XD, XN, XK, XM ROUTES: KINCARDINE – GRANGEMOUTH – CURRIE REFURBISHMENT	
Name of Scheme/Programme	SPNLT20105 XD Jnc. XN route to Kincardine Major Refurbishment (Recond 10cctkm) SPNLT20106 XK - Jnc. XN route to Jnc. XM route OHL modernisation Major Refurbishment (Recond 21cctkm) SPNLT20107 XM - Jnc. XK route to Currie OHL modernisation Major Refurbishment (Recond 62cctkm) SPNLT20108 XN Jnc. XD route to Jnc. XK route/ Jnc. XK route to Grangemouth Major Refurbishment (Recond 19cctkm)
Primary Investment Driver	Asset Health
Scheme reference/ mechanism or category	SPNLT20105/Overhead (Tower) Line SPNLT20106/Overhead (Tower) Line SPNLT20107/Overhead (Tower) Line SPNLT20108/Overhead (Tower) Line
Output references/type	NLRT2SP20105 OHL Fittings NLRT2SP20106 OHL Fittings NLRT2SP20107 OHL Fittings NLRT2SP20108 OHL Fittings
Cost	£11.03m
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
August 2020	Issue 1	First issue of document

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1. Introduction

These overhead line routes had been identified as potential candidates for intervention in the RIIO-T1 period but the works were interactive with a potential wider works reinforcement (an alternative to the DWNO NOA scheme which is now progressing) which would have required a different scope of works. The non-load related works were therefore classified as 'trigger' schemes and governed by the provisions of Licence Special Condition (LSpC) 6H. As confirmed by Ofgem in the mid-period review parallel work decision, the NOMS targets were set on the basis of no intervention on these routes. As the associated wider works did not proceed and SPT made no application for funding under LSpC 6H, these works were not funded in RIIO-T1.

Review of the assets' condition confirmed that the orginial planned scope – major refurbishment of the routes – could be deferred, therefore the works defined in LSpC 6H were not 'triggered'. However, a number of condition issues were identified that required intervention in late RIIO-T1 and early RIIO-T2 in advance of reconductoring work (please also see scheme SPNLT2032 which is planned for completion in 2030).

This paper supports a proposal for a targeted minor refurbishment of Currie-Kincardine (CURR-KINC), Kincardine-Grangemouth (KINC-GRMO) and Currie-Grangemouth (CURR-GRMO) circuits; towers XD128-XN001, XN001-XN032, XN030/XK004-XK035 and XM001-XM093. Works shall include for the replacement of insulators only (excluding insulators replaced on XN route in 2004) with fittings replaced where required and replacement of dampers and spacers where found to be defective. Cormon tests carried out identified evidence of corrosion of the earthwire on XM route. This in conjunction with previous earthwire optical fibre wrap damage and fittings failure has initiated the replacement of the earthwire system on XM route. The ACSR earthwire including fibre wrap shall be replaced with an optical ground wire (OPGW) containing an integral optical fibre cable within the earthwire. In addition, individual heavily corroded or damaged tower steelwork (above category 4) shall be replaced.

The sections being considered consist of:

- XD Route 400/275kV transmission double circuit overhead line between Kincardine substation and the Junction of XN Route (Tower XN001). The scope of this project includes only for the section between XD Route tower XD128 to the junction with the XN Route at tower XN001. This section of the line comprises 9 double circuit towers of L2 design, it has an approximate route length of 3.59 km and a circuit length of 7.18 km. The line was originally constructed with a twin 400 mm^2 ACSR "Zebra" phase conductor and a single 175 mm^2 ACSR "Lynx" earthwire conductor.
- XN Route 400/275kV transmission double circuit overhead line between Junction XD Route (Tower XD119), Junction XK Route (Tower XK004) and Grangemouth S/S. The line comprises 32 double circuit towers of L2(U) design, 1 double circuit tower of L8(c) design (XN30A), it has an approximate route length of 10.11 km and a circuit length of 20.22 km. The line was originally constructed with a twin 400 mm^2 ACSR "Zebra" phase conductor and a single 175 mm^2 ACSR "Lynx" earthwire conductor insulated for 400 kV operation but operated at 275 kV.
- XK Route 400/275kV transmission double circuit overhead line between Junction XN Route (Tower XN030) and Junction XM Route (Tower XM001). The line comprises 32 double circuit towers of L2(U) design, it has an approximate route length of 10.74 km and a circuit length of 21.48 km. The line was originally constructed with a twin 400 mm^2 ACSR "Zebra" phase

