XZ ROUTE 275kV OHL MAJOR REFURBISHMENT	
Name of Scheme/Programme	XZ Route 275kV OHL Major Refurbishment
Primary Investment Driver	Asset Health
Scheme reference/ mechanism or category	SPNLT204/Overhead (Tower) Line
Output references/type	NLRT2SP204/275kV OHL (Tower) Conductor, NLRT2SP204/275kV OHL Fittings, NLRT2SP204/275kV OHL Tower
Cost	£6.5M
Delivery Year	2023
Reporting Table	C0.7/C2.2a_AP/C2.2a_CI/C2.3/C2.4b/C2.5/C2.5a
Outputs included in RIIO T1 Business Plan	No

Issue Date	Issue No	Amendment Details
July 2019	Issue 1	First issue of document
December 2019	Issue 2	Gross cost, NPV, Monetised Risk, Long Term Risk Benefit and Delivery Year values updated.

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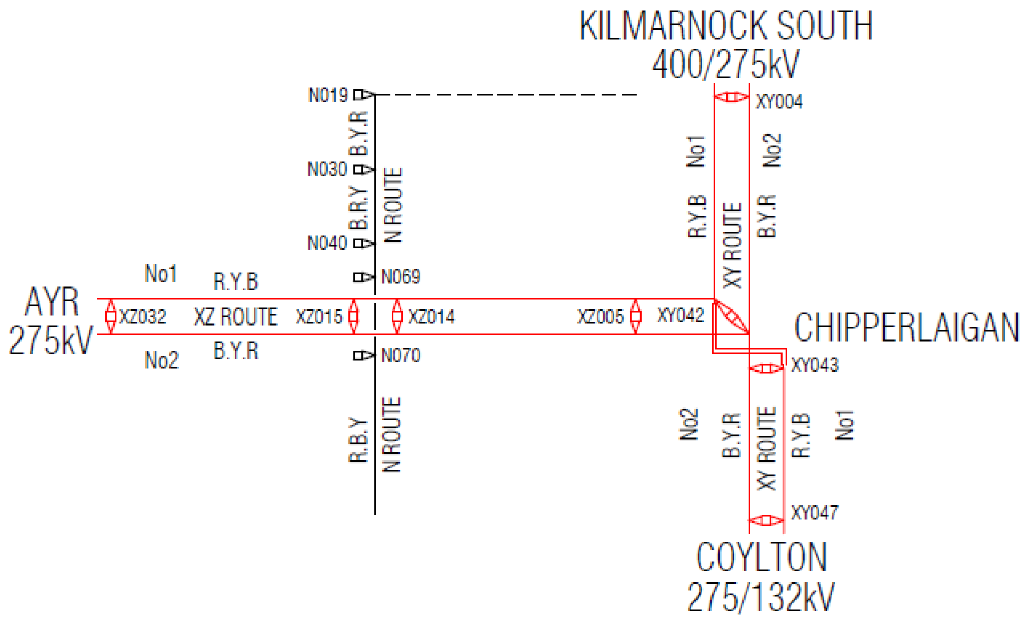
1. Introduction

This justification paper supports a proposal to carry out a major refurbishment of the XZ route, 275kV transmission overhead line between Chipperlaigan compound (tower XY042) and Ayr substation. The driver for the proposal is the asset health of phase conductors and earthwire which will be approaching the end of the operational life by end of RIIO-T2 without intervention after site specific investigations and data analysis.

The XZ route consists of a double circuit single ACSR 400mm2 ‘Zebra’ phase conductor and a single ACSR 175mm2 ‘Lynx’ earthwire conductor (with fibre optic wrap cable) all supported on 28 steel lattice towers (XZ005 to XZ032) of L2 design with an approximate route length of 9.4km and circuit length of 18.8km.



SYSTEM DIAGRAM EXTRACT

In line with above, the proposed 275kV outputs to be delivered in this project for the replacement option are:

Asset	Type of Activity	Disposal (cct. Km/sets/each)	Addition/Activity (cct. Km/set/each)
275kV OHL (Tower Line) Conductor	Replacement	18.8 cct. Km	18.8 cct. Km
275kV OHL Fittings	Replacement*	56 sets	56 sets
275kV Tower	Refurbishment Major	-	28 each

**OHL Fittings outputs refer to spacers and vibration dampers and not to the replacement of the whole insulator set.*

2. Background Information

The existing system (XZ Route) is a double circuit overhead line that forms a 275kV connection between Chipperlaigan compound (tower XY042) and Ayr substation which travels predominately through agricultural land. XZ Route was built at the same time as XY Route by the same OHL contractor using the same materials (BICC-H conductor). No alterations to the system configuration have been proposed.

