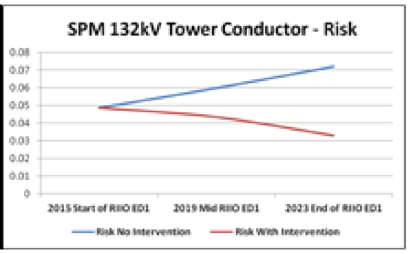
Our Policy for undertaking full refurbishment when all applicable is when all line components require replacement based on the ranked Condition Assessment Tables and Asset Life Expectancy, but does not include full tower support structure and foundation replacement. This will involve replacing the phase conductors; earth wire; insulators and fittings and vibration dampers (including spacers; spacer dampers where appropriate). An intrusive assessment of the underground tower foundations will be required to determine whether the foundations can withstand the rigours of conductor replacement or upgrade. Sufficient steelwork refurbishment work will be carried out during the scheme to ensure that the tower (with a satisfactory paint programme) will remain in good condition for the life expectancy of the new conductor. This may involve bar; cross arm; tower top replacement. Anti-climbing devices; signs and notices are also upgraded within the scope of the scheme. On single circuit overhead lines we assess the extent of the required refurbishment and consider the full replacement of the circuit with a wood pole construction to seek the best value option in terms of cost, deliverability and system security.

Our steel tower 132kV overhead lines age and condition profile is such that the vast majority of 132kV overhead line work programme in RIIO-ED1 will fall under this category.

Figure 6 below, shows the impact of our plans for Asset Replacement and Full Refurbishment on the health and criticality indices for 132kV tower line conductor. The reduction in risk is in line with our long term strategy and reflective of the increase in investment over the period. The balance figure of -44 is due to 44km of tower line being replaced by pole lines.

Figure 6: 132kV OHL Conductor Health and Criticality Indices with intervention during ED1

SPM	HI1	HI2	HI3	HI4	HI5	Total CI
CI1	10	0	0	0	-11	-1
CI2	325	0	0	0	-364	-39
CI3	33	0	0	0	-37	-4
CI4	0	0	0	0	0	0
Total HI	368	0	0	0	-412	-44



5.3. Minor Refurbishment

Any scheme that does not involve the replacement of phase conductors and earth wires or foundations is classed as Minor Refurbishment. Typically this will include the replacement of insulators and associated fittings; spacer and vibration dampers; steelwork refurbishment and minor steelwork replacement. If a conductor is considered to have a residual life of 10 to 15 years but some or all of the fittings are the life limiting factor (and if it is economical to do so) only the fittings of concern shall be replaced in order to utilise the full life of the conductor.

Our modeling indicates that in RIIO ED1 there is little or no requirement for this category of work and none is included in our budgeted plans, however routine Inspection and maintenance programmes will continue, in line with our policies, and will accommodate defect clearance on lines outside of the RIIO-EDI non load investment plan.

5.4. Steelwork Refurbishment

Steelwork refurbishment will take place during and co-ordinated within any Full or Minor Refurbishment scheme regardless of condition. Indeed it is preferable that steelwork is painted before the onset of corrosion (loss of galvanising). This will minimise costs; outage requirements; disruption to Grantors and avoid the need for new wayleave and consents. Towers deemed beyond economic recovery will be identified for replacement. Tower steelwork will normally be refurbished as part of a wholesale steelwork refurbishment programme on a fifteen year cycle.

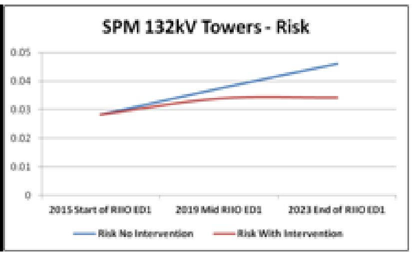
Routine tower painting is primarily opex driven, and the opex programme is reduced to reflect any towers targeted where steelwork refurbishment is being carried out in the capital programme.

In RIIO ED1 all towers on circuits identified for Replacement or Full refurbishment will undergo steelwork refurbishment as appropriate.

Figure 7 below, shows the impact of our plans for Steelwork (& Tower) Refurbishment on health and criticality for 132kV towers are shown in the matrix below. There will be 243 towers removed and replaced with a 132kV pole line. The HI improvement reflects our steelwork and foundation refurbishment programmes.

Figure 7: 132kV Health and Criticality Indices with intervention during ED1

	HI1	HI2	HI3	HI4	HI5	Total CI
CI1	0	35	-5	-11	-43	-24
CI2	0	598	-68	-357	-389	-216
CI3	0	32	-2	-27	-6	-3
CI4	0	0	0	0	0	0
Total HI	0	665	-75	-395	-438	-243



6. Overhead Line Asset Health Issues

6.1. Conductor

All overhead line conductors perform as part of a system, in dynamic and onerous environments, the combination of which tends to affect the condition of the asset over time. All conductors are susceptible to a similar degradation, the general causation being prolonged exposure to the weather or exposure to pollution in the atmosphere. Over time, corrosion of the conductor components has been established as a primary failure mode however, the rate of corrosion can depend on a number of factors notwithstanding the general premise of exposure to the weather. Such other factors which may affect the rate and severity of corrosion are, the age of the conductor, the type of conductor utilised, the quality of the conductor, the quality of the installation, or more commonly a combination of two or more of the aforementioned. Experience within the industry combined with our own knowledge and empirical evidence does indicate that conductors are more susceptible to failure due to corrosion from the age of circa 50 years. Conductors can and do fail earlier with common failure modes being mechanical damage or conductor fatigue caused by exposure to particularly onerous weather patterns, conductor vibration, lightning damage, windblown debris, bird impact, degradation of conductor fittings or in rare instances, poor installation. In view of this we use the 50-year criterion as a yardstick for longer term planning purposes, and supplement this by condition and risk assessment to refine our specific refurbishment and replacement plans.

As stated, aluminium conductor with galvanised steel reinforced core (ACSR) has been utilised on high voltage overhead lines for over 80 years. The design of this type of conductor, with its differing metallic elements, is susceptible to galvanic corrosion between the strands which is heavily influenced by the weather and pollutants in the atmosphere (attacking the galvanising on the steel core). In the early 1960s this issue began to be addressed by the application of grease to the steel core of conductor in an attempt to delay the onset of corrosion. Original application techniques were poor (by hand) and quality issues were common. By about 1966 all new conductor requests specified fully greased inner layers and to comply, manufacturers were building grease application into their automated conductor manufacturing processes. Since the early 1990s the industry has been moving away from ACSR conductor towards All Aluminium Alloy Conductors (AAAC). The AAAC conductor does not suffer from these galvanic corrosion issues, and we have no plans to invest in replacement of lines constructed from AAAC conductor in RIIO-ED1, and currently we do not expect to be investing in the replacement of it during RIIO-ED2.

The majority of the 132kV distribution overhead network was constructed between the 1930’s and the 1970’s utilising 175 sq mm “Lynx” Aluminium Conductor Steel Reinforced (ACSR) phase conductor such that over 485 km (36%) of the conductor on the SPM 132kV network is or will over 50 years old by the end of our DPCR5 asset replacement programme. This type of ACSR conductor is generally expected to have a mean asset life of circa 54 years and is therefore at or approaching end of life (Asset Health 4 or 5) and is now considered to require replacement. “Horse” Aluminium Conductor Steel Reinforced (ACSR) was generally installed as an earth wire and is of a similar vintage and condition to that of the phase conductor. Again, this type of ACSR conductor is generally expected to have a mean asset life of 54 years and is therefore also at or approaching end of life (Asset Health 4 or 5) and is now considered to require replacement. Replacement of the earth wire is generally undertaken in conjunction with phase conductor replacement, although some earth conductors were replaced in isolation using OPGW[7] as part of our digital communication programme.

There are a number of sampling techniques that can be utilised to determine the condition of ACSR conductors. On any given route there will be sections of overhead line that are more susceptible to corrosion and wind induced damage. An assessment is required to identify where these areas are, based on environment (past and present), geography, fault history and condition information. SPM have a number of heavy duty 132kV circuits built to Transmission voltage standard and these are susceptible to Aeolian vibration, sub-conductor oscillation and iced galloping. Cormon[8] is a non-intrusive conductor internal condition monitoring tool with the ability to determine the condition of the galvanised steel core. The Cormon test gear was developed in the 1990s by the Electricity Association and National Grid. The method involves inducing electrical currents into the conductor and measuring the resultant feedback. The results can be displayed graphically or in tabulated format. The results are best utilised when compared to a previous set of results over the same span indicating a rate of deterioration rather than an expiry date. The most onerous part of the process is the removal of spacers where fitted and navigating mid-span joints, and obviously needs an extended outage to carry out the work. However five spans can be monitored in the time it takes to remove a section of conductor for inspection. Cormon is recognised as being the only non-intrusive technique on the market. Where condition based information indicates a significant risk, we intervene to manage that risk as appropriate.

As previously stated a significant amount of the conductor on the 132kV network is currently in excess of 50 years old, which has to date shown no significant failure mode, as it migrates towards an end of life ‘bathtub’ characteristic.

Under normal weather and less extreme winter weather conditions we do not believe there to be an imminent risk of widespread conductor failure in the short term, however as shown in our health index analysis, and illustrated figure 6 below, based on our technical assumptions for degradation and the age of the conductor, we believe there to be a significant medium to long term risk of reactive condition based conductor failure if we do not intervene as detailed in our submission.

To illustrate this point during the extreme snow and Ice event in March 2013, SPEN experienced a number of conductor and conductor mid-span joint failures on our SPM network, where the aged lines previously identified and incorporated in our DPRC5 and RIIO-ED1 investment plans were exposed to severe weather and ice loading.

Images from AD line from winter 2013 prior to our DPRC5 investment programme

[7] OPGW - Optical Fibre Composite Overhead Ground Wire

[8] CORMON – Proprietary name, for overhead line conductor condition assessment

The method of conductor replacement and associated costs of doing so will depend on the residual strength of the conductor. If a conductor is badly corroded (i.e. the residual strength of the steel core cannot be assured) the only re-conductoring option available may involve dropping a conductor to ground level.

- *The costs of doing so will be up to 2.5 times more expensive than tension stringing or catenary block techniques.*

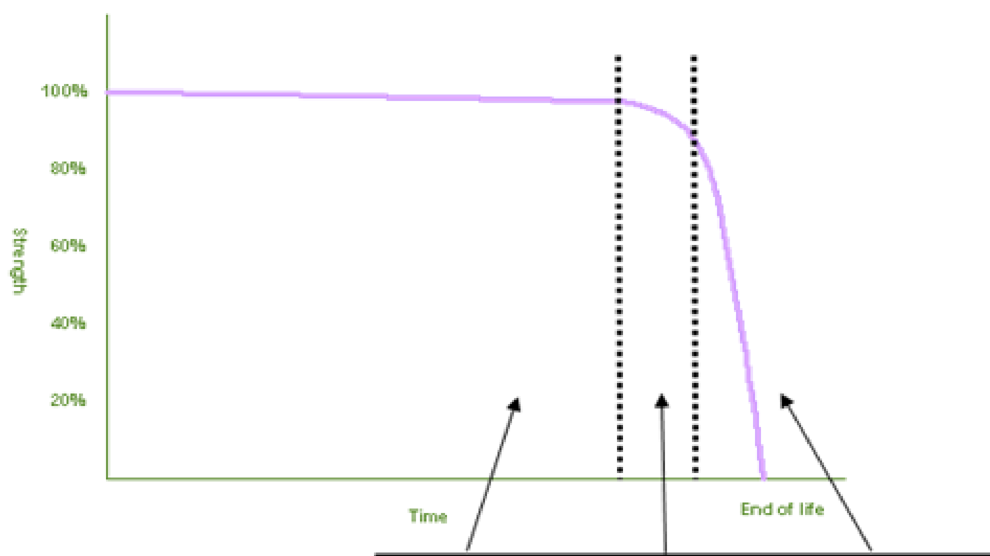
The diagram shown below in Figure 8 shows a typical conductor degradation curve measuring residual strength against time. It can be seen that over time, the residual strength of a conductor reduces significantly as it approaches end of life.

