ZA ROUTE 400kV OHL MAJOR REFURBISHMENT	
Name of Scheme/Programme	ZA Route 400kV OHL Major Refurbishment
Primary Investment Driver	Asset Health
Scheme reference/ mechanism or category	SPNLT205/Overhead (Tower) Line
Output references/type	NLRT2SP205/400kV OHL (Tower) Conductor, NLRT2SP205/400kV Fittings, NLRT2SP205/400kV OHL Tower
Cost	£44.6M
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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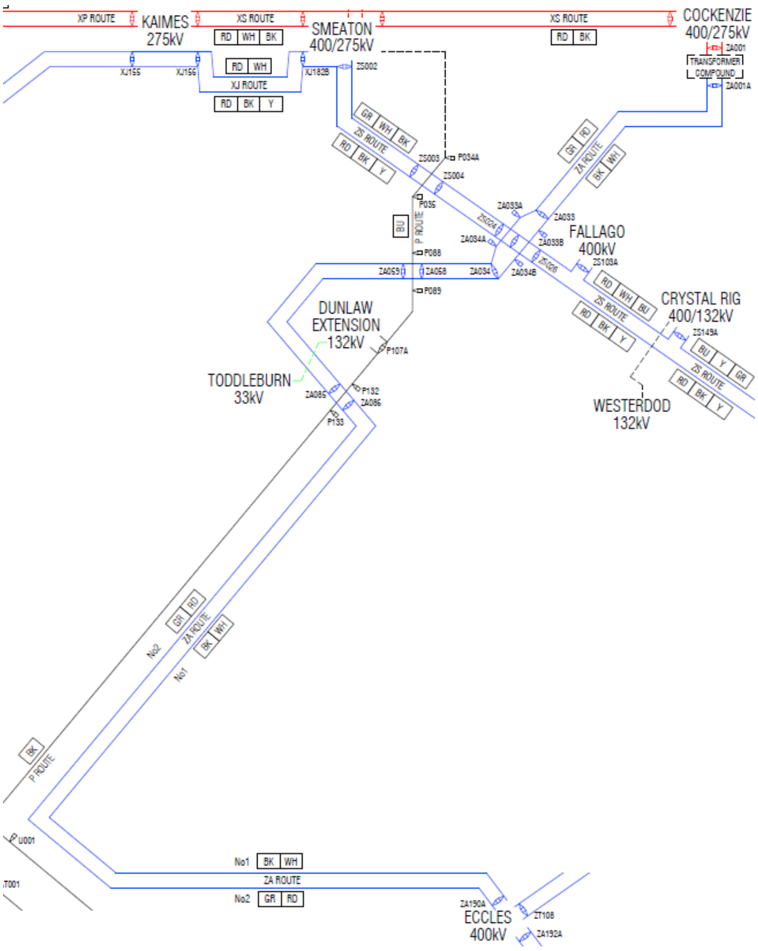
1. Introduction

This justification paper supports a proposal to carry out a conductor and fittings replacement of the ZA route 400kV transmission overhead line between towers ZA001 (Cockenzie S/S) and ZA190A (Eccles S/S) in 2021 and 2022 of the RIIO T2 period. The driver for the proposal is the asset health of phase conductors, earthwire, insulators/fittings and tower which will be approaching the end of the operational life by end of RIIO-T2 without intervention after site specific investigations and data analysis. *Note: the remainder of the ZA route from tower ZA192A to the junction with National Grid (NGET) boundary is out with this project scope.*

The section of route being considered consists of a double circuit twin ACSR 400mm^2 'Zebra' (core only greased) phase conductors and single earth wire conductor of equivalent type supported on 194 steel lattice towers of L6 design.



SYSTEM DIAGRAM EXTRACT

In line with above, the proposed 400kV 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)
400kV OHL (Tower Line) Conductor	Replacement	131.6 cct. Km	131.6 cct. Km
400kV OHL Fittings	Replacement	388 sets	388 sets
400kV Tower	Refurbishment Major	-	194 each

The delivery of the project is characterised by multiple wiring gangs (2) working concurrently in order to minimise access and constraints on the network.