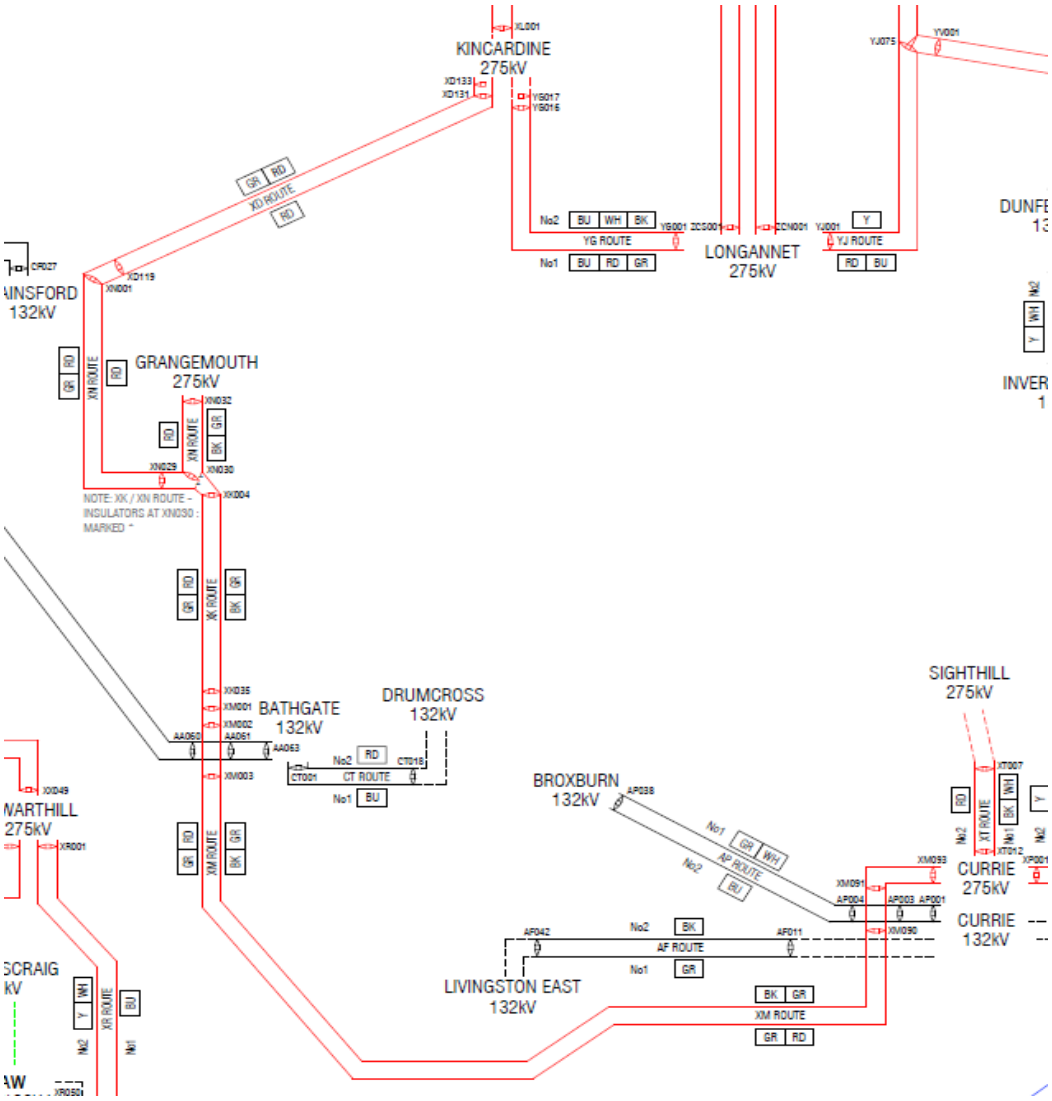
conductor and a single 175 mm^2 ACSR "Lynx" earthwire conductor insulated for 400 kV operation but operated at 275 kV.

- XM Route 400/275kV transmission double circuit overhead line between Junction XK Route (Tower XK035) and Currie S/S. The line comprises 93 double circuit towers of L2(U) design, it has an approximate route length of 30.77 km and a circuit length of 61.54 km. The line was originally constructed with a twin 400 mm^2 ACSR "Zebra" phase conductor and a single 175 mm^2 ACSR "Lynx" earthwire conductor insulated for 400 kV operation but operated at 275 kV.