- *Under normal circumstances, conductor replacement uses the existing conductor to “pull through” the new conductor in a technique called “Tension Stringing”. This is the preferred method with the lowest costs, and shortest outage time.*

- *As the conductor moves closer to the end of life position, the residual strength of the conductor cannot be relied on to allow full tension stringing and therefore techniques such as “Catenary Blocking” should be considered. Costs increase and time to deliver this work increase significantly by utilising this technique*

- *At a point close to end of life, the residual strength of the existing conductor is reduced to a point where it can no longer support the installation of new conductors and must be dropped to the ground before new conductors are installed.*

Figure 8: 132kV conductor replacement costs against time



		Tension stringing	Catenary blocking	Remove and replace
Refurbishment risk	Complexity	Low	High	Medium
	Lead times	Low	Medium	High
	Environmental impact	Medium	Low	High
Safety risk	Staff	Low	Medium	High
	Public	Low	Medium	High
System risk	Risk of 2nd circuit failure	Low	Medium	High
	Outage Duration	Low	Medium	High
	Return to service	Low	Medium	High
Programme risk	Flexibility	Low	Medium	High
	Control	Low	Low	High
Investment risk	Costs	Low	High	High
	Predictability	Low	Medium	High
Replacement Cost Multiplier x		1	1.5	2.5

This is discussed further in Appendix 4

The costs associated with these processes increase as the residual strength of the existing conductor reduces, such that replacing conductors at end of electrical life may be up to 2.5 times greater than at a point prior to where the residual strength starts to reduce significantly (the “knee” point). The optimum time for replacing conductor therefore is when the residual strength of the existing conductor allows for tension stringing taking place.

6.2. Insulators

Glass or porcelain insulators are generally at or approaching end of life at 40 years. As described above, the majority of 132kV Overhead Lines were constructed in or before the 1960’s and therefore insulators began reaching their end of life category in the period from 2000. An insulator failure in 2009 highlighted that a number of insulators on several 132kV Overhead Line routes were suffering from severe corrosion which is not identifiable through our CBA helicopter patrols. A targeted remedial programme of works has been put in place to remove end of life assets, and a risk management regime instigated to ensure appropriate condition information is developed. Glass and porcelain insulators are typically replaced as part of any reconductoring works if they are calculated to have an Asset Health of 4 or 5 or are over 30 years old at the time of the works. Conductor replacement is the principal driver for the replacement of insulators and SPEN will extend their operational life to co-ordinate replacement with conductor replacement, unless, as detailed a condition or type issue is identified.

6.3. Towers

Towers steelwork has a life span of circa 70 years however, this may be extended by circa 15 years if painted whilst the galvanising is intact or circa 8 years if painted after the steelwork has started to corrode. Tower condition is managed via the ongoing Tower Painting and Refurbishment Programmes based on condition information from our CBA helicopter patrols. Where interventions are proposed for a route it is considered appropriate to refurbish the towers prior to the commencement of the wider works. Steelwork which has corroded to a point that the Asset Health is calculated to be 4 or 5, or beyond the point of economic repair requires to be replaced which in extreme cases result in full tower top, or complete tower replacement..

6.4. Foundations

Above ground foundations (Muffs and Chimneys) are considered for repair or replacement when the Asset Health is calculated to be 4 or 5. The above ground foundations on routes considered for major investment of any type should be considered remedial works during (or before) works commence. A mid-life refurbishment programme was completed on the SPM 132kV tower 'above ground' foundations during the 1980's and this has prevented significant deterioration

The 'below ground' foundations are subjected to targeted assessment during, or before major works, this will include tower verticality assessments to check for any signs of subsidence.

Our experience has shown that foundation condition remedial works to be addressed, can be associated with the following issues

- *Tension / angle towers where the original design does not meet modern loading requirements.*

- *Tension and support towers where the quality of the original installation was poor, and which require rebuilt due to condition.*

Based on experience gained from previous work programmes both in SPM and on our transmission assets in SPT we will inspect every tension and angle tower, and sample 20% of suspension tower foundations, from which we anticipate that 15 to 20% of angle / tension tower foundations will require significant remedial works involving completely rebuilding the foundations during major refurbishment / re-conductoring.

We further anticipate that 10-15% of suspension towers foundations will require minor refurbishment.

In our RIIO-ED1 programme the single circuit 132kV route between Legacy in North Wales and Crewe in Cheshire built in 1958 has been identified as having substandard foundations. Therefore rather than refurbish the tower steelwork and replace all of the foundations as part of the conductor replacement programme, the line will be dismantled and rebuilt with a wood pole construction, as a less onerous and more cost effective option for this single circuit line.

We have previously PLPC to investigate options for in-situ refurbishment, see Appendix 6 however this is not the preferred intervention method as it will not address all asset condition issues on this line.

7. 132kV OHL Costs & Scheme Lists

The tables below are an excerpt, showing our RIIO-ED1 Asset Replacement and Asset Refurbishment plan for overhead lines.

Asset Replacement Expenditure	RIIO ED 1 Assets Removed	Average Population Removed (% per annum)	RIIO ED 1 Assets Added	RIIO ED 1 Expenditure
132kV OHL (Pole Line) Conductor	**-**	**-**	**42**	**5.5**
132kV Pole	**-**	**-**	**243**	**6.1**
132kV OHL (Tower Line) Conductor	**412**	**5%**	**368**	**28.9**
132kV Fittings	**1524**	**4%**	**1273**	**15.5**
132kV UG Cable (Non Pressurised)*	**-**	**-**	**3.5**	**3.01**
Total	**1936**		**1929.5**	**58.8**

*132kV UG Cable (non pressurised) value only covers 132kV OHL related investment

Asset Refurbishment Expenditure	Average Population Refurbished (% per annum)	RIIO ED 1 Assets Refurbished	RIIO ED 1 Expenditure
132kV Tower	1%	195	8
132kV Tower Painting	3%	755	8.3
132kV Tower Foundation	1%	318	16.2
Total		**1268**	**32.6**

The table below is an excerpt, showing our plan for the 132kV OHL overhead lines in our investment plan.

Section	Construction	Route	Circuit length km	Cost £m
Crewe to Hartford	Single circuit Steel Tower	A Route	17.0	3.88
St.Asaph to Dolgarrog	Double circuit Steel Tower	AC Route	40.6	5.72
Connahs Quay to St. Asaph	Double circuit Steel Tower	AC Route	56.7	7.92
Ellesmere Port to Shell Thornton to Ince	Double circuit Steel Tower	AE Route.	14.3	3.95
Birkenhead to Wallasey	Double circuit Steel Tower	AH & Q	13.9	5.38
Capenhurst to Crane Bank	Double circuit Steel Tower	AJ & EB	19.4	5.17
Legacy to Whitchurch inc Marchweil 'T'	BH Steel Gantry CT mixed Wood/Steel Gantry DF Double Circuit Steel Tower	BH CT & DF	35.3	8.89
Whitchurch to Crewe	BH Steel Gantry DF Double Circuit Steel Tower	BH	20.0	5.67
Bold to Windle	Double circuit Steel Tower	CB & CW	3.2	2.08
Southport to Penwortham	Single circuit Steel Tower	D2	19.3	4.48
Carrington to Warrington	Double circuit Steel Tower	H	25.1	9.21
Crewe to Lostock-Elworth 'T's	Double circuit Steel Tower	HA, EK & AN	29.3	4.63
Barlaston – Crewe	Single Circuit Steel Tower	PK	38.6	8.40
Frodsham - Ince Frodsham – Percival Lane	Double circuit Steel Tower	Q	19.0	3.59
Crewe – Whitfield – Cellarhead	Double circuit Steel Tower (275kV specification)	YS	60.7	12.42
		TOTAL	412.5	91.40

Plans for each line are discussed in more detail in Appendix 2, with an illustration of the categories included in preparing a project cost included in Appendix 6 - Typical OHL Cost Assessment Categories.

The following table shows an extract of our 132kV overhead line asset heat map, covering our RIIO ED1 investment plan