2. Background Information

The existing system (ZA Route) is a double circuit overhead line that forms a 400kV connection between Cockenzie and Eccles substations which travels predominately through agricultural land with some residential buildings in close proximity. The remainder of ZA route traverses from tower ZA192A to the boundary junction with National Grid (NGET) and is out with the responsibility of this project scope. No alterations to the system configuration have been proposed.

The existing conductors are 400mm2 ACSR 'Zebra' (core only greased) manufactured by British Insulated Callender Cables (BICC-H) with a configuration of two conductors per phase. The existing earth wire is also a 400mm2 ACSR 'Zebra' (core only greased) conductor with no optical fibre.

Circuits are twin conductor between towers ZA001 and ZA190A as follows:

- Phase Conductor Type: twin ACSR 400mm2 'Zebra' core only greased installed in 1966.
- Earth wire Conductor Type: single ACSR 400mm2 'Zebra' core only greased installed 1966.
- Insulators Type: glass installed in 1966.
- Conductor Spacer Type: 'Andre' spacers.
- Tower Type: steel lattice BICC L6 design.

There are 4 operating circuits on this route. Circuit nomenclatures and colours for the ZA route are:

- COCK – SGT3 (ZA001 – ZA001A): Circuit Colour black / white (B/WH).
- COCK – SGT4 (ZA001 – ZA001A): Circuit Colour green / red (G/R).
- COCK – ECCL1 (ZA001A – ZA190A): Circuit colour black / white (B/WH).
- COCK – ECCL2 (ZA001A - ZA190A): Circuit Colour green / red (G/R).

There has been no asset replacement or major refurbishment works on the ZA route since it was built other than limited tower painting carried out between 2013/14).

ZA route presents a number of critical locations adjacent to railways, main roads and HV OHLs, namely:

- 2no. 400kV OHL crossings ('ZS' route)
- 2no. 132kV OHL crossings ('P' route)
- Main Roads (A1, A68 & A697) crossings
- Main East Coast Railway line crossing
- Close proximity to urban areas, evident at beginning of route
- Terrain comprising of urban areas, open undulating farmland with some locations in excess of 400m high (A.O.D.)

The route traverses through various environmental areas with changing levels of pollution with more than 10% of the line located within the heavily polluted 5km zone adjacent to the coastline and the former Cockenzie coal power station.

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 corrosion monitoring, sampling and inspection under spacers have been employed to provide a detailed condition analysis of the OHL components.

- Aerial photographic inspection.
- Corrosion monitoring testing.
- Conductor assessment at spacer locations.
- Conductor sampling.

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 and Earth wire conductors:

Conductor samples collected from high/moderate/low polluted areas over the SP Network indicates that the anticipated life following an ageing profile (internal galvanic corrosion) of an ACSR 400mm^2 'Zebra' (core-only greased) conductor is 50 years (typically 60 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 and earth wire conductors installed along ZA route were manufactured in 1965 by British Insulated Callender Cables (BICC-H) where the steel wires were 'hot-dip' galvanised. Corrosion monitoring and conductor sample reports indicates loss of the galvanic zinc coating along the steel wires. A similar pattern of zinc loss was also observed along the existing XY route conductors (also manufactured by BICC-H in 1965) where the loss was due to delamination of the zinc coating through inadequate cleaning of the base material.

Removal of the originally installed rigid 'Andre' conductor spacers along the route highlights conductor fatigue and loss of strand wire cross sectional area.