The approximate cumulative overall length of the combined XD Route (XD119 – XD128), XN Route (XN001 – XN032) XK Route (XK004 – XK035) and XM (XM001-XM093) routes section is 55.21km with a circuit length of 110.42km.

The circuits cross major system boundary B5 and form the supply to the Grangemouth petrochemical complex.

The driver for the proposal is the asset health of insulators/fittings and XM Route earthwire which will be approaching the end of the operational life by end of RIIO-T1 without intervention after site specific investigations and data analysis.



SYSTEM DIAGRAM EXTRACT

In line with above, the proposed 275/400kV 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)
Earth wire Conductor (XM Route Only)	Replacement	30.8cct. Km	30.8cct. Km
275kV OHL Fittings	Replacement	334 sets	334 sets
275kV OHL Tower	Refurbishment Major	-	167

2. Background Information

The existing XD Route was built in 1962, XN Route built in 1965, XK Route built in 1964 and XM Route built in 1965 as a 275/400kV double circuit overhead line route using the L2 suite of towers. The overhead line routes form a connection between Kincardine, Grangemouth and Currie substations, traverse a mixture of terrain containing many natural and manmade elements whilst passing in close proximity to several buildings, football stadium and recreational areas (Helix Park,

Kelpies and playing fields), several main roads, unclassified roads, railway tracks, access tracks and watercourses along with numerous utility services were also noted crossing the routes including LV, 11kV, 33kV overhead lines and BP / National Grid gas pipe lines.

The XD section of the route (junction to the XN Route at tower XN001 and tower XD128) consist of existing twin conductor per phase designated as a 400mm^2 ACSR 'Zebra' installed in 1962 supported on steel lattice towers. The existing earth wire is designated as a 175mm^2 ACSR 'Lynx' conductor installed in 1962 with no optical fibre.

The XN section of the route (Tower XD119, Junction XK Route (Tower XK004) and Grangemouth S/S) consist of existing twin conductor per phase designated as a 400mm^2 ACSR 'Zebra' installed in 1965 supported on steel lattice towers. The existing earth wire is designated as a 175mm^2 ACSR 'Lynx' conductor installed in 1965 with fibre optic wrap installed in 1992. All Insulators on the XN route with the exception of tower XN30A were replaced in 2004.

The XK section of the route (Junction XN Route (Tower XN030) and Junction XM Route (Tower XM001)) consist of existing twin conductor per phase designated as a 400mm^2 ACSR 'Zebra' installed in 1964 supported on steel lattice towers. The existing earth wire is designated as a 175mm^2 ACSR 'Lynx' conductor installed in 1964 with fibre optic wrap installed in 1992.

The XM section of the route (Junction XK Route (Tower XK035) and Currie S/S) consist of existing twin conductor per phase designated as a 400mm^2 ACSR 'Zebra' installed in 1965 supported on steel lattice towers. The existing earth wire is designated as a 175mm^2 ACSR 'Lynx' conductor installed in 1965 with fibre optic wrap installed in 1992.

XD, XN, XK and XM route circuits are a twin conductor configuration:

Phase Conductor Type:

- XD119 to XD128 - (ACSR 'Zebra' core only greased installed 1965).
- XN001 to XN032 - (ACSR 'Zebra' core only greased installed 1965).
- XK004 to XK035 - (ACSR 'Zebra' core only greased installed 1964).
- XM001 to XM093 - (ACSR 'Zebra' core only greased installed 1965).

Earth wire Conductor Type:

- XD119 to XD128 - (ACSR 'Lynx' core only greased installed 1965).
- XN001 to XN032 - (ACSR 'Lynx' core only greased installed 1965).
- XK004 to XK035 - (ACSR 'Lynx' core only greased installed 1964).
- XM001 to XM093 - (ACSR 'Lynx' core only greased installed 1965).

Insulators Type:

- XD119 to XD128 - (Porcelain Brown installed 1962).
- XN001 to XN032 - (Glass Installed 1965; replaced 2004 with the exception of tower XN30A)
- XK004 to XK035 - (Glass installed 1964).
- XM001 to XM093 - (Glass installed 1965).

Spacer Type:

- XD119 to XD128 - ('Generic' twin spacers, installed 1962).