SPM 132kV Overhead Lines													Primary Condition Data					Secondary Condition Data					Asset Health Score		Circuit Info	
Route ID letters	Towers	Route section (low to high nos.)	Route Length (km)	No. of 2cct. towers	No. of 3cct. Towers	No. of 1cct. Towers	No. of 1cct. Poles	Total Circuit section length (km)	ED1 Towers	ED1 poles	ED1 Fittings	ED1 requirement Circuit section length (km)	Foundations	Steelwork	Insulators	Phase Conductor	Specific Issue	Earth Wire	Earth Wire Fittings	Dampers	Signs & Notices	ACDs	Asset Health Score	Score Combining Conductor & E/W	Route ID letters	Notes
BH	BH001R-104	Crewe to Jnc. DF route	20.0	1	-	107	-	20.0	1	106	1	20.0	5	5	4	5	4	5	1	3	3	3	28	23	BH	In ED1 Programme
BH	BH106-220	Jnc. DF route to Legacy	22.3	-	-	121	-	22.3		121	-	22.3	5	5	4	5	4	5	1	4	4	4	28	23	BH	In ED1 Programme
H	H025-073	Carrington to Warrington	12.6	50	-	-	-	12.6	50	-	100	12.6	3	5	4	4	5	4	2	5	4	2	25	21	H	In ED1 Programme
H	H025-073	Carrington to Warrington	-	-	-	-	-	12.6	-	-	-	12.6	3	5	4	4	5	4	2	5	5	3	25	21	H	In ED1 Programme
Q	Q159-162	Birkenhead to Jnc. AH route	0.7		-	-	-	0.7	-	-	-	0.7	3	5	5	3	5	3	5	5	5	1	24	21	Q	In ED1 Programme
CB	CB001-009	Bold to Jnc. C route	2.5	9	-	-	-	2.5	9	-	9	2.5	3	5	3	5	5	5	3	5	2	1	26	21	CB	In ED1 Programme
HA	HA060-086-EK16	Jnc. HA route to Jnc. EK route	8.1	27	-	-	-	8.1	11	-	22	3.8	3	4	5	5	4	5	4	4	2	4	26	21	HA	In ED1 Programme
HA	HA060-086-EK16	Jnc. HA route to Jnc. EK route	-	-	-	-	-	8.1	-	-	-	3.8	3	4	5	5	4	5	4	4	2	4	26	21	HA	In ED1 Programme
HA	HA088(EK16)-106A	Jnc. EK route to Jnc. AN route	-	-	-	-	-	6.1	-	-	-	5.8	3	4	5	5	4	5	4	4	2	4	26	21	HA	In ED1 Programme
HA	HA088(EK16)-106R	Jnc. EK route to Jnc. AN route	6.1	18	-	-	-	6.1	18	-	36	5.8	3	4	5	5	4	5	4	4	2	4	26	21	HA	In ED1 Programme
HA	HA106A	Jnc. AN route	-	-	-	1	-	-	1	-	1	-	3	4	5	5	4	5	4	4	2	4	26	21	HA	In ED1 Programme
HA	HA106A-139	Jnc. AN route to Crewe	8.8	35	-	-	-	8.8	8	-	16	2.7	3	4	5	5	4	5	4	4	2	4	26	21	HA	In ED1 Programme
HA	HA106R-139	Jnc. AN route to Crewe	-	-	-	-	-	8.8	-	-	-	2.7	3	4	5	5	4	5	4	4	2	4	26	21	HA	In ED1 Programme
Q	Q159-162	Birkenhead to Jnc. AH route	0.7	4	-	-	-	0.7	-	-	-	0.7	3	5	5	3	5	3	5	5	5	1	24	21	Q	In ED1 Programme
A	A069-131	Hartford to Crewe	17.0	-	-	65	-	17.0	65	-	65	17.0	4	5	3	3	5	3	5	3	5	2	23	20	A	In ED1 Programme
YS	YS0074-102	Whitfield to Cellarhead	9.3	-	-	-	-	-	-	-	-	9.3	3	3	5	4	5	4	5	5	4	3	24	20	YS	In ED1 Programme
YS	YS0074-102	Whitfield to Cellarhead		-	-	-	-	9.3	-	-	28	-	3	3	5	4	5	3	5	5	4	3	23	20	YS	In ED1 Programme
YS	YS071A	Whitfield	-	1	-	-	-	-	1	-	1	-	3	3	5	4	5	4	5	5	4	3	24	20	YS	In ED1 Programme
YS	YS072-074	Whitfield	1.0	3	-	-	-	1.0	3	-	3	1.0	3	3	5	4	5	4	5	5	4	3	24	20	YS	In ED1 Programme
AC	AC006-054	Connahs Quay to Jnc. AC route	13.8	50	-	-	-	13.8	50	-	100	13.8	3	4	5	5	2	5	4	5	3	3	24	19	AC	In ED1 Programme
AC	AC006-054	Connahs Quay to Jnc. AC route	-	-	-	-	-	13.8	-	-	-	13.8	3	4	5	5	2	5	4	5	3	3	24	19	AC	In ED1 Programme
AE	AE19R-20R	Shell Thornton to Ince	0.6	3	-	-	-	0.6	3	-	6	0.6	3	2	5	4	5	3	5	5	5	1	22	19	AE	In ED1 Programme
AE	AE19R-20R	Shell Thornton to Ince	-	-	-	-	-	0.6	-	-	-	0.6	3	2	5	4	5	3	5	5	5	1	22	19	AE	In ED1 Programme
AE	AE21R-26	Shell Thornton to Ince	1.4	6	-	-	-	1.4	6	-	12	1.4	3	2	5	4	5	3	5	5	5	1	22	19	AE	In ED1 Programme
AE	AE21R-26	Shell Thornton to Ince	-	-	-	-	-	1.4	-	-	-	1.4	3	2	5	4	5	3	5	5	5	1	22	19	AE	In ED1 Programme
AH	AH001-025	Jnc. Q route to Wallasay	6.2	27	-	-	-	6.2	27	-	54	6.2	3	5	5	5	1	5	5	5	3	3	24	19	AH	In ED1 Programme
AH	AH001-025	Jnc. Q route to Wallasay	-	-	-	-	-	6.2	-	-	-	6.2	3	5	5	5	1	5	5	5	3	3	24	19	AH	In ED1 Programme
AJ	AJ020-039	Capenhurst to Jnc. AB route	6.5	23	-	1	-	6.5	24	-	47	6.5	3	2	5	5	4	5	5	5	5	3	24	19	AJ	In ED1 Programme
AJ	AJ020-039	Capenhurst to Jnc. AB route	-	-	-	1	-	6.5	1	-	1	6.5	3	2	5	5	4	5	5	5	5	3	24	19	AJ	In ED1 Programme
DF	DF001-018	Jnc. BH route to Whitechurch	4.2	18	-	-	-	4.2	18	-	36	4.2	3	5	4	4	3	4	4	3	3	3	23	19	DF	In ED1 Programme
DF	DF001-018	Jnc. BH route to Whitechurch	-	-	-	-	-	4.2		-	-	4.2	3	5	4	4	3	4	4	3	3	3	23	19	DF	In ED1 Programme
YS	YS001-071	Crewe to Whitfield	25.2	73	-	-	-	25.2	73	-	146	25.2	3	2	5	4	5	4	5	5	4	3	23	19	YS	In ED1 Programme
YS	YS001-071	Crewe to Whitfield	-	-	-	-	-	25.2	-	-	-	25.2	3	2	5	4	5	3	5	5	4	3	22	19	YS	In ED1 Programme
CW	CW001-003	Windle to Jnc. C route	0.7	3	-	-	-	0.7	3	-	3	0.7	3	5	5	4	1	2	5	5	5	2	20	18	CW	In ED1 Programme
Q	Q001-017A	Percival Lane to Frodsham	3.7	18	-	-	-	3.7	18	-	36	3.7	3	5	5	3	1	3	3	5	5	2	20	17	Q	In ED1 Programme
Q	Q001-017A	Percival Lane to Frodsham	-	-	-	-	-	3.7	-	-	-	3.7	3	5	5	3	1	3	3	5	5	2	20	17	Q	In ED1 Programme
Q	Q018A-033	Frodsham to Ince	4.6	16	-	-	-	4.6	16	-	32	4.6	3	5	5	3	1	3	1	1	3	1	20	17	Q	In ED1 Programme
Q	Q018A-033	Frodsham to Ince	-	-	-	-	-	4.6	-	-	-	4.6	3	5	5	3	1	3	1	1	3	1	20	17	Q	In ED1 Programme

The full ED1 OHL heat map is available in Appendix 7

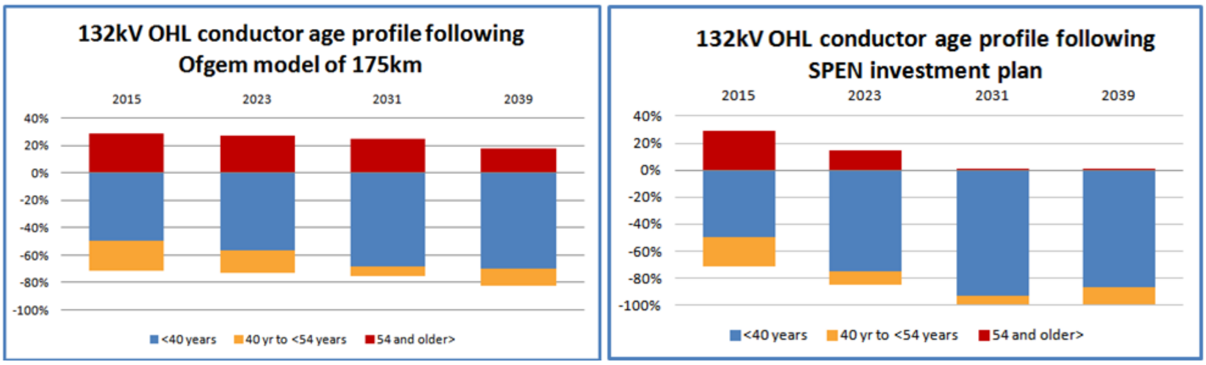
8. Overhead Line Modelling and Cost Benefit Analysis

8.1. Age Based Modelling Output

The age based modelling methodology provides a view of future replacement requirements. Our asset replacement programme for overhead lines is driven by conductor replacement and therefore our modelling is focussed on this area. Using the Ofgem model with SPM asset lives indicates that 175km of 132kV conductor should be replaced in RIIO-ED1. This perpetuates the current asset age of our 132kV infrastructure and does not reduce the current risk to safety or reliability.

SPENs view for RIIO-EDI targets 412.5km of 132kV conductor replacement with a further 257km in RIIO ED2 . This value is significantly above the Ofgem view but takes into account the age profile of SPM 132kV overhead assets, and economics of asset replacement described in 3.1 above, together with output of the Woodhouse APT toolset used as part of our optimal asset management decision making process to address the issue of ageing conductor. Figure 9 below compares the two strategies

Figure 9: Compares Ofgem and SPEN investment profiles on 132kV conductor age management



In 2013 where we experienced conductor and tower fittings on assets contained within our D5 and ED1 plan, this practical experience supports our view that increased investment is required to reduce the current risk to more acceptable levels. Ofgems view of 175km is broadly similar to that approved in our DPRC5 submission which implemented would not deliver the level of moderisation required commensurate with our asset age profile and modelling

Our investment plan is based on reducing the age of our oldest assets and improving safety and reliability, deferring circa 250km of conductor replacement from our ED1 plan into ED2 as Ofgem suggests will have the opposite effect by increasing the age of our oldest assets.

Outwith the concerns raised above, delays in implementing our investment plan will increase the cost of undertaking the work in later price review periods as the most economic method of replacement, tension pulling in some cases will be ruled out and a more expensive option of catenary block or dismantle and re-erect will be required.

8.2. Cost Benefit Analysis – OHL

SPEN utilise the Woodhouse APT toolset as part of our optimal asset management decision making process. This model allows us to visualise and consider the Total Business Impact (£) through considering a range of factors. For the overhead line conductor example (graph below) the following factors (curves) have been established in the model

- *Patch and Continue – These are the costs of failures of the conductor (direct repair costs and IIS regulatory penalties)*
- *Smooth Cash flow – This is the increasing costs we're going to have to pay to replace the conductor because the old asset is becoming difficult to handle (Tension -> Cradle blocks -> Dropping) comparison*
- *PV life cycle – This is the money you need to set aside today to replace the asset in future (assuming tension stringing). Add the smooth cash flow in this example to give the total PV because the costs are increasing if you delay the replacement.*

For the example shown below, for Lynx 175mm^2 ACSR conductor, we have modelled a conductor at 50 years old (50 yrs old = year zero), and considered the following factors, based on generic evaluation of risk and impact

APT Model – OHL conductor	**No constraints**
Failure rates (Conductor breaking)	0.0012 pa (new) 0.0024 pa (60yrs) 0.0096 pa (70yrs)
Direct Cost of failure (conductor repair) Taking account of typical topology of SPEN 132kV overhead lines across a mixture of farm land and encroaching on urban conurbations	Assume 80% of failures over farm land at £10.5k 10% have more difficulty and cost £26.25 10% cost even more at £36.75k Secondary damage to property etc 80% no damage 10% minor damage at £5.6k 10% significant damage and insurance claims at £110k
IIS Penalties	Assume : 90% at nil Penalty 5% at £560k – 35k customers for 1 hr 3% at £1.12m – 70K customers for 1 hr 2% at £2.41m – 150k customers for 2 hrs
Smooth cash flow	By year 65, the replacement cost for the asset has gone up by £12.5k per km. By year 75, the replacement cost for the asset has gone up by £25k per km.

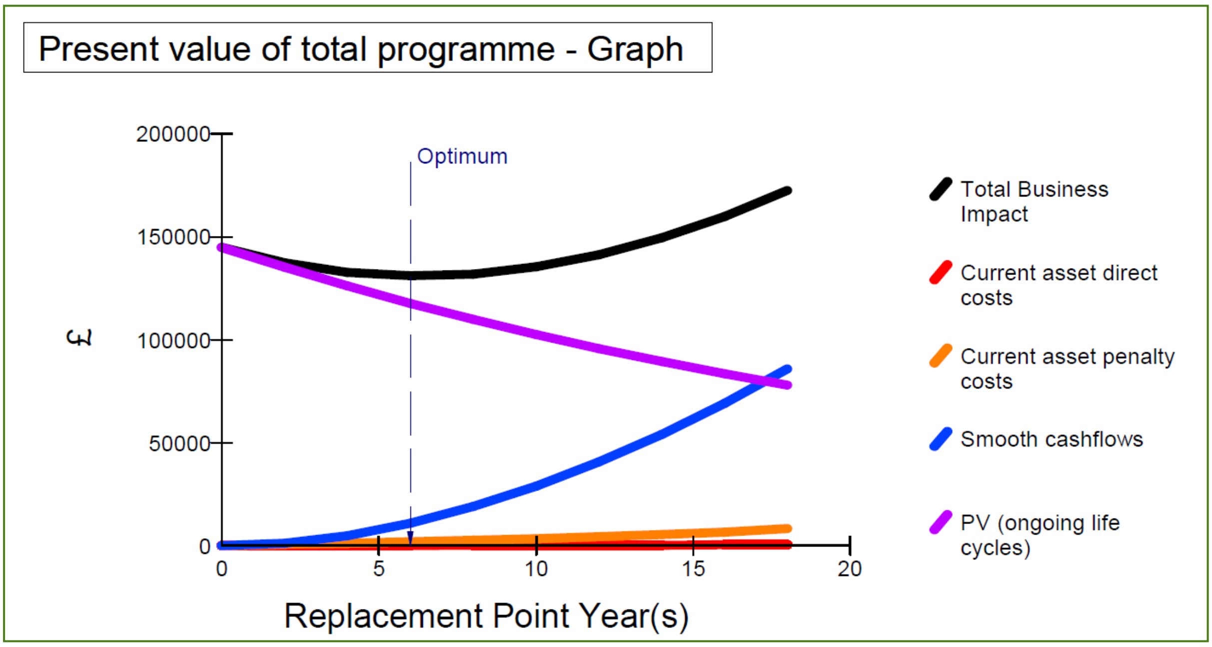
The curve descriptions are:

- *Total Business Impact – Sum of the other curves*
- *Patch and Continue – These are the cost of failures of the conductor (direct repair costs and IIS penalties)*
- *Smooth Cash flow – This is the increasing costs we're going to have to pay to replace the conductor because the old asset is becoming difficult to handle (Tension -> Cradle blocks -> Dropping)*

- *PV life cycle – This is the money that needs to be set aside today to replace the asset in future (assuming tension stringing). Add the smooth cash flow in this example to give the total PV because the costs are increasing if you delay the replacement.*

The optimum replacement time, as shown on the graph in Figure 10 below is at 56 years (50yrs +6yrs) when the lowest overall business impact is shown in terms of both direct and penalty costs.