A summary of the condition ratings is shown below:

Activity	Span	Summary Result	Condition Rating Value*
Corrosion monitoring earth wire: ACSR Zebra core only greased (1993)	ZA035-036	“None”	1-2
	ZA036-037	“None”	1-2
	ZA042-043	“Partial”	4
	ZA064-065	“Severe”	5
	ZA065-066	“Severe”	5
	ZA087-088	“None”	1-2
	ZA088-089	“None”	1-2
	ZA104-105	“Partial”	4
	ZA105-106	“Al loss”	5
Conductor Sample (2018)	ZA042	Zinc loss and Al wrap test well below 25 turns	5
	ZA064		5
	ZA103		5
	ZA125		5
Conductor under spacers (2018)	ZA087-088	Corrosion and signs of fatigue on conductor under spacer	4
	ZA088-089		4
	ZA104-105		4
	ZA105-106		4

**Note: condition rating derived from the RIIO T2 Overhead Lines Technical Asset Life and CBRM Methodology.*

Figure 1: erosion of steel wires damaging zinc coating and exposing the steel bulk material.

Figure 2: corrosion and signs of fatigue under spacer position.

Insulators and Fittings:

The ZA route insulators are of glass design with fog shrouded type predominately installed at suspension tower locations. Throughout the OHL route a number of towers have missing insulator discs and rust degradation affecting many insulator fittings. Numerous misaligned arcing horns are also a noted defect on many tension towers throughout the route.

Tension tower attachments are generally rust degraded with suspension tower earth wire fittings predominately corroded and worn, particularly the U-bolt and shackle components throughout the OHL.

Earth wire vibration dampers are generally in poor condition with a number of collapsed / broken vibration damper bells.

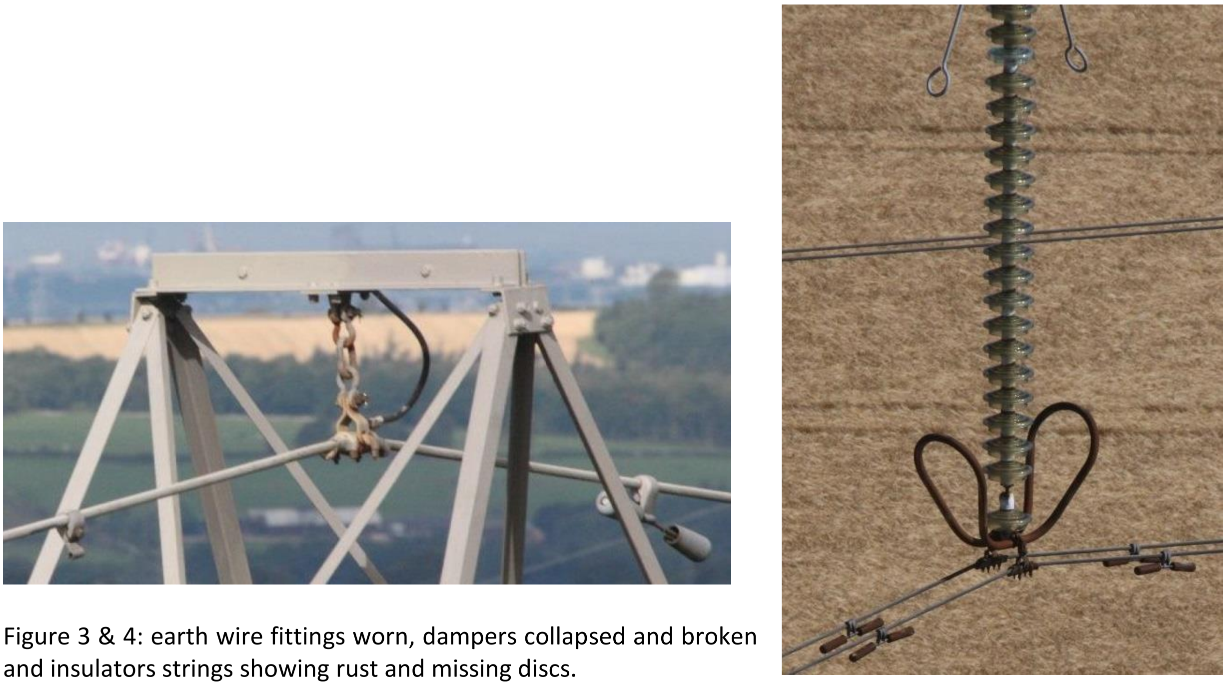


Figure 3 & 4: earth wire fittings worn, dampers collapsed and broken and insulators strings showing rust and missing discs.