The existing conductors are 400mm2 ACSR 'Zebra' (all inner greased) manufactured by British Insulated Callender Cables (BICC-H) with a configuration of two conductors per phase and a single ACSR 175mm2 'Lynx' earthwire conductor (with fibre optic wrap cable).

Circuits are twin conductor between towers XY042 and Ayr substation as follows:

- Phase Conductor Type: twin ACSR 400mm2 'Zebra' installed in 1966.
- Earth wire Conductor Type: single ACSR 175mm2 'Lynx' installed in 1966.
- Insulators Type: glass installed in 2006 at towers XZ005, 007, 009-0018, 020-025, 027-029 and XZ031, 2015 at towers (KILS-AYR1-COYL circuit) XZ006, 008, 019, 026, 030 and XZ032 and 2016 (KILS-AYR2-COYL circuit) XZ006, 008, 019, 026, 030 and XZ032.
- Tower Type: steel lattice L2 (U) design. All towers were painted in 2015.

There are 2 operating circuits on this route. Circuit nomenclatures and colours for the XZ route are:

- KILS-AYR1-COYL: Circuit Colour Black / White.
- KILS-AYR2-COYL: Circuit Colour Red / White.

2.1 Data Collection

As part of the SP Energy Networks (SPEN) OHL inspection regime, aerial photographic information in conjunction with site specific investigations such as conductor sampling have been employed to provide a detailed condition analysis of the OHL components.

- Aerial photographic inspection.
- Conductor sampling.

Note: conductor samples were collected along XY Route as part of the conductor replacement works.

2.2 Data Analysis and Interpretation

The collected condition data has been analysed following "ASSET-01-030 SPT Overhead Lines Technical Asset Life and CBRM Methodology" before condition ratings (1 to 5) per asset are defined and subsequently input to the SPEN Condition Based Risk Management (CBRM) tool.

The "ASSET-01-030 SPT Overhead Lines Technical Asset Life and CBRM Methodology" document covers the model describing how overhead line conductors' condition is expected to change over time and its calculated technical asset life based upon a condition data approach, conductor types, grease levels and environment type. It also defines a common way on how condition data is interpreted, removing subjectivity and providing a clear view on how condition ratings have been concluded.

Phase conductors:

Conductor samples collected from high/moderate/low polluted areas over the network indicates that the anticipated life following an ageing profile (internal galvanic corrosion) of an ACSR 400mm^2 'Zebra' (all-inner greased) conductor is 60 years (typically 65 years for "moderately and low polluted" areas). However, additional factors including quality, manufacturing, design and fatigue can accelerate the typical ageing profile of the conductors.

Phase conductor samples gathered along XY Route at 10 different locations in 2017 (Circuit 1: XY010-011, XY017A-018, XY026-027, XY041-042, XY046-047 and Circuit 2: XY004-005, XY013-014, XY018-019, XY033-034, XY043-044) revealed a significant levels of aluminium corrosion, grease discolouration and dried with significant loss of the galvanic zinc coating along the steel core strands. The extent of the coating delamination indicates that a poor coating adhesion was achieved during manufacturing of the steel core strands. Conductor was identified as BICC-H (hot-dip galvanic process) manufactured by BICC in 1966 based on SPEN records. A mapping exercise was then carried to identify where this type of conductor was installed through the entire SPEN Networks. XZ Route was identified as an OHL built at the same time as XY Route by the same OHL contractor using the same materials (BICC-H conductor); therefore XZ Route conductor present same quality defects as XY Route.

A summary of the condition ratings is shown below:

Activity	Span	Summary Result	Condition Rating Value*
Circuit 1			
Conductor Sample (2017)	XZ / XY010-011	Significant levels of aluminium corrosion product, Zinc layer breached and grease deteriorated	4
	XZ / XY017A-018		4
	XZ / XY026-027		4
	XZ / XY041-042		4
	XZ / XY046-047		4
Circuit 2			
Conductor Sample (2017)	XZ / XY004-005	Significant levels of aluminium corrosion product, Zinc layer breached and grease deteriorated	4
	XZ / XY013-014		4
	XZ / XY018-019		4
	XZ / XY033-034		4
	XZ / XY043-044		4

**Note: condition rating derived from the Overhead Lines Technical Asset Life and CBRM Methodology.*

Figure 1: inner aluminium strands exhibit a significant level of aluminium corrosion product and greased discoloured and hardened.

Figure 2: conductor sample showing low level of grease found between steel wires and significant loss of the galvanic zinc layer.

Steel Towers:

All towers along XZ Route were painted in 2015; however a generic design defect exists in the layout of body extensions incorporated into L2 towers where some incidence of buckling has been found in members of the body extensions as captured in TGN 161 “Modifications to L66, L2, L3, L3(c), L8 and L8(c) towers”. In addition, highlight the serious weakness of the outer steel flanges of the suspension insulator cross-arm attachment channel, as captured in TGN 163 “Suspension Insulator Crossarm Attachment Channels”, where a failure of the rectangular flange on a L2 tower resulted in a re-assessment of the safe working loads.