Fig 10: Lynx ACSR Conductor: Optimal Replacement at 56 years (50 yrs old =Year 0)



This entirely aligns with our investment plans for OHL conductor, as our strategy is to replace Lynx (175mm ACSR) conductor whilst it can be successfully tension strung, to minimise costs and outage durations.

The APT Toolset is explained in greater detail in Appendix 3.

9. Appendix 1 – Related Documents

This appendix describes the related documents which have been used to develop the RIIO ED1 Business Plan. They form part of our suite of internal Asset Management Documents.

9.1. Integrated Management System

Overview of our Integrated Management System in compliance with PASS55

IMS-01-002 SP Energy Networks Integrated Management System Manual

9.2. Asset Management Strategies and Policies

Asset Management strategies and policies are as detailed below:

ASSET-01-019 Asset Health Methodology

ASSET-01-021 Asset Inspection and Condition Assessment Policy

OHL-01-012(d) Refurbishment Policy for overhead lines supported on Broad based lattice steel Towers.

OHL-01-014(d) 132-400kV Overhead Line Investment Policy

10. Appendix 2 – OHL Project Details

This appendix provides further details of each of the overhead line circuits listed below and targeted for investment in ED1, it includes details of the

- *An outline of the circuit role*
- *Asset Health drivers for each circuit, both prior to and post intervention*
- *A description of the history of intervention on each circuit*
- *A description of the scope of the work planned for each circuit during RIIO-ED1*
- *(costs can be referred back to table in section 7 above)*

A Route. Hartford to Crewe 132kV Overhead Tower Line Modernisation

This route forms an integral part of the Mid Cheshire 132kV interconnected network, connecting Fiddlers Ferry 132kV GSP to Crewe 132kV substation, with BSP's connected at Hartford and Winsford. This section of the A route was originally constructed in 1933, and has a circuit length of approximately 17.01km. In 1974 and the circuit was partly re-conductored, and re-insulated. Fibre optic wrap was installed on the earth wire in the 1980's to develop the SPM corporate data infrastructure. During DPCR5, the earth wire and fibre wrap will be replaced with OPGW.

The route has been identified for modernisation in RIIO ED1 period due to age and condition. The earth wire fittings and signage are at or approaching end of life and elements of the tower steelwork is in very poor condition. In addition, the phase conductors and foundations are in poor condition. Signing, guarding and painting are due for completion in DPCR5. The Asset Health indices for this route are as follows:

Foundations	4	Earth Wire	3
Steelwork	5	Earth Wire Fittings	5
Insulators	3	Dampers	3
Phase Conductors	3	Signs & Notices	5
Specific Issues	5	ACDs	2

The ED1 plan for this route is 'Full Refurbishment' of the Hartford to Crewe 132kV tower line (A Route), towers A069 – A131. This shall include the replacement of all phase conductors, fittings, insulators, earth wire with integral fibre optics (OPGW), and vibration dampers. In addition tower steelwork will be replaced as required, all towers will be painted, and the foundations shall be inspected and assessed; all foundation issues shall be rectified.

The work will be co-ordinated for efficient delivery with our non load asset modernisation plans at Crewe 132kV substation, and load related investment plans in the Lostock area.

Total expenditure on this section of the A route: £3.88 million

A Route Towers A032 to A066 were refurbished in 1996 and are not considered in the scope of our ED1 plan.

AC Route. Connahs Quay to St Asaph and St Asaph to Dolgarrog 132kV Overhead Tower Line Modernisation

This route forms an integral part of the North Wales coast 132kV interconnected network, connecting Connahs Quay GSP to Pentir GSP, with BSP's connected at along its entire length at Holywell, St Asaph, Colwyn Bay, and Dolgarrog. The remaining sections of this Route (AC & AD route) between Dolgarrog and Pentir have been modernised during 2008 and 2013. This section of the AC route was originally constructed in 1952 with minor modification in 1963 and 1969. The line was modified again in 2007 to accommodate the connection of the off shore wind farm at Kimnel Bay. This section of the AC route has a circuit length of approximately 97.29km.

In 1997 towers AC183 and AC184 were re-conductored. The remaining towers were last painted in 1985. Limited steelwork replacement was carried out in 2007and conductors between towers AC101B-121R were replaced with Poplar conductor as the route was adapted to accommodate the increased export loading from the off-shore wind farm development near Kimnel Bay.

The route has been identified for modernisation in the RIIO ED1 period due to age and condition, indeed during the Easter Snow Storm in 2013, two conductor failures were experienced due to conductor failure close to the Connahs Quay end of the circuit (a further two failures were experienced on the section of AD route, modernised during the summer of 2013). The insulators, phase conductors, earth wire and dampers are at or approaching end of life. In addition, elements of the tower steelwork and earth wire fittings are in poor condition. The Asset Health indices for this route are as follows:

Foundations	3	Earth Wire	5
Steelwork	4	Earth Wire Fittings	4
Insulators	5	Dampers	5
Phase Conductors	5	Signs & Notices	3
Specific Issues	2	ACDs	3

The ED1 plan for this route is 'Full Refurbishment' of the Connahs Quay to St Asaph, and St Asaph to Dolgarrog 132kV tower line (AC Route), towers AC006 – AC101 & AC121 - AC193. This shall include the replacement of all phase conductors, fittings, insulators, earth wire with integral fibre optics (OPGW), and vibration dampers. In addition tower steelwork will be replaced as required, all towers will be painted, and the foundations shall be inspected and assessed; all foundation issues shall be rectified.

Total expenditure on this section of the AC route: £13.64 million.

(£5.72+ £7.92m from table in Section 7)

AE Route. Ellesmere Port to Shell Thornton to Ince 132kV Overhead Tower Line Modernisation

This circuit forms the 132kV connection between Ince and Ellesmere Port, and supplies much of the chemical and petro-chemical industry along the south east side of the river Mersey. The 132kV substation at Ince was replaced in 2003, and the substation at Ellesmere Port will be modernised in 2013/2014. The Route was originally constructed in 1954, and modified in 1983 as an upgrade to Shell UK's connection and has a circuit length of approximately 14.26 km.

Selected insulators were replaced along the route in 1993 and the towers were last painted in 2012 in preparation for conductor and fitting replacement in ED1

The route has been identified for modernisation in RIIO ED1 period due to age and condition, indeed during the Easter Snow Storm on 2013, a conductor was grounded due to the failure of a mid-span joint. The insulators, earth wire fittings, dampers and signage are at or approaching end of life. The Asset Health indices for this route are as follows:

Foundations	3	Earth Wire	3
Steelwork	2	Earth Wire Fittings	5
Insulators	5	Dampers	5
Phase Conductors	3	Signs & Notices	5
Specific Issues	5	ACDs	1

The ED1 plan for this route is 'Full Refurbishment' of the Ince to Shell Thornton to Ellesmere Port 132kV tower line (AE Route), towers AE001A – AE026. This shall include the replacement of all phase conductors, fittings, insulators, earth wire with integral fibre optics (OPGW), and vibration dampers. In addition, the foundations shall be inspected and assessed; all foundation issues shall be rectified.

Total expenditure on this section of the A route: £3.96 million

AH Route and Q Route between Birkenhead and Wallasey 132kV Overhead Tower Line Modernisation

This route forms two transformer feeder circuits between Birkenhead GSP and Wallasey Grid substation, providing supplies to the urban conurbations in the North West of the Wirral peninsula. This route also provides connection of the Off-shore wind farm at Burbo Bank. The AH Route was constructed in 1953, has a circuit length of approximately 6.24 km and has not been the subject of major refurbishment or modernisation. The Q Route was constructed in 1939, has a circuit length of 1.4 km and was re-conductored in 1978.

The route has been identified for modernisation in RIIO ED1 period due to age and condition. The phase conductors, phase conductor fittings, earth wire, earth wire fittings, insulators and dampers are at or approaching end of life and elements of the tower steelwork are in very poor condition. The Asset Health indices for this route are as follows:

AH route

Foundations	3	Earth Wire	5
Steelwork	5	Earth Wire Fittings	5
Insulators	5	Dampers	5
Phase Conductors	5	Signs & Notices	3
Specific Issues	1	ACDs	3

Q Route

Foundations	3	Earth Wire	3
Steelwork	5	Earth Wire Fittings	5
Insulators	5	Dampers	5
Phase Conductors	3	Signs & Notices	5
Specific Issues	5	ACDs	1

The ED1 plan for this route is 'Full Refurbishment' of the Birkenhead to Wallasey 132kV tower line (AH and Q Route), towers AH001 – AH025 and replacement of the Q line section towers Q159 to Q162 with a section of underground cable due to access and deliverability issues. This shall include the replacement of all phase conductors, fittings, insulators, earth wire with integral fibre optics (OPGW), and vibration dampers. In addition tower steelwork will be replaced as required, all towers will be painted, and the foundations shall be inspected and assessed; all foundation issues shall be rectified.

The route will form part of the Birkenhead Reinforcement scheme in our load related investment plan, the work will be co-ordinated with our non-load modernisation of the Birkenhead GSP investment plan to ensure efficient expenditure and reduced risk to our customer supplies.

Total expenditure on this section of the Q and AH route: £5.38 million

Q Route. Frodsham to Ince & Frodsham to Percival Lane 132kV Overhead Tower Line Modernisation

This route being one of the oldest 132kV routes in SPM originally constructed in 1931 and 1939, forms part of the interconnected network between Frodsham GSP and Ince 132kV substation, which supplies the major chemical and petrochemical sites along the south east side of the river Mersey. It also provides a supply to our BSP at Percival Lane supporting the Runcorn network, and provides an export route for 49MW CHP plant at Salt Union. The Route has a combined circuit length of approximately 19.03 km

The Route has been subject to targeted refurbishment over its lifespan. Towers Q018A – Q033 were re-conductored in 1980 and last painted in 2003.

This route has been identified for modernisation in the RIIO ED1 period due to age and condition. The phase conductors, insulators, earth wire and earth wire fittings, dampers and signage are at or approaching end of life and elements of the tower steelwork are in very poor condition. The Asset Health indices for this route are as follows:

Foundations	3	Earth Wire	3/5
Steelwork	5	Earth Wire Fittings	5
Insulators	5	Dampers	5
Phase Conductors	3/5	Signs & Notices	5
Specific Issues	5	ACDs	1

The ED1 plan for this route is 'Full Refurbishment' of the Frodsham to Ince 132kV tower line towers Q018A – Q033 and the Frodsham to Percival Lane 132kV tower line, towers Q001 to Q17A. This shall include the replacement of all phase conductors, fittings, insulators, earth wire with integral fibre optics (OPGW), and vibration dampers. In addition tower steelwork will be replaced as required, all towers will be painted, and the foundations shall be inspected and assessed; all foundation issues shall be rectified.

Total expenditure on this section of the Q route: £3.59 million.