Steel lattice towers:

Previous limited painting on random tower sections has resulted in surface rust / degradation of steelwork most evident on cross-arms. In conjunction, tower step bolts are severely rust degraded throughout the first half of the route from Cockenzie power station.

Figure 5: typical non-painted steelwork condition showing rust.

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 ZA Route 400kV	1966	11.99	8,615,608.15
Phase Fittings ZA Route 400kV	1966	13.15	89,226,385.59
Steel Tower ZA Route 400kV	1966	13.15	3,259,310.94

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

3. Optioneering

Three options have been considered based on the requirements identified within the condition assessments produced for the existing ZA 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 and fittings/insulators being at their end of life and no intervention will add considerable risk to two of the most critical 400kV 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 - Full Refurbishment • Major refurbishment intervention (replacement of phase conductor, earth wire and insulator/fitting) in RIIO-T2 (2026).	Considered and Proposed	-
Option 2 – Full Replacement	Rejected	Replacement of the existing OHL is unacceptable due to current condition and anticipated remaining life of the towers. 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, earth wire and fittings/insulators while refurbishing the OHL Towers during RIIO-T2 period and thereby reducing the overall risks to the network and costs. Baseline and Option 1 have been considered for a CBA analysis including 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, fittings/insulators 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 minimum twin 'Totara' 425mm^2 All Aluminium Alloy Conductor (AAAC) EHC at maximum 90^{o}C for operation at 400kV.
- Replace earth wire with a single "Keziah" 190mm^2 AACSR equivalent OPGW.
- Replace all tension and suspension insulators and conductor end fittings.
- Replace earth wire attachment configuration fittings and earth wire bonds.
- Replace tower muff foundations as required per condition.
- Upgrade foundations as required per condition.
- Replace downleads including insulators and fittings at Cockenzie and Eccles substations.
- Replace heavily corroded or damaged steelwork (above category 4).
- Carry out tower painting.
- 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	1680
Winter Post Fault	2890	2000
Spring/Autumn Pre Fault	2330	1610
Spring/Autumn Post Fault	2770	1920
Summer Pre Fault	2170	1500
Summer Post Fault	2580	1790

**at 90C Maximum Operation Temperature at 400kV.*

Specific factors attributable to this option which results in additional costs are listed below:

- 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.

- Allowances for the undergrounding of distribution crossing have also been made.

- ZA route presents a number of critical locations adjacent to railways, main roads and HV OHL's, namely:
    - Crossing type 2no. 400kV OHL crossings ('ZS' route).
    - 2no. 132kV OHL crossings ('P' route).
    - Main Roads (A1, A68 & A697) crossings.
    - Main East Coast Railway line crossing.
    - Close proximity to urban areas, evident at beginning of route.
- Terrain comprising of urban areas, open undulating farmland with some locations in excess of 400m high (A.O.D.).

The following specific risks have been identified for this option:

- 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/under or adjacent to other transmission OHL's ('P' & 'ZS' routes) to be addressed through controlled outages or by deployment of a catenary support system.
- 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	£ 1,562.79	£ -
1	Full Refurbishment	Y	£ 1,827.76	£ 264.97

5. Conclusion

The 3 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, earth wire and insulator/fittings) is the selected option:

- Scheme Total Cost: £44.6M
- Timing of investment: 2020 – 2023
- Declared outputs:

Asset Description	Type of Activity	Disposal (cct. Km/sets/each)	Addition/Activity (cct. Km/set/each)
400kV OHL (Tower Line) Conductor	Replacement	131.6 cct. Km	131.6 cct. Km
400kV OHL Fittings	Replacement	388 sets	388 sets
400kV Tower	Refurbishment Major	-	194 each

- Long term risk benefit (LR£m):

Asset Description	Long Term Risk Benefit (LR£m)
400kV OHL (Tower Line) Conductor	430.91
400kV OHL Fittings	1,388.86
400kV Tower	53.87

- 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