AL ROUTE 132kV OHL MAJOR REFURBISHMENT	
Name of Scheme/Programme	AL Route 132kV OHL Major Refurbishment
Primary Investment Driver	Asset Health
Scheme reference/ mechanism or category	SPNLT207/Overhead (Tower) Line
Output references/type	NLRT2SP207/132kV OHL (Tower) Conductor, NLRT2SP207/132kV OHL Fittings, NLRT2SP207/132kV OHL Tower
Cost	£8.9M
Delivery Year	2024
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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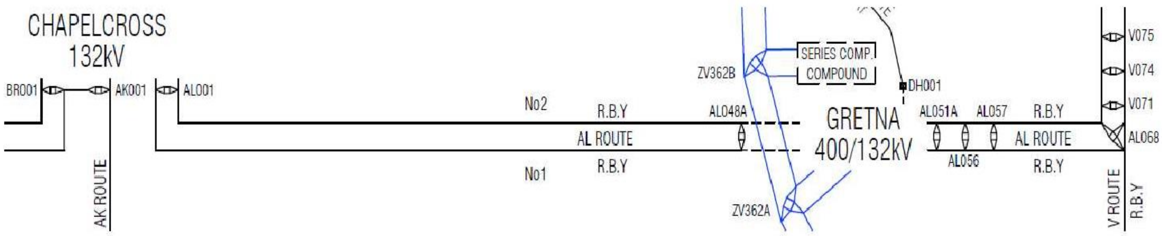
1. Introduction

This justification paper supports a proposal to carry out a major refurbishment of the AL route, 132kV transmission overhead line between Chapelcross and Gretna substations and the junction with National Grid (NGET) boundary.

The section of route between Chapelcross and Gretna substations consists of a double circuit single ACSR 175mm2 'Lynx' phase conductor and a single ACSR 70mm2 'Horse' earthwire conductor supported on 49 steel lattice towers (AL001 to AL048A) of PL16/L4 design with an approximate route length of 12.90km and circuit length of 25.80km. The section of route between Gretna substation and the NGET boundary consists of a double circuit single ACSR 175mm2 'Lynx' phase conductor and an equivalent AACSR 'Horse' OPGW earthwire supported on 6 steel lattice towers (AL051A to AL056) of PL16/L4 design with an approximate route length of 1.41km and circuit length of 2.82km. The driver 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.



SYSTEM DIAGRAM EXTRACT

A requirement to increase the level of generation within the area resulted in a proposed re-conductoring of the GRNA-HAWI-HARK circuit (TORI 233; AL051A – AL056) with AAAC 200mm^2 Poplar conductor to facilitate an increase of the thermal rating capability of the OHL. Both the condition and the load drivers are satisfied by this proposal and this project is included in the non-load related business plan.

In line with above, the proposed 132kV 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)
132kV OHL (Tower Line) Conductor	Replacement	28.6 cct. Km	28.6 cct. Km
132kV OHL Fittings	Replacement*	98 sets	98 sets
132kV Tower	Refurbishment Major	-	55 each

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

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 (AL Route) is a double circuit overhead line that forms a 132kV connection between Chapelcross, Gretna substations and the NGET boundary which traverses predominately through agricultural land with occasional residential property and outbuildings located in close proximity. No alterations to the system configuration have been proposed.

The existing conductor from towers (AL001 – AL047A) is designated as a 175mm2 ACSR 'Lynx' installed in 1958 with a configuration of one conductor per phase. Alterations at Gretna substation resulted in the construction of towers (AL048A, AL051A & AL052) in 2003 which have 200mm^2 AAAC 'Poplar' conductor installed with a configuration of one conductor per phase. Downleads at tower AL048A are also 200mm^2 AAAC 'Poplar' conductor. The existing section of earthwire which runs from towers (AL001 - AL048A) is designated as a 70mm2 ACSR 'Horse' conductor with no optical fibre. The remainder of the route from towers (AL051A - AL056) has an equivalent earthwire conductor, AACSR 'Horse' with an integral Optical Ground Wire (OPGW) installed.