AJ Route & EB route forming the Capenhurst to Crane Bank 132kV Overhead Tower Line Modernisation

This route forms a single transformer feeder circuit between Capenhurst GSP and Crane Bank BSP in Chester, supplying the commercial centre and major banking centres based in Chester along with the domestic population. This was part constructed in 1958 and was extended in 1976, as the feeding arrangements of Crane Bank was modified. The Route has a combined circuit length of approximately 9.72 km

All towers on the AB section were last painted in 2010. There has been no major refurbishment or modernisation on the EB route other than tower painting. Fibre optic wrap was installed on the earth wire in the 1980's to develop the SPM corporate data infrastructure.

This route has been identified for modernisation in the RIIO ED1 period due to age and condition The insulators, phase conductors, earth wire, earth wire fittings, dampers and signage are at or approaching end of life. In addition, elements of the tower steelwork on the EB line are in poor condition. The Asset Health indices for this route are as follows:

AB route

Foundations	3	Earth Wire	5
Steelwork	2	Earth Wire Fittings	5
Insulators	5	Dampers	5
Phase Conductors	5	Signs & Notices	5
Specific Issues	4	ACDs	3

EJ route

Foundations	3	Earth Wire	3
Steelwork	4	Earth Wire Fittings	5
Insulators	5	Dampers	3
Phase Conductors	3	Signs & Notices	3
Specific Issues	2	ACDs	2

The ED1 plan for this route is 'Full Refurbishment' of the AJ and EB route between Capenhurst and Crane Bank towers AJ020 – AJ039 and EB001 – EB012. This shall include the replacement of all conductors, conductor fittings, insulators; earth wire will be replaced with integral fibre optics (OPGW), vibration dampers, anti-climbing devices and all signage.

In addition tower steelwork will be replaced as required, towers will be painted where required, and the foundations shall be inspected and assessed; all foundation issues shall be rectified.

Total expenditure on this section of the AJ and EB route: £5.17 million

BH Route. Crewe to Legacy 132kV Overhead Line Rebuild and Modernisation of the DF double circuit route to Whitchurch and Modernisation CT Route to Marchwiel 132kV substations

The BH route provides the strategically important interconnector between Legacy GSP and Crewe 132kV substations. The BH route was built in 1956 and is now run split for load flow control but provides contingency for Engineering Recommendation P2/6 compliance. The route was modified to provide supply to SPM BSP's at Marchwiel and Whitchurch in 1963 and 1964 respectively. This combined route has a circuit length of 55.29km.

The earth wire fittings were replaced on the BH route in 2007, steelwork has been routinely painted and 12 poles have been replaced on the CT route in 1992.

This route has been identified for modernisation in the RIIO ED1 period due to age and condition. The foundations on the steel gantries on the BH and CT routes have been identified as substandard making the steel gantries also at or approaching end of life. The phase conductors, earth wire and earth wire fittings are in poor condition. The Asset Health indices for this route are as follows:

BH Route

Foundations	5	Earth Wire	5
Steelwork	3	Earth Wire Fittings	1
Insulators	4	Dampers	4
Phase Conductors	5	Signs & Notices	4
Specific Issues	4	ACDs	4

DF Route

Foundations	3	Earth Wire	4
Steelwork	5	Earth Wire Fittings	4
Insulators	4	Dampers	3
Phase Conductors	4	Signs & Notices	3
Specific Issues	3	ACDs	3

CT Route

Foundations	5	Earth Wire	N/A
Steelwork	3	Earth Wire Fittings	N/A
Insulators	3	Dampers	4
Phase Conductors	5	Signs & Notices	4
Specific Issues	1	ACDs	2

The ED1 plan for this route is ‘Asset Replacement’ of the BH line, towers BH001R – BH104 & BH106 – BH220, and the CT line poles/towers CT001 – CT026, with ‘Full Refurbishment’ of the DF line towers DF001 – DF018. The BH line and CT routes will be rebuilt using wood pole design specification, with underground sections to meet planning consent.

The DF route modernisation shall be the replacement of all conductors, conductor fittings, insulators, anti-climbing devices and all signage, tower steel work will be painted. The earth wire will be replaced with an equivalent conductor with integral fibre optics (OPGW). In addition tower steelwork will be replaced as required, all towers will be painted, and the foundations shall be inspected and assessed; all foundation issues shall be rectified.

Total expenditure on the BH, CT and DF route: £14.56 million

(£8.89 + 5.67m from table in Section 7)

CB Route. Bold to Junction C Line 132kV Overhead Tower Line Modernisation & CW Line: Windle – Junction C Line

The CB route up to the junction with the C Route forms a single transformer feeder circuit between Bold 132kV substation and Kirkby, providing supply to the large commercial and domestic sectors in and around the Kirkby, Merseyside. The original route also provided supply into the adjacent DNO (ENWL) which has now been decommissioned, and indeed the towers are subject to asset transfer from ENWL to SPM before the end of DPCR5. The CB Route was originally constructed in 1958, has a circuit length of approximately 2.49km.

The CW route was developed from the C route in 1970 to allow the connection of Windle Grid transformer which feeds the glass industry, commercial centres and domestic customer supplies in and around St Helens Merseyside. The route has not been subject to any major refurbishment and has a circuit length of 0.71 km

This route has been identified for modernisation in the RIIO ED1 period due to age and condition. The phase conductors, earth wire and dampers are at or approaching end of life. Elements of the tower steelwork are in very poor condition. The Asset Health indices for this route are as follows:

CB Route

Foundations	3	Earth Wire	5
Steelwork	5	Earth Wire Fittings	3
Insulators	3	Dampers	5
Phase Conductors	5	Signs & Notices	2
Specific Issues	5	ACDs	1

CW Route

Foundations	3	Earth Wire	2
Steelwork	5	Earth Wire Fittings	5
Insulators	5	Dampers	5
Phase Conductors	4	Signs & Notices	5
Specific Issues	1	ACDs	2

The ED1 plan for this route is ‘Full Refurbishment’ of the CB line, towers CB001 to CB009 and CW line towers CW 001 to CW003 This shall include the replacement of all conductors, conductor fittings, insulators, anti-climbing devices and all signage. Earth Wire will be replaced with an equivalent conductor with integral fibre optics (OPGW). In addition tower steelwork will be replaced as required, all towers will be painted, and the foundations shall be inspected and assessed; all foundation issues shall be rectified.

Total expenditure on the CB and CW route: £2.08 million

The C line which also forms part of this route is out of scope in RIIO ED1 having undergone modernisation in 1992 and 2004.

D2 Route. Southport to Penwortham 132kV Overhead Tower Line Modernisation

The D2 route forms part of the strategically important interconnector between Kirkby GSP and ENWL's GSP at Penwortham. Specifically the D2 route is the Penwortham to Southport section and also supplies two Grid Transformers at Southport, providing supply to the industrial/commercial/leisure and domestic sectors in and around Southport. The Route was constructed in 1933 and has a circuit length of approximately 19.31 km.

In the mid 1980's the tower steelwork was replaced and in 2006, the insulators, earth wire fittings and dampers were replaced. The route was part re-conductored in 1955.

This route has been identified for modernisation in the RIIO ED1 period due to age and condition. The phase conductors and the earth wire are at or approaching end of life. In addition, the steelwork whilst replaced in the 1980's requires significant attention. The Asset Health indices for this route are as follows:

Foundations	3	Earth Wire	5
Steelwork	4	Earth Wire Fittings	3
Insulators	1	Dampers	3
Phase Conductors	5	Signs & Notices	1
Specific Issues	1	ACDs	1

The ED1 plan for this route is 'Full Refurbishment' of the Southport to Penwortham 132kV tower line (D2 Route), towers D2 001 – D2 070A. This shall include the replacement of all conductors, conductor fittings, insulators, anti-climbing devices and all signage. Earth Wire will be replaced with an equivalent conductor with integral fibre optics (OPGW). In addition tower steelwork will be replaced as required, all towers will be painted, and the foundations shall be inspected and assessed; all foundation issues shall be rectified.

The project will be co-ordinated with the Non load replacement of Southport Grid Transformers to reduce network risk and has been discussed with ENWL as part of ED1 stakeholder engagement.

Total expenditure on the D2 route: £4.48 million

H Route. Carrington to Warrington 132kV Overhead Tower Line Modernisation

The H route forms part of the strategically important interconnector between Carrington GSP and Fiddlers Ferry GSP, specifically the H Route forms the Carrington to Warrington section interconnector and provides supplies into the chemical industry, commercial and domestic sectors in Warrington. The Route was constructed in 1933 and has a circuit length of approximately 12.55 km.

This route was reinsulated in 1973. In 1996 it was part re-conductored and towers H025 to H042 were refurbished.

This route has been identified for modernisation in the RIIO ED1 period due to age and condition the dampers and signage are in poor condition and elements of the tower steelwork are in very poor condition. In addition, the insulators, phase conductors and earth wire are in poor condition. The Asset Health indices for this route are as follows:

Foundations	3	Earth Wire	4
Steelwork	5	Earth Wire Fittings	2
Insulators	4	Dampers	5
Phase Conductors	4	Signs & Notices	5
Specific Issues	5	ACDs	3

The ED1 plan for this route is 'Full Refurbishment' of the Carrington to Warrington 132kV tower line (H Route), towers H025 – H073. This shall include the replacement of all conductors, conductor fittings, insulators, anti-climbing devices and all signage. Earth Wire will be replaced with an equivalent conductor with integral fibre optics (OPGW). In addition due to condition significant tower steelwork is required to be replaced (including complete tower ort tower tops at some locations), all towers will be painted, and the foundations shall be inspected and assessed; all foundation issues shall be rectified.

The route will form part of the Warrington Reinforcement scheme in our load related investment plan, the work will be co-ordinated to ensure efficient expenditure and reduced risk to our customer supplies.

Total expenditure on the H route: £9.21 million

HA route junction with AN/EK Lines and Crewe132kV Overhead Tower Line Modernisation

The HA route forms part of the strategically important interconnector between Carrington GSP and Crewe 132kV substation, it also provides supply to Knutsford, Lostock, ICI Wade and Elworth BSP's along the route, serving industrial, commercial and domestic sectors. In addition the route provides generation export routes at BM Winnington and Elworth. This section of the route was originally constructed in 1951, modified in 1963, 1969 & 1971, and has a circuit length of approximately 29.9 km.

The route was reinsulated in 1983 and has had ad-hoc insulator replacement since that time due to pollutants in the area. This HA route has been identified for modernisation due to age and condition, with the majority of the HA& AN route modernised with the SPEN DPRC5 programme, and this last remaining section will complete the modernisation of the route.

The conductors, insulators and earth wire are at or approaching end of life and elements of the tower steelwork are in poor condition. In addition, the earth wire fittings, dampers and ACD's are in poor condition. The Asset Health indices for this route are as follows:

Foundations	3	Earth Wire	5
Steelwork	4	Earth Wire Fittings	4
Insulators	5	Dampers	5
Phase Conductors	5	Signs & Notices	2
Specific Issues	4	ACDs	5

The ED1 plan for this route is 'Full Refurbishment' of this section of the HA 132kV tower line towers HA075 - HA115, HA 088 t- EK 1, EK 008 - EK016, HA106R - AN2. This shall include the replacement of all conductors, conductor fittings, insulators, anti-climbing devices and all signage. In addition tower steelwork will be replaced as required, all towers will be painted, and the foundations shall be inspected and assessed; all foundation issues shall be rectified.

This completes the modernisation work commenced in DPRC5 on the entire HA/AN/EK route. This section deferred to EDI due to network access and specific engineering reasons in relation work on and around tower EK16

Total expenditure on the HA/EK/AN route: £4.63 million

PK Route. Crewe to Barlaston to Radway Green 132kV Overhead Tower Line Modernisation

The PK route forms part of the strategically important interconnector between Crewe 132kV substation and the Western Power Distribution (WPD) GSP at Barlaston. The route also provides supply to the Radway Green BSP providing supply to the rail, industrial, ordinance commercial and domestic sectors in and around Crewe. The route was originally constructed in 1933 and modified in 1955 and has a circuit length of approximately 38.64 km.