Body extension modifications and replacement of the suspension insulator cross-arm channels following TGN161 and 163 respectively are considered within the proposed scheme.

2.3 CBRM Summary

CBRM extract is shown below indicating End of Life (EoL) for each of the identified asset for replacement:

Asset Description	Year of Installation	EoL*	Monetised Risk (R£m)*
Phase Conductor XZ Route 275kV	1966	8.86	4,128,183.16

**Values at the end of the RIIO-T2 period with no intervention as per NOMs methodology.*

Note: no replacement proposed to phase fittings and steel towers along XZ Route; however allowance to replace sporadic heavily corroded or damaged steelwork and foundation upgrades have been made.

3. Optioneering

Four options have been considered based on the requirements identified within the condition assessments produced for the existing XZ route overhead line, where Option 1 has been recognised as the only viable option which meets the project objectives.

Option	Status	Reason for rejection
Baseline – Do Minimum: • Deferral of the major refurbishment intervention to RIIO-T3 (2026).	Considered	This option is unacceptable due to the overall condition of the OHL conductor being at their end of life and no intervention will add considerable risk to these circuits within the SPT Network. In addition, deferring the investment will accelerate the continual deterioration of the OHL components, in particular the OHL conductor which strength will be compromised preventing its use as pulling bond, significantly increasing the costs for conductor stringing activities.
Option 1 - Conductor and earth wire Replacement: • Major refurbishment intervention (replacement of phase conductor and earth wire) in RIIO-T2 (2026).	Considered and Proposed	-
Option 2 - Full Refurbishment • The replacement of phase conductor, earth wire and insulators in RIIO-T2 (2026).	Rejected	Insulators along XZ Route were installed in 2006 with an anticipated life of 50 years.
Option 3 - Full Replacement	Rejected	Replacement of the existing OHL towers is unacceptable due to its condition and anticipated remaining life. Full Replacement will incur in a more onerous cost and delivery timescales due to environmental planning constraints (which is not in the best interests of system security or consumers).

4. Detailed analysis

Option 1 achieves the main objective of replacing phase conductor and earth wire while refurbishing the OHL Towers and thereby reducing the overall risks to the network and costs. Baseline and Option 1 have been considered for a CBA analysis where whole life monetised benefits and comparison of respective project option costs.

4.1 Option 1: Full Refurbishment

This option considers replacement of the replacement of all phase conductors and earthwire assets as identified earlier through condition data, data analysis and interrogation. The following interventions are proposed to be replaced in a staged manner in this option:

- Re-conductor all circuits with twin 'Totara' 425mm2 All Aluminium Alloy Conductor (AAAC) EHC at maximum 90°C for operation at 275kV.
- Replace earthwire with a single "Keziah" 190mm2 AACSR equivalent OPGW.
- Replace all tension and suspension conductor end fittings.
- Replace earthwire fittings.
- Steelwork modifications as per TGN161 and TGN163.
- Replace heavily corroded or damaged steelwork (above category 4).
- Replace tower muff foundations where required.
- Upgrade foundations where deemed necessary.
- Replace downleads and fittings at Ayr substation and at Chipperlaigan compound.
- Update all OHL records to reflect the works carried out.
- Carry out condition assessments on sections of removed conductor.
- Provide report to the Asset manager to include condition of all redundant conductors, steelwork and foundations along with associated tests logs for existing/new concrete.

The standard replacement minimum twin conductor 425mm^2 AAAC (Totara) EHC system thermal ratings*:

Season / State	Amps	MVA
Winter Pre Fault	2430	1160
Winter Post Fault	2890	1380
Spring/Autumn Pre Fault	2330	1110
Spring/Autumn Post Fault	2770	1320
Summer Pre Fault	2170	1030
Summer Post Fault	2580	1230

**at 90C Maximum Operation Temperature at 275kV.*

<u>Specific factors attributable to this option which results in additional costs are listed below:</u>

- Works also include for exploratory ground investigations to assess the condition of the tower foundations below ground level. Above ground foundation and/or muffs will be repaired or replaced where required by their condition.

  The majority of SPT towers use foundations of the pyramid block and chimney design, with most of the rest being piled. For the majority of well-constructed foundations using the appropriate materials there are no significant means of degradation but workmanship and past design details do give rise to potentially serious problems. Insufficient embedment of stubs into the block and a lack of cleats can result in uplift failures where the pyramid block remains in the ground. Corrosion of the tower steel stub can occur when moisture and oxygen come into contact with it. The corrosion is usually only found at the chimney/muff interface where poor construction has left the joint open exposing the bare steel.