AL route circuits are single conductor between towers AL001 and AL056:

Phase Conductor Type:

- AL001 – AL047A (ACSR 'Lynx' installed in 1958).
- AL047A – AL048A (AAAC 'Poplar', installed in 2003).
- AL051A – AL052 (AAAC 'Poplar', installed in 2003).
- AL052 – AL056 (ACSR 'Lynx', installed in 1958).

Earthwire Conductor Type:

- AL001 – AL048A (ACSR 'Horse', installed in 1958).
- AL051A – AL056 (AACSR 'Horse' equivalent OPGW, installed 2007).

Insulators Type:

- AL001 – AL048A (Glass, installed in 2015).
- AL051A - AL056 (Glass, installed 2012).

Tower Type:

- AL001 – AL048A (steel lattice Blaw Knox, PL16 design, installed in 1958).
- AL051A & AL052 (steel lattice, L4 design, installed in 2003).
- AL053 – AL056 (steel lattice, Blaw Knox, PL16 design, installed in 1958).

AL route has 4 no. operating circuits with circuit nomenclatures and colours as follows:

- CHAP – GRNA1 (AL001 – AL048A / AL051A – AL056) Circuit Colour: black (B).
- CHAP – GRNA2 (AL001 – AL048A / AL051A – AL056) Circuit Colour: red / white (R/WH).
- GRNA – HAWI Circuit Colour: green (GR).
- GRNA – HAWI – HARK Circuit Colour: red / blue (R/BU).

AL route presents a number of critical locations adjacent to railways, main roads and HV OHL's, namely:

- 8no. 11kV OHL crossings.
- 1no. 33kV OHL crossings.
- Main Roads (A74) crossing.
- Main Railway line crossing.
- Terrain comprising of urban areas, open undulating farmland with some locations in excess of 100m high (A.O.D.).

The route traverses through varied environmental areas with differing levels of pollution with more than 70% of the line located within the heavily polluted 5km zone adjacent to the coastline.

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, conductor sampling, steelwork inspection and foundation intrusive have been employed to provide a detailed condition analysis of the OHL components.

- Aerial photographic inspection.
- Cormon testing.
- Conductor sampling.
- Steelwork inspection.
- Foundation intrusive investigation.

2.2 Data Analysis and Interpretation

The collected condition data has been analysed following "ASSET-01-030 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 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.

<u>Phase and Earth wire conductors:</u>

Conductor samples collected from highly polluted areas over the SP Network indicates that the anticipated life following an ageing profile (internal galvanic corrosion) of an ACSR 'Lynx' (core-only greased) conductor is 45 years (typically 55-60 years for "moderately and low polluted" areas).

However, additional factors including quality, manufacturing, design and lack of maintenance can accelerate the typical ageing profile of the conductors:

Cormon testing was carried out on the top phase conductor and earthwire over several span locations throughout the route in 2006 and 2018 indicating a deterioration of the steel wires' galvanic protection (zinc layer) from 'partial' to 'severe' readings.

A conductor sample was collected at the span AL042-043 (*top phase/Chap-Grna 2 cct.*) which presented steel core strands exhibiting rusting, low levels of bitumen between wires, significant levels of corrosion product associated with the inner aluminium strands and aluminium wires torsion test failure.

A summary of the condition ratings is shown below:

Activity	Span	Summary Result	Condition Rating Value*
Cormon Phase conductor: ACSR Lynx core only greased	AL007-008	"Severe"	5
	AL043-044	"Partial"	4
Cormon earthwire conductor: ACSR Horse	AL007-008	"Severe"	5
	AL043-044	"Partial"	4
Conductor Sample Phase conductor: ACSR Lynx core only greased	AL042-043	Zinc degradation and Al torsion test well below 25 turns	5

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

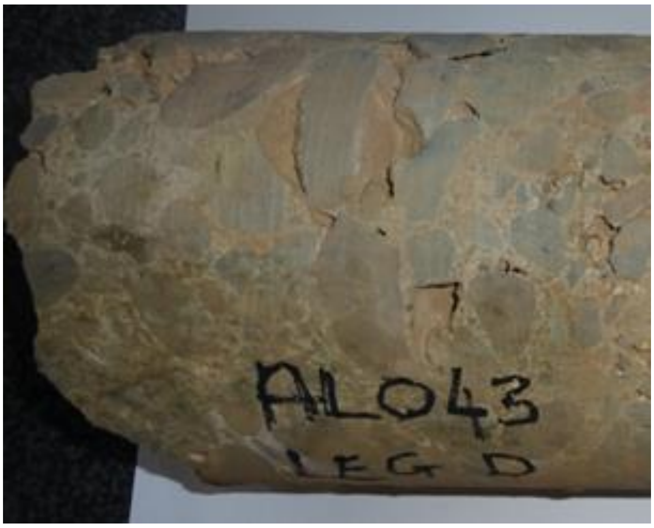
Figure 1: inner aluminium strands exhibit a significant level of aluminium corrosion product.

Figure 2: steel core strands exhibiting rusting.

Steel Towers:

AL route tower steelwork condition from towers (AL001 - AL048A) is considered to be of an adequate condition; however foundation intrusive inspection carried out on 3 towers (AL007, AL030, AL043) presented significantly smaller dimensions than the original foundation records for this type of structures while concrete core sample taken at tower AL043 didn't meet the minimum concrete strength requirements.

AL043 Tower Foundation



Concrete core sample

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 AL Route 132kV	1958	9.89	1,202,599.60

**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 AL 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 AL 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 AL Route were installed in 2015 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 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 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 single 'Poplar' 200mm2 All Aluminium Alloy Conductor (AAAC) EHC at maximum 75C for operation at 132kV. It will fulfil requirements on TORI 233.
- Replace earthwire, towers (AL001 – AL048A) with a single "Horse" 70mm2 AACSR equivalent OPGW.
- Replace all tension and suspension conductor end fittings.
- Replace earthwire fittings.
- Replace tower muff foundations where required.
- Upgrade foundations as required per condition.
- Replace downleads and fittings at Chapelcross substation and at sealing end platform, Gretna substation.
- Replace heavily corroded or damaged steelwork (above category 4).
- 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 conductor, 200mm2 AAAC (Poplar) EHC system thermal ratings*:

Season / State	Amps	MVA
Winter Pre Fault	615	140
Winter Post Fault	730	167
Spring/Autumn Pre Fault	590	134
Spring/Autumn Post Fault	700	160
Summer Pre Fault	540	124
Summer Post Fault	645	147

**at 75C Maximum Operation Temperature*

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

- Foundation intrusive investigations carried out along AL Route exhibit foundations with no significant means of degradation but poor workmanship translating into smaller foundation dimensions when compared to original designs. This is translated into a lack of uplift and compression capacity so careful assessment is needed.

  Additional foundation intrusive inspections have been carried out on a sample of PL16 towers at identified locations across the Network (a total of 29 inspections) in order to further understand its condition and workmanship quality.

  Collected information has been analysed, grouped by types of defects and calculated the probability of having those defects across a bigger population following CIGRE 141 "Refurbishment and Upgrading of Foundations". Results are summarised below:

  - 45% (for a P50% confidence probability level) of the towers along the PL16 routes build on the 50s-60s could present small pyramid when compared to original designs or non-existent. This present a lack of foundation uplift/compression capacity.
  - 17% of the towers along the PL16 routes build on the 50s-60ss could present signs of degradation (honeycombing, fatigue, discolour).

  Based on the above and following a risk based assessment, an allowance for foundation upgrade on all towers in close proximity to relevant crossings has been considered (roads, motorways and rail) representing a minimum of 17% of the total towers along the route.

  In addition, further exploratory ground investigations to assess the condition of the tower foundations below ground level are included on quantified risk assessments (QRA) approach.

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

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 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	£ 66.83	£ -
1	Conductor and earth wire Replacement	Y	£ 70.21	£ 3.38

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: £8.9M
- Timing of investment: 2020 – 2024
- Declared outputs:

Asset	Type of Activity	Disposal (cct. Km/sets/each)	Addition/Activity (cct. Km/set/each)
132kV OHL (Tower Line) Conductor	Replacement	28.6 cct. Km	28.6 cct. Km
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- Longer term risk benefit (LR£m):

Asset	Long Term Risk Benefit (LR£m)
132kV OHL (Tower Line) Conductor	77.71

- Price control period of outputs: 2024

6. <u>FUTURE PATHWAYS – NET ZERO</u>

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