The initial section of the route from Barlaston (originally Meaford) is constructed from double circuit towers and shares a WPD circuit, before continuing as single circuit construction to Crewe. Towers PK3 to PK35, together with associated earth wire and fittings are owned and operated by WPD.

Towers PK090 – PK127 were re-conductored in 1978. Towers PK036 – PK143 were painted in 2007.

This route has been identified for modernisation in the RIIO ED1 period due to age and condition, the phase conductors, earth wire, earth wire fittings and dampers are at or approaching end of life. The insulators, signage and ACDs are in poor condition. The Asset Health indices for this route are as follows:

Foundations	3	Earth Wire	5
Steelwork	2	Earth Wire Fittings	5
Insulators	4	Dampers	5
Phase Conductors	5	Signs & Notices	4
Specific Issues	1	ACDs	4

The ED1 plan for this route is ‘Full Refurbishment’ of the SPM owned assets on the PK line between towers PK003 – PK143R This shall include the replacement all conductors, conductor fittings, insulators, anti-climbing devices and all signage. In addition tower steelwork will be replaced as required, all towers will be painted, and the foundations shall be inspected and assessed; all foundation issues shall be rectified. Earth Wire will be replaced with an equivalent conductor with integral fibre optics (OPGW) between PK 143R and PK099/DG031, consideration should be given to extending this to Barlaston if agreement can be reached with WPD. In addition on towers PK035 to PK143R tower steelwork will be replaced as required, all towers will be painted, and the foundations shall be inspected and assessed; all foundation issues shall be rectified.

Work on the PK line will be co-ordinated with Crewe 132kV substation, and BH l132kC overhead line non load related modernisation to ensure efficient expenditure and minimise network risk

This project and associated network outages have been discussed with WPD and NGC as part of ED1 stakeholder engagement.

Total expenditure on the PK route: £8.4 million

YS Route. Crewe to Whitfield to Cellarhead 132kV Overhead Tower Line Modernisation

The YS route forms part of the strategically important interconnectors between Crewe 132kV substation and WPD’s GSP Cellarhead and Whitfield 132kV substation. The route also provides supply to the Coppenhall and Radway Green BSP’s providing supply to the rail, industrial, ordinance, commercial and domestic sectors in and around Crewe. The route was originally constructed in 1962 to 275kV towers design with twin conductor specification as the original intention at the time was to develop a GSP at Crewe.

SPM own and operate one complete circuit from Cellarhead to Crewe and a second circuit on the Whitfield to Crewe section only. WPD own and operate the towers and earth wire between Cellarhead and Whitfield and operate a circuit on that section of the route.

The SPM section of the YS line has a circuit length of 60.63km

Towers YS001 – YS071 were painted in 2005/06. This Route has been identified for modernisation in the RIIO ED1 period due to age and condition. The insulators, earth wire fittings and dampers are at or approaching end of life. In addition, the phase conductors, earth wire and the signage are in poor condition. The Asset Health indices for this route are as follows:

Foundations	3	Earth Wire	4
Steelwork	2	Earth Wire Fittings	5
Insulators	5	Dampers	5
Phase Conductors	4	Signs & Notices	4
Specific Issues	5	ACDs	3

The ED1 plan for this route is 'Full Refurbishment' of the SPM owned assets on the YS line between towers YS001 and YS102 to the existing 275kV specification and therefore increased costs over that of lines constructed to 132kV specification.

This shall include the replacement of all conductors, conductor fittings, insulators, anti-climbing devices and all signage. In addition tower steelwork will be replaced as required, all towers will be painted, and the foundations shall be inspected and assessed; all foundation issues shall be rectified. Earth Wire will be replaced with an equivalent conductor with integral fibre optics (OPGW) between YS001 at Crewe and YS071 at Whitfield, consideration should be given to extending this to Cellarhead if agreement can be reached with WPD. In addition on towers YS001 to YS073 tower steelwork will be replaced as required, all towers will be painted, and the foundations shall be inspected and assessed; all foundation issues shall be rectified.

Work on the YS line will be completed ahead of the Crewe 132kV substation non load related modernisation to ensure the connection to Cellarhead GSP is reliable throughout. The work will be completed over two outage seasons staggered by one year to ensure security of supply to customers in the adjacent Legacy GSP network during load related reinforcement at Legacy GSP.

This project and associated network outages have been discussed with WPD and NGC as part of ED1 stakeholder engagement.

Total expenditure on the YS route: £12.42 million

11. Appendix 3 - APT Toolset

As referred to in section 8 of the main body of this annex, SPEN utilise the APT toolset as part of its optimal asset management decision making process. This toolset was developed by The Woodhouse Partnership (www.twpl.com) and is a suite of decision support software tools that assist in cost/risk optimization of physical asset management strategies, *particularly when available information is incomplete or uncertain*. They were developed by an international consortium under the European MACRO Project (EU1488) and represent the leading edge of practical business impact quantification for different inspection, maintenance, spares, asset replacement, shutdowns and engineering projects. They provide systematic discipline in collating existing knowledge from different disciplines, (they 'force the right questions to be asked') and they introduce a broad and flexible range of quantification methods to turn technical information or opinion into business significance and financial value. They also perform a comprehensive range of reliability, risk, life cycle costing and cost/risk and short-term/long-term trade-off calculations to find the optimal solution - and demonstrate the impact of constraints or 'intangibles', again in financial or business impact terms.

The module we have used for our investment decisions is:

APT-LIFESPAN (asset life cycle costing & optimal asset replacement timing).

APT-LIFESPAN helps to quantify the effects of short- and long-term options, and convert all life cycle assumptions, risks and performance aspects into a common financial view. It is a decision-support tool to identify the best mix of capital investment, operating and maintenance expenditures, residual risks and the optimum life itself. It exploits whatever hard data or range-estimates and uncertain assumptions that are available (using instant 'what if?' facilities), and calculates the optimal equipment replacement timing, the merits of technology upgrade, the net value-for-money difference between design options and a host of other common asset management decisions.

For existing assets:

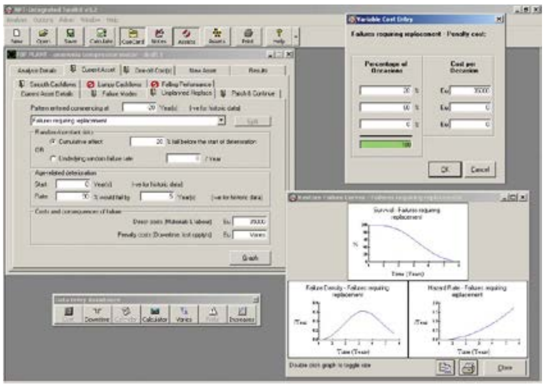
- *Calculates the optimal renewal timing or decommissioning/disposal point.*
- *Quantifies and evaluates the costs, benefits and risks of alternatives such as ongoing maintenance, Like-for-like renewal, life extension/refurbishments, technology upgrades and other options.*

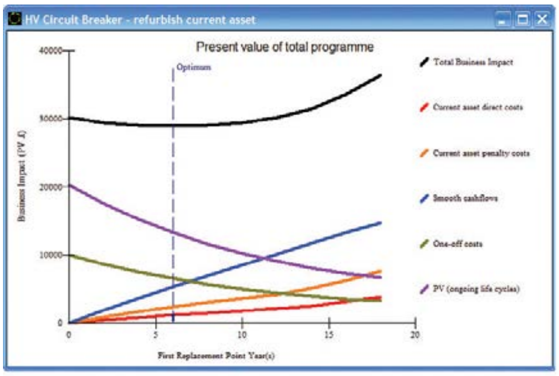
For new asset acquisitions:

- *Evaluates the total present value impact of capital investment and future operating costs, reliability& risks, performance, maintenance costs and life expectancies.*
- *Provides a structured way of evaluating equipment purchase options based on whole life costs and value, even when available data is poor.*

Fig 1: Sample Input Screen

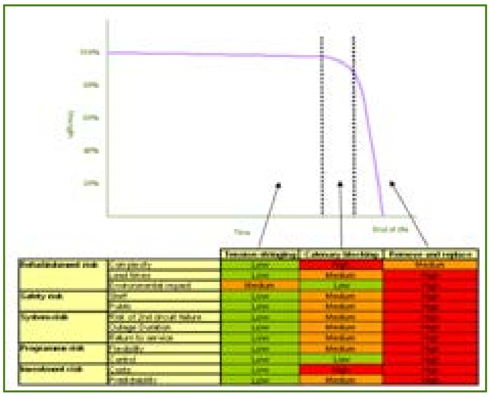
Fig 2: Output from Model showing optimum investment period





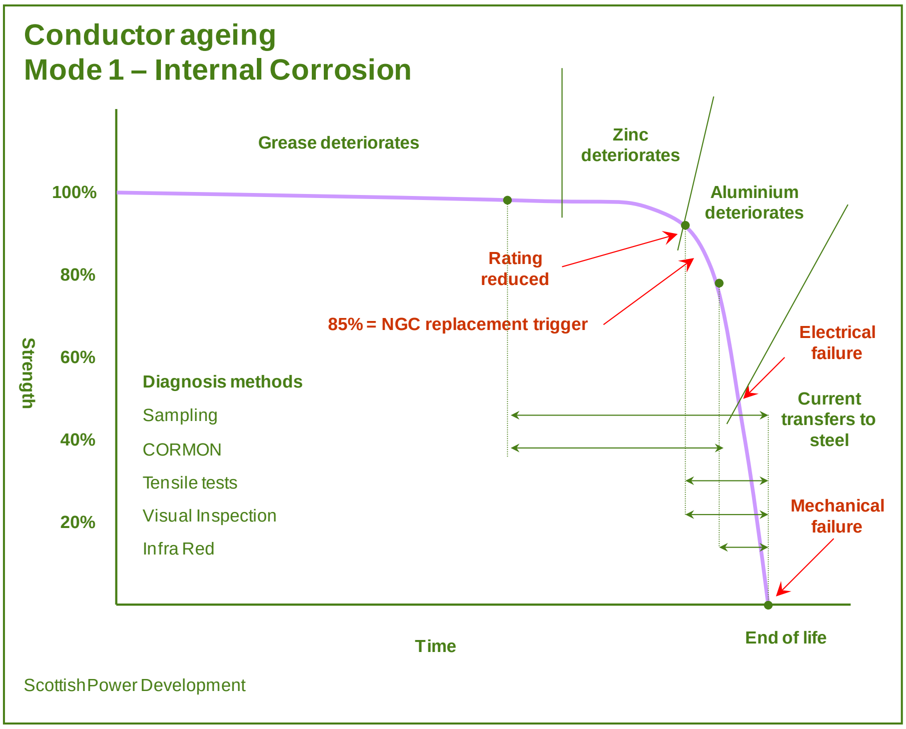
12. Appendix 4 – Conductor Aging Model

Referring back to the efficient cost of replacement of ACSR conductor, as described in Section 6 of the main document it can be seen that replacement utilising the most efficient/least cost method called 'Tension Stringing' should be undertaken before any deterioration has taken place on the Zinc Galvanisation of the steel inner steel core, and before mechanical strength is diminished by corrosion.



During the period that follows when the inner grease has deteriorated and the Zinc galvanisation starts to deteriorate, but before the Aluminium conductors corrode then catenary stringing techniques the residual strength of the conductor cannot be relied on to allow tension stringing and therefore techniques such as "Catenary Blocking" should be considered. Costs increase by 50 to 100% and time to deliver this work increase significantly by utilising this technique

If the conductor condition deteriorates further and the aluminium strands start to corrode then the residual strength of the existing conductor is reduced to a point where, for safety reasons the conductor can no longer support the installation of new conductors and must be dropped to the ground before new conductors are installed. Costs increase an estimated 2.5 to 5 fold depending on specification, and the outage durations increase significantly using this method in comparison to 'Tension stringing 'and 'Catenary blocking'



To determine the cost differences an expert panel within SPEN have evaluated our current cost sheet and systematically reviewed each item against the cost for tension stringing, catenary Blocking and, drop recover and re-erect replacement techniques. We have applied this to each route in our RIIO ED1 programme, allowing an average cost differential to be determined. We have also had high level discussions with two of our current contracting partners, who have offered their opinion on the additional costs for the element that would fall within the overhead line contract, not withstanding this they broadly matched or exceeded our own view.