- XN001 to XN032 - ('Generic' twin spacers, installed 1965).
- XK004 to XK035 - ('Generic' twin spacers, installed 1964).
- XM001 to XM093 - ('Generic' twin spacers, installed 1965 / between towers XM021 & XM025 on CURR-GRMO Circuit only, pendulum, rigid and spacer damper de-turners installed 1995).

Tower Type:

- XD119 to XD128 - (Steel Lattice L2 Design, Installed 1965).
- XN001 to XN032 - (Steel Lattice L2 Design, Installed 1965 with the exception of tower XN30A this is an L8c Design).
- XK004 to XK035 - (Steel Lattice L2 Design, Installed 1964).
- XM001 to XM093 - (Steel Lattice L2 Design, Installed 1965).

There are 3 operating circuits on these routes. Circuit nomenclatures and colours for the XD, XN, XK and XM routes are:

- CURR – KINC (XD) – Circuit Colour; Red / Green (B/R/Y).
- GRMO – KINC (XD) – Circuit Colour; Red (Y/B/R).
- CURR – KINC (XN) - Circuit Colour; Red / Green (B/R/Y).
- CURR – GRMO (XN) - Circuit Colour; Black / Green (Y/B/R).
- GRMO – KINC (XN) – Circuit Colour; Red (Y/B/R).
- CURR – GRMO (XK) - Circuit Colour; Black / Green (Y/B/R).
- CURR – KINC (XK) - Circuit Colour; Red / Green (B/R/Y).
- CURR – GRMO (XM) - Circuit Colour; Black / Green (Y/B/R).
- CURR – KINC (XM) - Circuit Colour; Red / Green (B/R/Y).

XD, XN, XK and XM routes present a number of critical locations adjacent to watercourses, main roads, buildings and HV OHLs:

- 6no. Water Crossing (1no. XD / 2no. XN / 1no. XK / 2no. XM).
- 2no. Canal Crossing (0no. XD / 1no. XN / 1no. XK / 0no. XM).
- 11no. Railway Crossings (0no. XD / 1no. XN / 1no. XK / 9no. XM).
- 23no. Building Crossings (1no. XD / 8no. XN / 8no. XK / 6no. XM).
- 11no. Gas Pipe line Crossings (0no. XD / 1no. XN / 1no. XK / 0no. XM).
- 20no. Single Lane B Road (0no. XD / 10no. XN / 1no. XK / 0no. XM).
- 22no. Double Lane B Road (0no. XD / 3no. XN / 6no. XK / 13no. XM).
- 15no. A Road (0no. XD / 3no. XN / 4no. XK / 8no. XM).
- 4no. Dual Carriageway (0no. XD / 4no. XN / 0no. XK / 0no. XM).
- 7no. Motorway (0no. XD / 4no. XN / 1no. XK / 2no. XM).
- 3no. 132kV OHL crossing ('AA' , 'AF' & 'AP' route).
- 41no. 11kv OHL crossing (5no. XD / 1no. XN / 14no. XK / 21no. XM).
- 6no. 11kv OHL crossing (0no. XD / 2no. XN / 2no. XK / 2no. XM).

2.1 Data Collection

As part of the SP Energy Networks (SPEN) OHL inspection regime, aerial photographic information has been employed to provide a detailed condition analysis of the OHL components.

XD Route:

- Aerial photographic inspection 2019
- Phase conductor sample 2019

XN Route:

- Aerial photographic inspection 2018
- Phase conductor sample 2019

XK Route:

- Aerial photographic inspection 2013
- Phase conductor sample 2019

XM Route:

- Aerial photographic inspection 2014
- Phase conductor sample 2019

2.2 Data Analysis and Interpretation

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

The conductor samples taken in 2019 indicate that there is sufficient remaining life to defer the replacement of the phase conductors until the RIIO-T3 period.

In accordance with ASSET-01-030, the following details the anticipated lives of the insulators on these routes

Route	Environment Class	Expected Life	Age at End of RIIO-T1
XD Route	Class A	40 years	59 years
XK Route	Class B	45 years	57 years
XM Route	Class B	45 years	56 years
XN Route	Class A	40 years	17 years

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£)*
Phase Conductor XD Route (XD119 to XD128)	1962	6.90	1,032,798.10
Phase Fittings XD Route (XD119 to XD128)	1962	10.87	49,228,229.59
Phase Conductor XN Route (XN001 to XN032)	1965	6.92	4,238,657.36
Phase Conductor XK Route (XK004 to XK035)	1964	6.92	3,437,445.44
Phase Fittings XK Route (XK004 to XK035)	1964	10.85	141,063,425,35
Phase Conductor XM Route (XM001 to XM093)	1965	6.92	8,087,721.68
Phase Fittings XM Route (XM001 to XM093)	1965	9.49	181,875,272.69

**Values at the end of the RIIO-T1 period with no intervention as per NOMs methodology.*

Note: no replacement proposed to steel towers along Route; however, allowances to replace heavily corroded or damaged steelwork and foundation upgrades have been made.

3. Optioneering

Three options have been considered based on the requirements identified within the condition assessments produced for the existing XD, XN, XK and XM overhead line routes, 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 all refurbishment interventions to RIIO-T3.	Rejected	This option is unacceptable due to the overall condition of the fittings/insulators and earthwire (XM route) being at their end of life and no intervention will add considerable risk to two of the most critical 275kV circuits within the SPT Network.
Option 1 - Minor Refurbishment: • Minor refurbishment intervention (replacement of earth wire on XM Route and insulators XD, XK and XM) in late RIIO-T1/ early RIIO-T2	Considered & proposed	
Option 2 – Major Refurbishment • In addition to the scope of option 1, replacement of phase conductors.	Rejected	Conductor tests from 2019 indicate that there is sufficient remaining life to defer intervention until RIIO-T3. The works are planned to complete in 2030 (scheme SPNLT2032).

4. Detailed analysis

Option 1 achieves the main objective of replacing earth wire on XM Route and fittings/insulators on XD, XK and XM Routes while refurbishing the OHL Towers and thereby reducing the overall risks to the network and costs.

4.1 Option 1: Minor Refurbishment

This option considers replacement of the replacement of the XM Route earthwire conductors and XD, XK, XM and XN routes' fittings as identified through condition data, data analysis and interrogation. The following interventions are proposed to be replaced in a staged manner in this option:

- Replacement of Lynx (fibre wrapped) earthwire with Keziah equivalent OPGW on XM route only. Cognisance shall be taken of previously experienced galloping problems on the section of XM route between towers XM021 and XM025.
- Tate and Noral joints shall be identified along the XK, XN and XM OHL routes and where required addressed through installation of a tethered joint by-pass system.
- Carry out conductor sampling in different locations of the XD, XK, XN & XM routes overhead lines to update the predicted remaining life of the existing conductor in support of future intervention.
- All insulators on XD, XK and XM routes shall be replaced to suit 400kV construction, operating at 275kV with exception of previously replaced insulators on the XN route in 2004. Fittings shall be assessed and replaced where required. Insulators on XN route, tower XN030A only, to be assessed and replaced as necessary.
- All downlead insulators, fixtures and fittings shall be assessed and replaced as required.
- Fibre optic connections into Currie and Grangemouth substations together with the Optical Distribution Frames (ODF) and cabinets installed within substations telecomms room.
- All tower steelwork shall be assessed and replaced as required in conjunction with the installation of any outstanding TGN(E) 163 modifications; required only where suspension insulators are being replaced.
- All tower foundation muffs shall be inspected and if found to be defective, broken out and replaced where required.
- Tower steelwork on XM route OHL only shall be painted.
- Provide report to the Asset manager to include condition of all redundant conductors, fittings, steelwork and foundations along with associated tests logs for existing/new concrete.

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

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

4.2 Selected Option

Option 1 fulfils the requirement of addressing critical condition issues while minimising costs through the maximisation of the economic life of the phase conductor.

5. Conclusion

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

In line with the costs prepared and the proposed scope of works, option 1 (minor refurbishment) is the selected option:

- Scheme Total Cost: £11.03m
- Timing of investment: 2023
- Declared outputs:

Asset	Type of Activity	Disposal (cct. Km/sets/each)	Addition/Activity (cct. Km/set/each)
Earth wire Conductor (XM Route Only)	Replacement	30.8cct. Km	30.8cct. Km
275kV OHL Fittings	Replacement	334 sets	334 sets
275kV OHL Tower	Refurbishment Major	-	167

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 conducted was part of a wider analysis which included the reinforcement aspects of the project. 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 for this element of the wider project were 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

Whole system benefits have been considered as part of this proposal. The capacity and capability of the preferred option is consistent with the provision of whole system solutions.

7. OUTPUTS INCLUDED IN RIIO T1 PLANS

N/A