SPT has developed a methodology (applied in RIIO-T1) based upon a comprehensive desktop/site intrusive study to undertake a quantified risk assessment (QRA) approach to determine the foundation sites that require any type of refurbishment:

- Importance of the circuits.
- Ground investigation desktop study. Misalignment of installed foundation type with soil type identified on the British Geological Survey (BGS) maps.
- Tower lean and towers required to have wind stays removed under the contract.
- Highly loaded towers (in relation to new and design loads).
- Access difficulties.
- Proximity to crossings, residential areas, etc.
- Other high risk factors (e.g. existing damage, relative location to highly distressed towers, etc.).
- Primary investigations (Level 1 inspection): non-intrusive surveys.
- Secondary investigations (Level 2 inspection): foundation intrusive.

Once the above aspects have been considered, a risk rating will be applied grading the perceived suitability. This in turn will form the basis for any recommendation of foundation refurbishments.

Based on the experience gathered in RIIO-T1 for the same type of towers and age, an allowance of 10% of the suspension towers and all pulling positions have been allocated to the project for foundation intrusive investigation and refurbishment.

- Consideration for body extension modifications and replacement of the suspension insulator cross-arm channels following TGN161 and 163 respectively.
- Allowances for the undergrounding of distribution crossing have also been made.
- Temporary ADSS Telecom conductor to provide diversion to the existing earthwire fibre wrap.

<u>The following specific risks have been identified for this option:</u>

- Conductor condition monitoring before works starts to allow an early indication of the suitability of the conductor and earth wire to be used as pulling bonds.
- Working over existing distribution overhead lines to be addressed by diverting or undergrounding on a temporary basis.
- Railway and road crossings to be mitigated through scaffolding and traffic management systems or deployment of a catenary support system.
- Utilities within working areas to be addressed through procurement of records for duration of the project.
- Access routes to be addressed through early engagement with landowners, employing low bearing pressure ground vehicles and trackway where possible to minimise extents of stone tracks.
- Foundation condition and shape not being able to provide necessary uplift/compression capacity.

- Optimisations of Network access by the introduction of multiple gangs.
- Network operability/wayleave/environmental restrictions which impact on the progression of works as planned.

4.2 Selected Option

Baseline and Option 1 have been considered for a CBA analysis where whole life monetised benefits and comparison of respective project option costs.

Option No.	Description Of Option	Preferred Option	Total NPV (£m) *(Incl. Monetised Risk)*	Delta *(Option to baseline)*
Baseline	Baseline	N	£ 247.68	£ -
1	Conductor and earth wire Replacement	Y	£ 264.54	£ 16.86

5. Conclusion

The 2 options proposed have been reviewed in terms of scope feasibility, cost, timescales and construction risks with Option 1 demonstrating the primary objective of lead assets replacement whilst affording greatest reduction in risk to the network.

In line with the costs prepared, the proposed scope of works and CBA analysis, option 1 (replacement of phase conductor and earth wire during the RIIO-T2 period) is the selected option:

- Scheme Total Cost: £6.5M
- Timing of investment: 2020 – 2023
- Declared outputs:

Asset	Type of Activity	Disposal (cct. Km/sets/each)	Addition/Activity (cct. Km/set/each)
275kV OHL (Tower Line) Conductor	Replacement	18.8 cct. Km	18.8 cct. Km
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275kV Tower	Refurbishment Major	-	28 each

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- Long term risk benefit (LR£m):

Asset	Long Term Risk Benefit (LR£m)
275kV OHL (Tower Line) Conductor	266.55

- Price control period of outputs: 2023

6. FUTURE PATHWAYS – NET ZERO

6.1 Primary Economic Driver

The primary driver for this investment is asset condition and risk. The investment does not have a strong reliance on environmental benefits.

6.2 Payback Periods

The CBA indicates that a positive NPV results in all assessment periods (10, 20, 30 & 45 years) which is consistent with the lifetime of the intervention. Consumers benefit from reduced network risk immediately on completion of the project.

6.3 Pathways and End Points

The network capacity and capability that result from the proposed option has been tested against and has been found to be consistent with the network requirements determined from the ETYS and NOA processes. Additionally, the proposed option is consistent with the route-specific capacity requirements from SPT's Energy Scenarios.

6.4 Asset Stranding Risks

Electricity generation, demand and system transfers are forecast to increase under all scenarios. The stranding risk is therefore considered to be very low.

6.5 Sensitivity to Carbon Prices

The CBA inputs are not sensitive to carbon prices.

6.6 Future Asset Utilisation

It has been assessed that the preferred option is consistent with the future generation and demand scenarios and that the risk of stranding is very low.

6.7 Whole Systems Benefits

The supergrid voltage proposals do not inhibit whole system solutions but are more remote from the interfaces.

7. OUTPUTS INCLUDED IN RIIO T1 PLANS

N/A