We also completed a CBA on the options for 132kV overhead line conductor as part of our RIIO-ED1 submission; the CBA supported our engineering approach.

Details can be found in **Annex C6 – Cost Benefit Analysis – SPEN** – No.48.

13. Appendix 5 – PLPC BH line foundation report

BH Route, Wrexham

Tower 174 Foundation improvement works

Background

Pole BH174 is a lattice steel H suspension structure. Each leg is an 8” “PB” style lattice made up of 2 x channel sections with angle braces.

During 2011 the structure was found to be off plumb and the cross-arm off level, having being previously satisfactory.

As a temporary measure a stay and a cross brace was installed to prevent further movement.

At this time the foundation was partially excavated to expose the concrete. This was found to be in poor condition (crumbling and falling away).

It was also noted that the ground water table is approximately 500mm BGL which will make any excavation work below this level quite difficult. It is likely that the ground water level has risen in recent years due to the poor condition of the nearby waterways which are clogged and overgrown; this has also caused frequent flooding of the area.

Having evaluated the foundation and ground conditions it is believed that the movement on the structure is the result of one leg sinking due to the combination of soft ground, water levels and deteriorated concrete base.

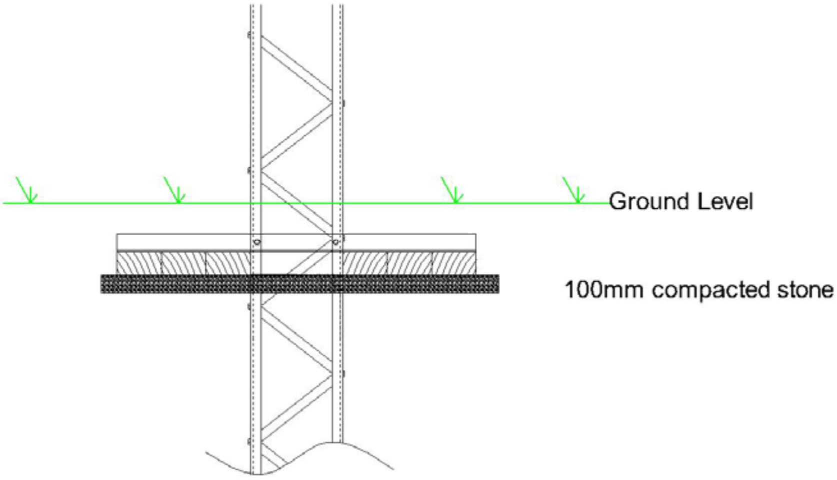
Existing profile for 8” PB pole

Proposal

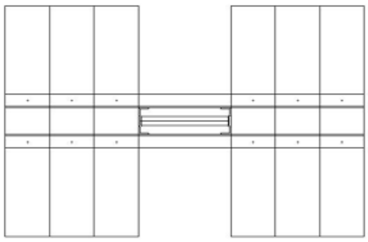
Our proposal is to stabilize the structure to prevent further movement.

This would be achieved by installing a raft foundation to each leg.

The raft would be constructed from treated timber blocks on a compacted stone base, with steel bearers bolted to the structure legs, all below ground level.



6 x timber blocks, 130 x 250 x 1300



Installation procedure

An area around the left leg (already low) will be excavated to a level of 500mm deep by 2.5m x 1.5m.

Any remaining concrete will be removed.

The excavation shall be level and compacted firm, then a layer of type 1 or similar gravel 100mm deep laid, graded and compacted.

6 x Timber blocks 250mm x 130mm x 1300mm size will be laid as shown below, to be square and level.

2 x Galvanized angle sections (75 x 100mm) shall be positioned, marked, drilled & bolted to the PB poles as shown.

The blocks shall be attached to the steelwork using 12 x coach bolts.

The tower will be painted with bitumastic paint up to 400mm AGL and the area reinstated.

With the left leg completed the structure will now be plumbed and the procedure will be repeated for the right leg.

14. Appendix 6– Typical OHL Cost Assessment Categories

OVERHEAD LINES

Cost Estimate (Level 2 Estimate)

LOCATION
TOWERS
ENQUIRY REF.
NOTES
Date of Costing
ATTACHMENTS / Links

Section			Notes	Cost	Cost for Catenary Block	Cost for Drop / recover / re-errect	Quantity	Total Tension	total Catenary	Total D/R/R	Conductor	Fittings	Structure
1	Environmental Engineering												
		Site Specific											
	Section total							£ -	£ -	£ -	£ -	£ -	£ -
2	Technical Consultants												
		Per km			£ -	£ -		£ -	£ -	£ -	£ -	£ -	£ -
	Section Total							£ -	£ -	£ -	£ -	£ -	£ -
3	Deeds of Servitude / Legal Fees												
		Per Tower/Pole						£ -	£ -	£ -	£ -	£ -	£ -
	Section Total							£ -	£ -	£ -	£ -	£ -	£ -
4	Overhead Line Contract												
		Per km			£ -	£ -		£ -	£ -	£ -	£ -	£ -	£ -
	Section Total										£ -	£ -	£ -
5	Other Contracts												
		Per Span						£ -	£ -	£ -	£ -	£ -	
	Section Total							£ -	£ -	£ -	£ -	£ -	£ -
6	Land access as per Grantors Charter												
		Per Site						£ -	£ -	£ -	£ -	£ -	£ -
	Section Total							£ -	£ -	£ -	£ -	£ -	£ -
8	Others												
		Per Site						£ -	£ -	£ -	£ -	£ -	£ -
	Section Total							£ -	£ -	£ -	£ -	£ -	£ -
	ESTIMATED TOTAL (PRIME)								£ -	£ -	£ -	£ -	£ -
	ESTIMATED TOTAL (ONCOSTED %)							£ -	£ -	£ -	£ -	£ -	£ -
									#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!

15. Appendix 7 – 132kV Steel Tower Line Heatmap

SPM 132kV Overhead Lines													Primary Condition Data					Secondary Condition Data					Asset Health Score		Circuit Info	
Route ID letters	Towers	Route section (low to high nos.)	Route Length (km)	No. of 2cct. towers	No. of 3cct. Towers	No. of 1cct. Towers	No. of 1cct. Poles	Total Circuit section length (km)	ED1 Towers	ED1 poles	ED1 Fittings	ED1 requirement Circuit section length (km)	Foundations	Steelwork	Insulators	Phase Conductor	Specific Issue	Earth Wire	Earth Wire Fittings	Dampers	Signs & Notices	ACDs	Asset Health Score	Score Combining Conductor & E/W	Route ID letters	Notes
BH	BH001R-104	Crewe to Jnc. DF route	20.0	1	-	107	-	20.0	1	106	1	20.0	5	5	4	5	4	5	1	3	3	3	28	23	BH	In ED1 Programme
BH	BH106-220	Jnc. DF route to Legacy	22.3	-	-	121	-	22.3		121	-	22.3	5	5	4	5	4	5	1	4	4	4	28	23	BH	In ED1 Programme
H	H025-073	Carrington to Warrington	12.6	50	-	-	-	12.6	50	-	100	12.6	3	5	4	4	5	4	2	5	4	2	25	21	H	In ED1 Programme
H	H025-073	Carrington to Warrington	-	-	-	-	-	12.6	-	-	-	12.6	3	5	4	4	5	4	2	5	5	3	25	21	H	In ED1 Programme
Q	Q159-162	Birkenhead to Jnc. AH route	0.7		-	-	-	0.7	-	-	-	0.7	3	5	5	3	5	3	5	5	5	1	24	21	Q	In ED1 Programme
CB	CB001-009	Bold to Jnc. C route	2.5	9	-	-	-	2.5	9	-	9	2.5	3	5	3	5	5	5	3	5	2	1	26	21	CB	In ED1 Programme
HA	HA060-086-EK16	Jnc. HA route to Jnc. EK route	8.1	27	-	-	-	8.1	11	-	22	3.8	3	4	5	5	4	5	4	4	2	4	26	21	HA	In ED1 Programme
HA	HA060-086-EK16	Jnc. HA route to Jnc. EK route	-	-	-	-	-	8.1	-	-	-	3.8	3	4	5	5	4	5	4	4	2	4	26	21	HA	In ED1 Programme
HA	HA088(EK16)-106A	Jnc. EK route to Jnc. AN route	-	-	-	-	-	6.1	-	-	-	5.8	3	4	5	5	4	5	4	4	2	4	26	21	HA	In ED1 Programme
HA	HA088(EK16)-106R	Jnc. EK route to Jnc. AN route	6.1	18	-	-	-	6.1	18	-	36	5.8	3	4	5	5	4	5	4	4	2	4	26	21	HA	In ED1 Programme
HA	HA106A	Jnc. AN route	-	-	-	1	-	-	1	-	1	-	3	4	5	5	4	5	4	4	2	4	26	21	HA	In ED1 Programme
HA	HA106A-139	Jnc. AN route to Crewe	8.8	35	-	-	-	8.8	8	-	16	2.7	3	4	5	5	4	5	4	4	2	4	26	21	HA	In ED1 Programme
HA	HA106R-139	Jnc. AN route to Crewe	-	-	-	-	-	8.8	-	-	-	2.7	3	4	5	5	4	5	4	4	2	4	26	21	HA	In ED1 Programme
Q	Q159-162	Birkenhead to Jnc. AH route	0.7	4	-	-	-	0.7	-	-	-	0.7	3	5	5	3	5	3	5	5	5	1	24	21	Q	In ED1 Programme
A	A069-131	Hartford to Crewe	17.0	-	-	65	-	17.0	65	-	65	17.0	4	5	3	3	5	3	5	3	5	2	23	20	A	In ED1 Programme
YS	YS0074-102	Whitfield to Cellarhead	9.3	-	-	-	-	-	-	-	-	9.3	3	3	5	4	5	4	5	5	4	3	24	20	YS	In ED1 Programme
YS	YS0074-102	Whitfield to Cellarhead		-	-	-	-	9.3	-	-	28	-	3	3	5	4	5	3	5	5	4	3	23	20	YS	In ED1 Programme
YS	YS071A	Whitfield	-	1	-	-	-	-	1	-	1	-	3	3	5	4	5	4	5	5	4	3	24	20	YS	In ED1 Programme
YS	YS072-074	Whitfield	1.0	3	-	-	-	1.0	3	-	3	1.0	3	3	5	4	5	4	5	5	4	3	24	20	YS	In ED1 Programme
AC	AC006-054	Connahs Quay to Jnc. AC route	13.8	50	-	-	-	13.8	50	-	100	13.8	3	4	5	5	2	5	4	5	3	3	24	19	AC	In ED1 Programme
AC	AC006-054	Connahs Quay to Jnc. AC route	-	-	-	-	-	13.8	-	-	-	13.8	3	4	5	5	2	5	4	5	3	3	24	19	AC	In ED1 Programme
AE	AE19R-20R	Shell Thornton to Ince	0.6	3	-	-	-	0.6	3	-	6	0.6	3	2	5	4	5	3	5	5	5	1	22	19	AE	In ED1 Programme
AE	AE19R-20R	Shell Thornton to Ince	-	-	-	-	-	0.6	-	-	-	0.6	3	2	5	4	5	3	5	5	5	1	22	19	AE	In ED1 Programme
AE	AE21R-26	Shell Thornton to Ince	1.4	6	-	-	-	1.4	6	-	12	1.4	3	2	5	4	5	3	5	5	5	1	22	19	AE	In ED1 Programme
AE	AE21R-26	Shell Thornton to Ince	-	-	-	-	-	1.4	-	-	-	1.4	3	2	5	4	5	3	5	5	5	1	22	19	AE	In ED1 Programme
AH	AH001-025	Jnc. Q route to Wallasay	6.2	27	-	-	-	6.2	27	-	54	6.2	3	5	5	5	1	5	5	5	3	3	24	19	AH	In ED1 Programme
AH	AH001-025	Jnc. Q route to Wallasay	-	-	-	-	-	6.2	-	-	-	6.2	3	5	5	5	1	5	5	5	3	3	24	19	AH	In ED1 Programme
AJ	AJ020-039	Capenhurst to Jnc. AB route	6.5	23	-	1	-	6.5	24	-	47	6.5	3	2	5	5	4	5	5	5	5	3	24	19	AJ	In ED1 Programme
AJ	AJ020-039	Capenhurst to Jnc. AB route	-	-	-	1	-	6.5	1	-	1	6.5	3	2	5	5	4	5	5	5	5	3	24	19	AJ	In ED1 Programme
DF	DF001-018	Jnc. BH route to Whitechurch	4.2	18	-	-	-	4.2	18	-	36	4.2	3	5	4	4	3	4	4	3	3	3	23	19	DF	In ED1 Programme
DF	DF001-018	Jnc. BH route to Whitechurch	-	-	-	-	-	4.2		-	-	4.2	3	5	4	4	3	4	4	3	3	3	23	19	DF	In ED1 Programme
YS	YS001-071	Crewe to Whitfield	25.2	73	-	-	-	25.2	73	-	146	25.2	3	2	5	4	5	4	5	5	4	3	23	19	YS	In ED1 Programme
YS	YS001-071	Crewe to Whitfield	-	-	-	-	-	25.2	-	-	-	25.2	3	2	5	4	5	3	5	5	4	3	22	19	YS	In ED1 Programme
CW	CW001-003	Windle to Jnc. C route	0.7	3	-	-	-	0.7	3	-	3	0.7	3	5	5	4	1	2	5	5	5	2	20	18	CW	In ED1 Programme
Q	Q001-017A	Percival Lane to Frodsham	3.7	18	-	-	-	3.7	18	-	36	3.7	3	5	5	3	1	3	3	5	5	2	20	17	Q	In ED1 Programme
Q	Q001-017A	Percival Lane to Frodsham	-	-	-	-	-	3.7	-	-	-	3.7	3	5	5	3	1	3	3	5	5	2	20	17	Q	In ED1 Programme
Q	Q018A-033	Frodsham to Ince	4.6	16	-	-	-	4.6	16	-	32	4.6	3	5	5	3	1	3	1	1	3	1	20	17	Q	In ED1 Programme
Q	Q018A-033	Frodsham to Ince	-	-	-	-	-	4.6	-	-	-	4.6	3	5	5	3	1	3	1	1	3	1	20	17	Q	In ED1 Programme
AC	AC121R-162	St. Asaph to Jnc. CQ route	12.1	40	-	-	-	12.1	40	-	80	12.1	3	4	4	5	1	4	3	4	3	1	21	17	AC	In ED1 Programme
AC	AC121R-162	St. Asaph to Jnc. CQ route	-	-	-	-	-	12.1	-	-	-	12.1	3	4	4	5	1	4	3	4	3	1	21	17	AC	In ED1 Programme
AC	AC162-192A	Jnc. CQ route to Dolgarrog	8.2	32	-	-	-	8.1	32	-	64	8.1	3	4	4	5	1	4	3	4	3	1	21	17	AC	In ED1 Programme
AC	AC162-192A	Jnc. CQ route to Dolgarrog	-	-	-	-	-	8.1	-	-	-	8.1	3	4	4	5	1	4	3	4	3	1	21	17	AC	In ED1 Programme
AC	AC192A-193	Dolgarrog	0.1	-	-	1	-	0.1	1	-	1	0.1	3	4	4	5	1	4	3	4	4	1	21	17	AC	In ED1 Programme
EB	EB001-012	Jnc. AB route to Crane Bank	3.2	12	-	-	-	3.2	12	-	24	3.2	3	4	5	3	2	3	5	3	3	2	20	17	EB	In ED1 Programme
EB	EB001-012	Jnc. AB route to Crane Bank	-	-	-	-	-	3.2	-	-	-	3.2	3	4	5	3	2	3	5	3	3	2	20	17	EB	In ED1 Programme
PK	PK003-143R	Crewe-Barlaston-Radway green	38.6	-	-	106	-	38.5	106	-	106	38.5	3	4	4	5	1	5	5	5	4	4	22	17	PK	In ED1 Programme
CT	CT001-026	Jnc. BH route to Marchwiel	4.7	-	-	15	11	4.7	1	11	1	4.7	5	3	3	5	1	N/A	N/A	4	4	2	17	17	CT	In ED1 Programme
AC	AC054-101	Jnc. AC route to St. Asaph	14.3	49	-	-	-	14.3	49	-	98	14.3	3	3	3	5	2	5	3	3	4	3	21	16	AC	In ED1 Programme
AC	AC054-101	Jnc. AC route to St. Asaph	-	-	-	-	-	14.3	-	-	-	14.3	3	3	3	5	2	5	3	3	4	3	21	16	AC	In ED1 Programme
AN	AN001-008	Jnc. AH route to Elworth	2.1	8	-	-	-	2.1	1	-	1	0.4	3	4	2	2	5	1	5	3	3	3	17	16	AN	In ED1 Programme
AN	AN001-008	Jnc. AH route to Elworth	-	-	-	-	-	2.1	-	-	-	0.4	3	4	2	2	5	1	5	3	3	3	17	16	AN	In ED1 Programme
AC	AC301-302	Jnc. AC route to Holywell	0.3	2	-	-	-	0.3	2	-	4	0.3	3	3	3	4	2	4	3	2	4	3	19	15	AC	In ED1 Programme
AC	AC301-302	Jnc. AC route to Holywell	-	-	-	-	-	0.3	-	-	-	0.3	3	3	3	4	2	4	3	2	4	3	19	15	AC	In ED1 Programme
AE	AE001A-018R	Ellesmere Port to Shell Thornton	5.2	21	-	-	-	5.2	21	-	42	5.2	3	2	3	5	1	3	4	3	3	3	17	14	AE	In ED1 Programme
AE	AE001A-018R	Ellesmere Port to Shell Thornton	-	-	-	-	-	5.2	-	-	-	5.2	3	2	3	5	1	3	4	3	3	3	17	14	AE	In ED1 Programme
D2	D2 001A-066	Southport to Penwortham	18.5	1	-	66	-	18.5	67	-	67	18.5	3	4	1	5	1	5	1	1	1	1	19	14	D2	In ED1 Programme
D2	D2 067-070A	Southport to Penwortham	0.8	5	-	-	-	0.8	5	-	5	0.8	3	4	1	5	1	5	1	1	1	1	19	14	D2	In ED1 Programme
EK	EK005-016	Jnc. JK route to Jnc. HA route	3.5	12	-	-	-	3.5	8	-	16	2.4	3	3	1	5	1	5	1	1	4	3	18	13	EK	In ED1 Programme
EK	EK005-016	Jnc. JK route to Jnc. HA route	-	-	-	-	-	3.5	-	-	-	2.4	3	3	1	5	1	5	1	1	4	3	18	13	EK	In ED1 Programme
Q	Q033-36-238	Frodsham to Ince	1.2	4	-	-	-	1.2	4	-	8	1.2	2	3	2	3	1	3	2	1	2	1	14	11	Q	In ED1 Programme
Q	Q033-36-238	Frodsham to Ince	-	-	-	-	-	1.2	-	-	-	1.2	2	3	2	3	1	3	2	1	2	1	14	11	Q	In ED1 Programme
		TOTALS	288.7	571	0	484	11	439.9	**755**	**238**	**1,272**	**412.5**														

16. Appendix 8 – 33kV Steel Tower Overhead Lines

Our 33kV overhead line distribution network on towers includes some of the oldest assets on our overhead line network with several lines constructed in the 1930s to specifications no longer utilised by the industry. Repairs are onerous and several lines are located in exposed areas susceptible to severe weather. Other circuits are located alongside 132kV circuits on double circuit towers requiring close coordination with 132k works.

Our overhead line asset replacement programmes related to these assets are built up from individually detailed plans, coordinated well in advance with external stakeholders such as National Grid, and are coordinated with other asset replacement and network reinforcement works which maximises efficiency across these programmes.

In both the SPD and SPM areas, 33kV Tower lines are constructed utilising both single and double circuit towers. The specifications used were generally the early PL type construction types which were the early forerunners to the more traditional 132kV tower types.

The conductor utilized was generally smaller than that used at 132kV and in many instances of a size or type no longer supported by the company. For instance, a 125mm^2 ACSR “Coyote” type conductor predominates in SPM. This conductor is not greased, such that it is susceptible to weather and is showing signs of deterioration. ACSR conductor deterioration is discussed in detail within the main body of this Annex

These assets are at, or approaching “end of life” and our plan is to address a significant proportion of the large population of 1950/60s ACSR conductor on the 33kV network in RIIO-ED1, modernising 102km of lines in SPM and 80km in SPD, replacing conductor, fittings and insulators. We will address towers steelwork and foundation issues refurbishing as required during the conductor replacement programme, Towers will be painted and steelwork will be replaced where necessary. In addition, foundations will be evaluated and replaced or repaired as required and we will comply with all legal and license obligations.

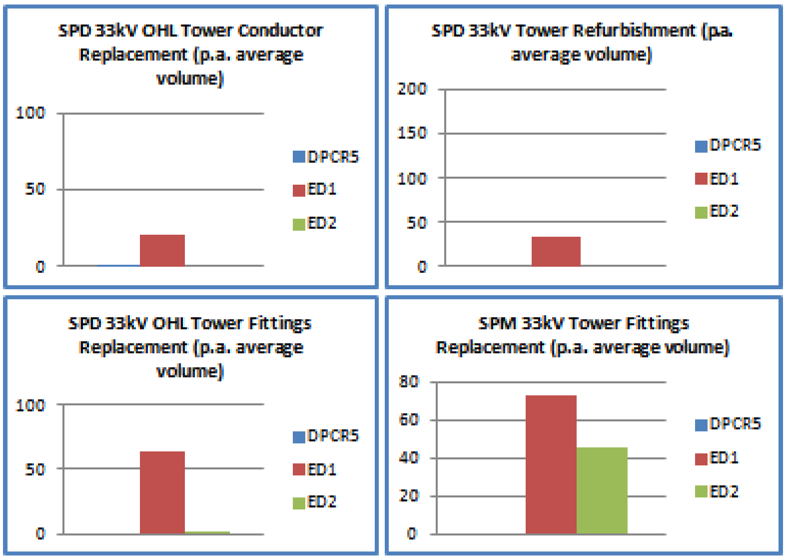
Our strategy is to invest in this asset and deliver improved resilience and reliability of these strategic assets for the next 4 or 5 decades.

Our strategy and the scope of our 33kV steel tower line moderisation programme is similar to that required on our 132kV Steel tower overhead lines network, and therefore the unit costs we have applied to this asset reflect the age and complexity of the works required to bring up to a modern standard.

Several circuits comprise of sections on both towers and wood poles. In these circumstances we will replace “like for like” unless it is efficient and cost effective to consider other alternatives. Where the wood pole section of line is to be retained, it will form part of the overall project and will be modernised alongside the tower line conversant with our EHV wood pole strategy.

Our plans to begin modernising our 33kV Tower Line network in the ED1 period is in recognition that these assets are in a similar condition to the 132kV assets included in the 132kV Tower Line element of our plan. Figure 1 below illustrates the focus of our expenditure in ED1 and ED2, which differs between licence areas due to different age and condition of the 33kV Tower Lines.

Figure 1



The same condition assessment techniques and conductor age modelling as applied to 132kV Tower Lines also apply the 33kV Tower Network.

An example of one of the circuits we will be modernising in during ED1 is shown below: