OHL MINOR REFURBISHMENT PROGRAMME	
Name of Scheme/Programme	SPNLT200 – ZD & ZC(S) Routes 275kV Minor Refurbishment SPNLT201 – ZC(N) Route 275kV Minor Refurbishment) SPNLT20138 – ZP Route 400kV Minor Refurbishment (circuit 2) SPNLT203 – ZP Route 400kV Minor Refurbishment (circuit 1) SPNLT2013 – ZE Route 275kV Minor Refurbishment SPNLT2014 – ZF Routes 400kV Minor Refurbishment SPNLT2015 – YK Route 275kV Minor Refurbishment SPNLT2016 – YQ Route 275kV Minor Refurbishment SPNLT2017 – XD Route: Kincardine Crossing Towers Minor Refurbishment SPNLT2019 – ZS Route 400kV Minor Refurbishment SPNLT2020 – ZT Route 400kV Minor Refurbishment
Primary Investment Driver	Asset Health
Scheme reference/ mechanism or category	SPNLT200/Overhead (Tower) Line SPNLT201/Overhead (Tower) Line SPNLT203/Overhead (Tower) Line SPNLT2013/Overhead (Tower) Line SPNLT2014/Overhead (Tower) Line SPNLT2015/Overhead (Tower) Line SPNLT2016/Overhead (Tower) Line SPNLT2017/Overhead (Tower) Line SPNLT2019/Overhead (Tower) Line SPNLT2020/Overhead (Tower) Line
Output references/type	NLRT2SP200: 275kV OHL (Tower) Conductor/275kV Fittings/275kV OHL Tower NLRT2SP201: 275kV OHL (Tower) Conductor/275kV Fittings/275kV OHL Tower NLRT2SP203: 400kV OHL (Tower) Conductor/400kV Fittings/400kV OHL Tower NLRT2SP2013: 275kV OHL (Tower) Conductor/275kV Fittings/275kV OHL Tower NLRT2SP2014: 275kV OHL (Tower) Conductor/275kV Fittings/275kV OHL Tower NLRT2SP2015: 275kV OHL (Tower) Conductor/275kV Fittings/275kV OHL Tower NLRT2SP2016: 275kV OHL (Tower) Conductor/275kV Fittings/275kV OHL Tower NLRT2SP2017: 275kV OHL (Tower) Conductor/275kV Fittings/275kV OHL Tower NLRT2SP2019: 275kV OHL (Tower) Conductor/275kV Fittings/275kV OHL Tower NLRT2SP2020: 275kV OHL (Tower) Conductor/275kV Fittings/275kV OHL Tower
Cost	SPNLT200 – ZD & ZC(S) Routes 275kV Minor Refurbishment: £8.4M SPNLT201 – ZC(N) Route 275kV Minor Refurbishment: £4.3M SPNLT203 – ZP Route 400kV Minor Refurbishment (Circuit 1): £4.5M (£3.9M in T2) SPNLT20138 – ZP Route 400kV Minor Refurbishment (Circuit 2): £4.5M (£3.9M in T2) SPNLT2013 – ZE Route 275kV Minor Refurbishment: £1.8M SPNLT2014 – ZF Routes 400kV Minor Refurbishment: £2.7M SPNLT2015 – YK Route 275kV Minor Refurbishment: £0.7M SPNLT2016 – YQ Route 275kV Minor Refurbishment: £0.4M SPNLT2017 – XD Route: Kincardine Crossing Towers Minor Refurb.: £5.2M SPNLT2019 – ZS Route 400kV Minor Refurbishment: £8.6M SPNLT2020 – ZT Route 400kV Minor Refurbishment: £2.8M
Delivery Year	2022 – 2027
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	Yes (SPNLT2015 – YK Route 275kV Minor Refurbishment)

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. ZP Route project updated to ZP Route (circuit 1).
August 2020	Issue 3	Draft Determination Consultation Response. ZP Route project updated to both circuits (Schemes SPNLT203 and SPNLT20138).

Table of contents

1. Introduction

This paper supports a proposal to carry out a minor refurbishment programme whose interventions include the replacement of insulators and associated fittings, spacer and vibration dampers, steelwork refurbishment and minor steelwork replacement.

The principal drivers for the proposal are:

- Insulator/Fittings: glass or porcelain insulators which present an increased risk of flashover or a decrease in mechanical strength due to corrosion of the steel fittings holding the insulator string to the supports or cotter pin migration (in particular on L6 tower fitting arrangement as observed and reported from different parts of the SPT Network).
- Spacer, Spacer Dampers and vibration Dampers: these items are designed to be fitted to conductors mid-span and are utilised to protect the conductor system from damage, however evidence indicates that end of life for some ACSR conductor OHL routes at certain operating environments is caused by fatigue due to wind induced damage at conductor to conductor component fitting locations and not corrosion. Damage mostly occurs around fittings and spacers affecting the conductor aluminium strand wires. This form of deterioration may become the limiting aspect for L6 OHL's with all inner layers greased conductors, in particular where quad 'Andre' spacers have been installed and 'Bowthorpe' semi-rigid spacer on twin bundle.

  In some geographical areas, quad bundle conductors are particularly prone to sub-conductor oscillation. This phenomenon proves difficult to proactively predict where it will occur, however, this programme will incorporate spacers including an element of damping to provide a degree of protection in such situations.

  Spacer replacement interventions are also proposed on those OHL routes where spacer dampers were originally installed and there is evidence of damping reduction or spacer collapse. This will prevent fittings wear and conductor damage and therefore maintain the protection of the conductor system and avoid its early degradation and replacement caused by fatigue and not corrosion.

As part of the SPT OHL inspection regime, aerial photographic information in conjunction with route specific investigations including climbing inspections have been employed to provide a detailed condition analysis rating of the OHL components.

The following OHL routes and level of interventions are included within this programme:

1.1 ZD and ZC(S) OHL 275kV Routes

It is proposed to carry out spacer replacement and tower painting along ZD Route and spacer, phase insulator/fitting, earth wire fittings and individual steelwork members replacement and conductor repairs along ZC(S) Route between towers ZC(S) 001-ZC(S) 054A.

In line with above, the proposed 275kV outputs to be delivered are:

Asset	Type of Activity	Disposal (cct. Km/sets/each)	Addition/Activity (cct. Km/sets/each)
275kV OHL (Tower Line) Conductor	Repair	-	103 cct. Km
275kV OHL Fittings	Replacement	298 sets	298 sets
275kV Tower	Refurbishment Major	-	149 each

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

1.2 ZC(N) OHL 275kV Route

It is proposed to carry out spacer, phase insulator/fitting and earth wire fittings replacement, conductor repairs and individual steelwork members replacement between towers ZC(N)001-ZC(N)054A.

In line with above, the proposed 275kV outputs to be delivered are:

Asset	Type of Activity	Disposal (cct. Km/sets/each)	Addition/Activity (cct. Km/sets/each)
275kV OHL (Tower Line) Conductor	Repair	-	37.6 cct. Km
275kV OHL Fittings	Replacement	108 sets	108 sets
275kV Tower	Refurbishment Major	-	54 each

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

1.3 ZP OHL 400kV Route (Circuits 1 & 2)

It is proposed to carry out spacer, phase insulator/fitting, earth wire fittings and individual steelwork member replacement, conductor repairs and tower painting along ZP Route.

In line with above, the proposed 400kV outputs to be delivered are:

Asset	Type of Activity	Disposal (cct. Km/sets/each)	Addition/Activity (cct. Km/sets/each)
400kV OHL (Tower Line) Conductor	Repair	-	55 cct. Km
400kV OHL Fittings	Replacement	162 sets	162 set
400kV Tower	Refurbishment Major	-	81 each

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

1.4 ZE OHL 275kV Route

It is proposed to carry out phase insulator/fitting, earth wire fitting, conductor repairs and individual steelwork member replacement along ZE Route.

In line with above, the proposed 275kV outputs to be delivered are:

Asset	Type of Activity	Disposal (cct. Km/sets/each)	Addition/Activity (cct. Km/sets/each)
275kV OHL (Tower Line) Conductor	Repair	-	20.8 cct. Km
275kV OHL Fittings	Replacement	60 sets	60 sets
275kV Tower	Refurbishment Major	-	30 each

1.5 ZF OHL 400kV Route

It is proposed to carry out spacer, phase insulator/fitting, earth wire fitting replacement, conductor repairs and individual steelwork member replacement along ZF Route. In line with above, the proposed 400kV outputs to be delivered are:

Asset	Type of Activity	Disposal (cct. Km/sets/each)	Addition/Activity (cct. Km/sets/each)
400kV OHL (Tower Line) Conductor	Repair	-	37.6 cct. Km
400kV OHL Fittings	Replacement	98 sets	98 sets
400kV Tower	Refurbishment Major	-	49 each

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

1.6 YK OHL 275kV Route

It is proposed to carry out spacer, earth wire fitting replacement, conductor repairs, individual steelwork member replacement and tower painting along YK Route.

In line with above, the proposed 275kV outputs to be delivered are:

Asset	Type of Activity	Disposal (cct. Km/sets/each)	Addition/Activity (cct. Km/sets/each)
275kV OHL (Tower Line) Conductor	Repair	-	8.1 cct. Km
275kV Fittings	Replacement *(spacers)*	30 sets	30 sets
275kV Tower	Refurbishment Major	-	15 each

1.7 YQ OHL 275kV Route

It is proposed to carry out spacer, earth wire fitting replacement, conductor repairs, individual steelwork member replacement and tower painting along YQ Route.

In line with above, the proposed 275kV outputs to be delivered are:

Asset	Type of Activity	Disposal (cct. Km/sets/each)	Addition/Activity (cct. Km/sets/each)
275kV OHL (Tower Line) Conductor	Repair	-	6.9 cct. Km
275kV Fittings	Replacement *(spacers)*	24 sets	24 sets
275kV Tower	Refurbishment Major	-	12 each

1.8 XD 275kV Route: Kincardine Crossing Towers

It is proposed to carry out phase insulator/fitting, earth wire fitting replacement and tower painting on towers XD128, 129, 130, 131 and remedial foundation works on tower XD130.

In line with above, the proposed 275kV outputs to be delivered are:

Asset	Type of Activity	Disposal (cct. Km/sets/each)	Addition/Activity (cct. Km/sets/each)
275kV OHL Fittings	Replacement	8 sets	8 sets
275kV Tower	Refurbishment Major	-	4 each

1.9 ZS OHL 400kV Route

It is proposed to carry out spacer and earth wire fittings and individual steelwork member replacement, conductor repairs and tower painting along ZS Route.

In line with above, the proposed 400kV outputs to be delivered are:

Asset	Type of Activity	Disposal (cct. Km/sets/each)	Addition/Activity (cct. Km/sets/each)
400kV OHL (Tower Line) Conductor	Repair	-	108.1 cct. Km
400kV OHL Fittings	Replacement *(spacers)*	356 sets	356 sets
400kV Tower	Refurbishment Major	-	178 each

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

1.10 ZT OHL 400kV Route

It is proposed to carry out spacer, earth wire fittings and individual steelwork member replacement and conductor repairs along ZT Route.

In line with above, the proposed 400kV outputs to be delivered are:

Asset	Type of Activity	Disposal (cct. Km/sets/each)	Addition/Activity (cct. Km/sets/each)
400kV OHL (Tower Line) Conductor	Repair	-	68.5 cct. Km
400kV OHL Fittings	Replacement *(spacers)*	216 sets	216 sets
400kV Tower	Refurbishment Major	-	108 each

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

2. Background Information

2.1 ZD and ZC(S) OHL 275kV Routes

ZD Route is a double circuit overhead line constructed in 3 sections. It is comprised of 99 steel lattice towers L6 construction.

There are 3 operating circuits on this route:

- CLYM-LOAN: ZD001-ZD095A
- CLYM-EERH: ZD001-ZD026B
- EERH-LOAN: ZD026C-ZD095A

CLYM-LOAN, CLYM-EERH and EERH-LOAN circuits are of twin and quad bundle formation:

- Phase Conductor Type:
    - CLYM-LOAN (ZD001-ZD095), CLYM-EERH (ZD001-ZD026) and EERH-LOAN (ZD026-ZD095A): quad bundle ACSR 'Zebra' (all inner greased) installed in 1968.
    - CLYM-EERH (ZD026A-ZD026C) and EERH-LOAN (ZD026B & ZD026A): quad bundle ACSR 'Zebra' (all inner greased) installed in 1975.
- Earth wire Conductor Type:
    - CLYM-LOAN (ZD001-ZD095), CLYM-EERH (ZD001-ZD026C) and EERH-LOAN (ZD026B-ZD095A): AACSR 'Keziah' OPGW installed in 2008.
- Insulators:
    - CLYM-LOAN (ZD001-ZD095A), CLYM-EERH (ZD001-ZD026C) and EERH-LOAN (ZD026B-ZD095): 400kV construction voltage operating at 275kV. All glass installed in 2008.

ZC(S) Route is a double circuit overhead line. It is comprised of 63 steel lattice towers L6 construction.

There are 2 operating circuits on this route:

- CLYM-LOAN: ZCS001-ZD095A
- EERH-LOAN: ZCS001-ZD095A

CLYM-LOAN and EERH-LOAN circuits are of twin and quad bundle formation:

- Phase Conductor Type:
    - CLYM-LOAN and EERH-LOAN (ZCS001-ZCS054A): quad bundle ACSR 'Zebra' (all inner greased) installed in 1970.
    - CLYM-LOAN and EERH-LOAN (ZCS054A-ZD095A): twin bundle AAAC 'Araucaria' installed in 2015.
- Earth wire Conductor Type:
    - CLYM-LOAN and EERH-LOAN (ZCS001-ZCS054A): ACSR 'Zebra' (all inner greased) installed in 1970.
    - CLYM-LOAN and EERH-LOAN (ZCS054A-ZD095A): AACSR 'Keziah' OPGW installed in 2015.

- Insulators:
    - CLYM-LOAN and EERH-LOAN (ZCS001-ZCS054A): 400kV construction voltage operation to 275kV. All glass installed in 1970.
    - CLYM-LOAN and EERH-LOAN (ZCS054A-ZD095A): 400kV construction voltage operation to 275kV. All glass installed in 2015.

Data Collection

As part of the SPT OHL inspection regime, aerial photographic information in conjunction with site specific investigations such as conductor corrosion monitoring and sampling have been employed to provide a detailed condition analysis of the OHL components.

ZD Route:

- Aerial photographic inspection.
- Conductor corrosion monitoring.
- Conductor sample.

ZC(S) Route:

- Aerial photographic inspection and walking patrol.
- Conductor sample.
- Reliability factors: 'Andre' spacers (TDC 850) and cotter pins (TDC 501).

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 SPT Condition Based Risk Management (CBRM) tool.

ZD and ZC(S)001-ZC(054A) Routes: spacers

Andre rigid spacers are targeted within SPT Network for routine inspection as identified in TDC 850 “Damage to conductor adjacent to Andre spacers on L6 overhead lines” and their replacement at the earliest opportunity once evidence of conductor fatigue/damage are recorded in order to avoid early conductor deterioration. Evidence of conductor damage at spacer clamping position is starting to manifest along ZD and ZC(S) route as shown below:

Figure 1: conductor damaged at ‘Andre’ spacer clamping position at ZD Route.

Figure 2: conductor damaged at ‘Andre’ spacer clamping position at ZD Route.

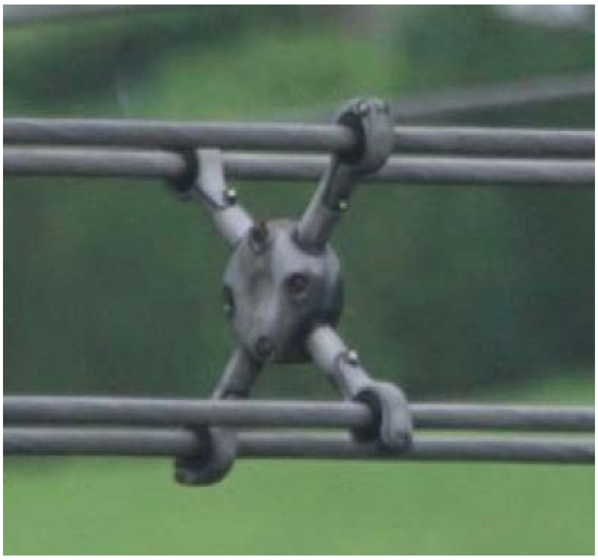

Figure 3: typical “Andre” spacer along ZCS Route.

ZC(S)001-ZC(054A) Route: Insulators and Fittings

This OHL section along ZC(S) route consists of L6 original insulator and fitting arrangement where cotter pins were used. This type of fitting arrangement is targeted within SPT Network for routine inspection as identified in TDC 501 "L6 Construction Displacement of Cotter Pins in Suspension Sets and Inspection of Suspension Hardware" due to their risk of cotter pin migration and wear under wind induced effects as observed and reported from different parts of the Network.

In addition, condition information gathered shows signs of corrosion on fittings and insulators along the ZC(S) Route between towers ZC(S)001-054A:

Figure 4: rust degraded suspension insulator set at ZC(S) Route.

Figure 5: tension insulator severely rust and degraded mechanical caps at ZC(S) Route.

ZD Route: Steel lattice towers

ZD route exhibits steelwork rust discolouration through deterioration of the galvanised outer layer protection to the upper steelwork sections and the condition worsens from tower ZD016 onwards, with bracing and peak often having more than 20% surface rust and poor paint condition.

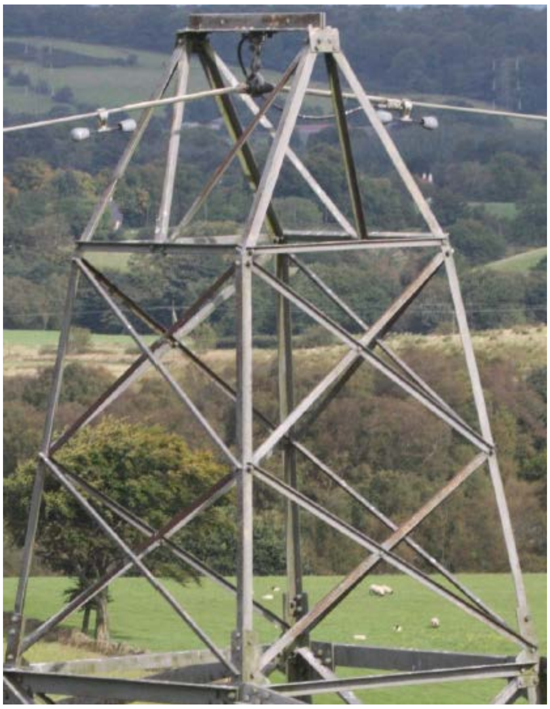

Figure 6: ZD Route typical rust steelwork degradation.

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 ZD Route 275kV	1968	8.31	10,310,787.53
Steel Tower ZD Route 275kV	1968	13.30	4,122,236.47
Phase Conductor ZC(S)001-ZC(054A)	1970	8.53	5,976,947.37
Phase Fittings ZC(S)001-ZC(054A)	1970	10.60	140,822,162.73

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

2.2 ZC(N) OHL 275kV Route

It is comprised of 63 steel lattice towers L6 construction.

There are 2 operating circuits on this route:

- DENN-LOAN: ZC(N)001-ZC(N)063A
- LOAN-LAMB-WIYH-1: ZC(N)001-ZC(N)063A

DENN-LOAN and LOAN-LAMB-WIYH-1 circuits are of twin and quad bundle formation:

- Phase Conductor Type:
  - DENN-LOAN and LOAN-LAMB-WIYH-1 (ZCN001-ZCN054A): quad bundle ACSR 'Zebra' (all inner greased) installed in 1970.
  - DENN-LOAN and LOAN-LAMB-WIYH-1 (ZCN054A-ZCN063A): twin bundle AAAC 'Araucaria' installed in 2015.
- Earth wire Conductor Type:
  - DENN-LOAN and LOAN-LAMB-WIYH-1 (ZCN001-ZCN054A): ACSR 'Zebra' (all inner greased) installed in 1970.
  - DENN-LOAN and LOAN-LAMB-WIYH-1 (ZCN054A-ZCN063A): AACSR 'Keziah' OPGW installed in 2015.
- Insulators:
  - DENN-LOAN and LOAN-LAMB-WIYH-1 (ZCN001-ZCN054A): 400kV construction voltage operation to 275kV. All glass installed in 1970.
  - DENN-LOAN and LOAN-LAMB-WIYH-1 (ZCN054A-ZCN063A): 400kV construction voltage operation to 275kV. All glass installed in 2015.

Data Collection

As part of the SPT OHL inspection regime, aerial photographic information in conjunction with site specific investigations have been employed to provide a detailed condition analysis of the OHL components.

- Aerial photographic inspection.
- Reliability factors: 'Andre' spacers (TDC 850) and cotter pins (TDC 501).

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 SPT Condition Based Risk Management (CBRM) tool.

<u>Spacers</u>

Andre rigid spacers are targeted within SPT Network for routine inspection as identified in TDC 850 "Damage to conductor adjacent to Andre spacers on L6 overhead lines" and their replacement at the earliest opportunity once evidences of conductor fatigue/damage are recorded in order to avoid early conductor deterioration.

Insulators and Fittings

This OHL section along ZC(N) route consists of L6 original insulator and fitting arrangement on where cotter pins were used. This type of fitting arrangement is targeted within SPT Network for routine inspection as identified in TDC 501 "L6 Construction Displacement of Cotter Pins in Suspension Sets and Inspection of Suspension Hardware" due to their risk of cotter pin migration and wear under wind induced effects as observed and reported from different parts of the Network.

In addition, condition information gathered shows corrosion on fittings and insulators along the ZC(N) Route between towers ZC(N)001-054A:

Figure 25: rust degraded suspension insulator set at ZC(N) Route.

Figure 26: tension insulator severely rusted and degraded mechanical caps at ZC(N) Route.

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 ZC(N)001-ZC(054A)	1970	8.53	1,176,234.04
Phase Fittings ZC(N)001-ZC(054A)	1970	10.60	26,935,688.99

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

2.3 ZP OHL 400kV Route

ZP Route was constructed in 1977 and is comprised of 81 double circuit steel lattice towers L6 construction.

There are 2 operating circuits on this route:

- HUER-KILS: ZP001-ZP081
- HUER-STHA: ZP001-ZP080/XV001

HUER-KILS and HUER-STHA circuits are of quad bundle formation:

- Phase Conductor Type: ACSR ‘Zebra’ (all inner greased) installed in 1977.
- Earth wire Conductor Type: ACSR ‘Zebra’ (all inner greased) installed in 1977.

Insulators: all Glass installed in 1977, except for circuit HUER-KILS tower ZP081 has Porcelain-Grey and Glass.

Data Collection

As part of the SPT OHL inspection regime, aerial photographic information in conjunction with site specific investigations have been employed to provide a detailed condition analysis of the OHL components.

- Aerial photographic inspection.
- Climbing Inspection and Insulator examination.
- Reliability factors: cotter pins (TDC 501).

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 SPT Condition Based Risk Management (CBRM) tool.

Spacers

A number of incidents related to wind induce effects have been reported along ZP Route:

- Original spacers along the ZP Route were replaced in 2004 due to fatigue risk on the conductor at spacer positions. 'Dunlop' spacers installed in section ZP007-011.
- Conductor horizontal oscillation/galloping reported in spans ZP050-051-052.
- A number of jumper repairs at spacer locations have been carried out along ZP route within the last 5 years (ZP015, 023, 027, 032, 043, 060, 064 and 068).
- Conductor damages at spacer locations within the last 3 years: ZP023-024, ZP060-061, ZP062-063, ZP074-075.

Figure 7: conductor damaged at 'Dulmison' spacer-damper clamping position at ZP Route (023-024).

Figure 8: conductor damaged at 'Dulmison' spacer-damper clamping position at ZP Route (062-063).

Figure 9: conductor damaged at 'Dulmison' spacer-damper clamping position at ZP Route (074-075).

Figure 10: conductor damaged at jumper spacer clamping position at ZP Route (068).

Insulators and Fittings

ZP route consists of L6 original insulator and fitting arrangement on where cotter pins were used. This type of fitting arrangement is targeted within SPT Network for routine inspection as identified in TDC 501 "L6 Construction Displacement of Cotter Pins in Suspension Sets and Inspection of Suspension Hardware" due to their risk of cotter pin migration and wear under wind induced effects as observed and reported from different parts of the Network.

Condition information gathered in 2017 indicates signs of corrosion on fittings and insulators, becoming severe on approximately 20% of the towers within the OHL route by 2026 based on experience from this type of installation. This shows close correlation with the future condition forecast by the NARM/CBRM models:

Figure 11: worn suspension strand and cotter pin at ZP Route

Figure 12: worn suspension connection at ZP008

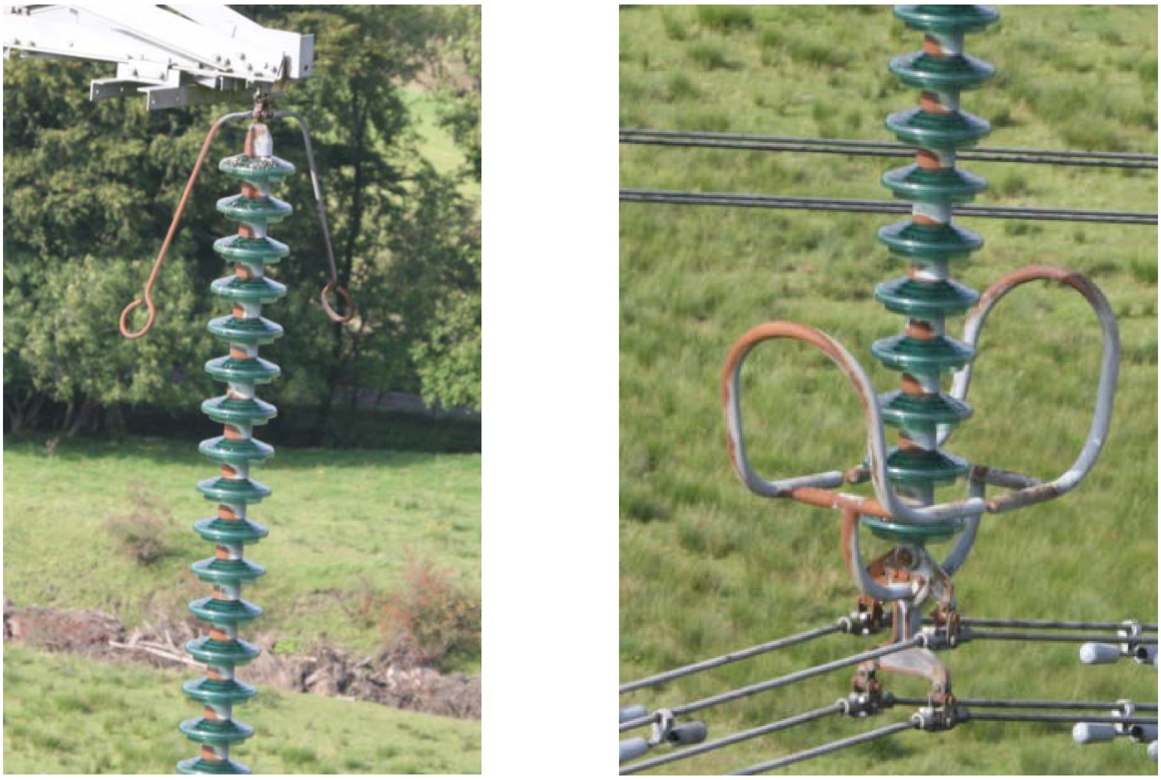

Figure 13: level of rust at ZP Route insulator sets

Earth wire Fittings

Wear on the earth wire peak fitting has been reported along ZP route due to earth wire wind induced oscillation and poor historical design of the earth wire fittings at the tower peak.

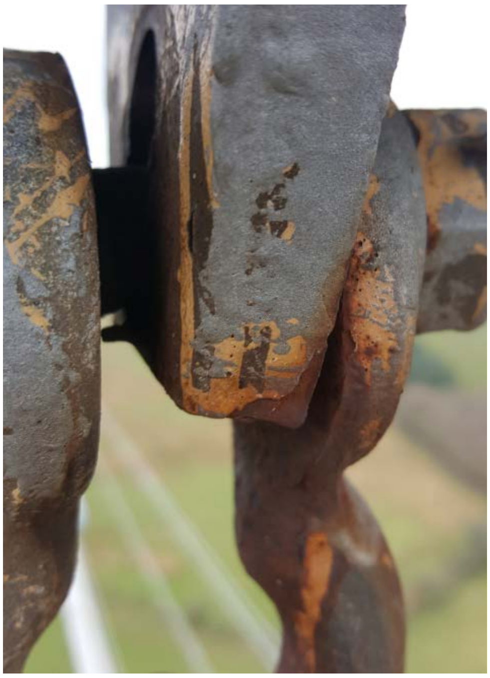

Figure 14: worn of suspension earth wire fitting at ZP051

Figure 15: worn of earth wire suspension connection at ZP005

Tower steelwork

ZP route exhibits steelwork rust discolouration through deterioration of the galvanised outer layer protection to the different steelwork sections.

Figure 16: severely rusted ZP017.

Figure 17: severely rusted cross-arm ZP007.

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 ZP Route 400kV	1977	8.64	£R 17,599,676.53
Phase Fittings ZP Route 400kV	1977	11.06	£R 589,499,665.16
Steel Tower ZP Route 400kV	1977	14.18	£R 20,541,764.78

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

2.4 ZE OHL 275kV Route

ZE Route was constructed in 1978 and is comprised of 30 double circuit steel lattice towers L6 construction.

There are 2 operating circuits on this route:

- CLYM-EKIL-STHA 1: ZE001-ZE030
- CLYM-EKIL-STHA 2: ZE001-ZE030

CLYM-EKIL-STHA 1 and 2 are of twin bundle formation:

- Phase Conductor Type: ACSR ‘Zebra’ (all inner greased) installed in 1978.
- Earth wire Conductor Type: ACSR ‘Zebra’ (all inner greased) installed in 1978. Wrap fibre installed in 1992.
- Insulators: 400kV construction voltage operating at 275kV. All porcelain-grey installed in 1978.

Data Collection

As part of the SPT OHL inspection regime, aerial photographic information in conjunction with site specific investigations have been employed to provide a detailed condition analysis of the OHL components.

- Aerial photographic inspection.
- Climbing Inspection and spacer replacement.
- Reliability factors: cotter pins (TDC 501).

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 SPT Condition Based Risk Management (CBRM) tool.

Insulators and Fittings

ZE route consists of L6 original insulator and fitting arrangement where cotter pins were used. This type of fitting arrangement is targeted within SPT Network for routine inspection as identified in TDC 501 “L6 Construction Displacement of Cotter Pins in Suspension Sets and Inspection of Suspension Hardware” due to their risk of cotter pin migration and wear under wind induced effects as observed and reported from different parts of the Network.

Condition information gathered in 2014 and 2019 indicates signs of corrosion on fittings and insulators, becoming severe on a number of the towers within the OHL route by 2026 based on experience from this type of installation. This shows close correlation with the future condition forecast by the NARM/CBRM models.

Grey porcelain insulators originally installed exhibit signs of degradation (inspection report 2014) with a projection of deterioration by end of the regulatory period in 2026. Related type damage has also been reported on similar porcelain insulators in different parts of the Network. Therefore utilising the available information and observations together with reference to an industry wide Transmission Design Circular, TDC 898; “Defective Porcelain Insulators on Overhead Lines” and its detailed findings supports the requirement to replace all grey porcelain insulators along the route.

Figure 18: level of rust at ZE Route porcelain insulator caps and wear of suspension strand.

Figure 19: conductor damage at spacer clamping position at ZE Route.

A number of incidents related to wind induce effects have been reported along ZE Route:

- Original ‘Bowthorpe’ spacers installed along the ZE Route showing signs of fatigue on the conductor at a number of span locations: ZE008-009, ZE023-024, ZE024-025, and ZE028-029 observed within the last 5 years.

Spacers have been replaced along this route however there is significant concern on how the suspension clamps have affected the conductor, therefore the need for its replacement.

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 Conductors ZE Route 275kV	1978	8.77	1,925,649.72
Phase Fittings ZE Route 275kV	1978	11.58	50,345,946.70

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

2.5 ZF OHL 400kV Route

ZF Route was constructed in 1972 and comprises 49 double circuit steel lattice towers L8/L2 construction.

There are 2 operating circuits on this route:

- HUNE-DEVM: ZF123-ZF171
- HUNE-NEIL: ZF123-ZF171

HUNE-DEVM and HUNE-NEIL circuits are of twin bundle formation:

- Phase Conductor Type: ACSR ‘Zebra’ (all inner greased) installed in 1972.
- Earth wire Conductor Type: ACSR ‘Lynx’ (all inner greased) installed in 1972.
- Insulators: all glass installed in 1972.

Data Collection

As part of the SPT OHL inspection regime, aerial photographic information in conjunction with site specific investigations have been employed to provide a detailed condition analysis of the OHL components.

- Aerial photographic inspection.

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 SPT Condition Based Risk Management (CBRM) tool.

Spacers

There have been a number of incidents on the ZF Route recorded since it was built in 1978. The most critical incident along ZF Route happened in 2014 when a conductor broke at a spacer ("Bowthorpe type") position. 'Bowthorpe' type spacers have been deployed with conductor outer aluminium strand damage and subsequent repair works carried out at numerous spacer locations throughout the route. Previous reports of similar damage on same conductor configuration in different parts of the Network have also been noted with the same spacer type. Therefore the information noted supports the requirement to replace all spacers along the route.

- Conductor damage at spacer positions have been reported for the following span: ZF135-136, ZF141-142, ZF160-161, ZF163-164.

Figure 19: conductor damage at spacer clamping position at ZF Route.

Figure 20: conductor damage at spacer clamping position at ZF 141-142.

Insulators and Fittings

Condition information gathered indicates signs of corrosion on fittings and insulators along ZF Route.

Figure 21: suspension set at ZF Route.

Figure 22: tension set at ZF Route.

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 ZF Route 400kV	1972	9.40	7,820,413.49
Phase Fittings ZF Route 400kV	1972	13.74	287,352,758.69

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

2.6 YK OHL 275kV Route

YK Route was constructed in 1970 and is comprised of 15 double circuit steel lattice towers L2 construction.

There are 2 operating circuits on this route:

- LAMB-PORD-WGEO-1: YK001-YK015.
- LAMB-PORD-WGEO-2: YK001-YK015.

LAMB-PORD-WGEO-1 and 2 circuits are of twin bundle formation:

- Phase Conductor Type: ACSR ‘Zebra’ (all inner greased) installed in 1970.
- Earth wire Conductor Type: ACSR ‘Lynx’ (all inner greased) installed in 1970. Wrap fibre installed in 1992.
- Insulators: all glass installed in 2012.

Data Collection

As part of the SPT OHL inspection regime, aerial photographic information in conjunction with site specific investigations have been employed to provide a detailed condition analysis of the OHL components.

- Aerial photographic inspection.

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 SPT Condition Based Risk Management (CBRM) tool.

Spacers

Bowthorpe spacers are installed along YK Route. Conductor outer aluminium strand damage has been recorded from different parts of the Networks (including a major failure along ZF Route) on the routes where “Bowthorpe” spacers were installed. It is proposed its replacement to prevent conductor outer aluminium strand damage and subsequent repair works throughout the route where all inner greased conductor is installed.

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 YK Route 275kV	1970	8.30	888,595.73
Steel Tower YK Route 275kV	1970	14.06	33,708,455.13

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

2.7 YQ OHL 275kV Route

YQ Route was constructed in 1975 and is comprised of 11 double circuit steel lattice towers L8 construction.

There are 2 operating circuits on this route:

- WISH-NEAR-GOWK-1: YQ001-YQ011.
- WISH-NEAR-GOWK-2: YQ001-YQ011.

WISH-NEAR-GOWK -1 and 2 circuits are of twin bundle formation:

- Phase Conductor Type: ACSR ‘Zebra’ (all inner greased) installed in 1975.
- Earth wire Conductor Type: AACSR ‘Keziah’ OPGW installed in 2007.
- Insulators: all glass installed in 2017.

Data Collection

As part of the SPT OHL inspection regime, aerial photographic information in conjunction with site specific investigations have been employed to provide a detailed condition analysis of the OHL components.

- Aerial photographic inspection.

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 SPT Condition Based Risk Management (CBRM) tool.

Spacers

Bowthorpe spacers are installed along YQ Route. Conductor outer aluminium strand damage has been recorded from different parts of the Networks (including a major failure along ZF Route) on the routes where "Bowthorpe" spacers were installed. It is proposed its replacement to prevent conductor outer aluminium strand damage and subsequent repair works throughout the route where all inner greased conductor is installed.

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 YQ Route 275kV	1975	8.53	1,231,540.50

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

2.8 XD 275kV Route: Kincardine Crossing Towers

Kincardine crossing was constructed in 1962 and is comprised of 2 special anchor towers and 2 special suspension crossing towers double circuit steel lattice.

There are 2 operating circuits on this route:

- CURR-KINC: XD128-XD131
- GRMO-KINC: XD128-XD131

CURR-KINC and GRMO-KINC circuits are of twin bundle formation:

- Insulators: all brown-porcelain installed in 1962.

Data Collection

As part of the SPT OHL inspection regime, aerial photographic information in conjunction with site specific investigations have been employed to provide a detailed condition analysis of the OHL components.

- Aerial photographic inspection.
- Climbing inspection.

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 SPT Condition Based Risk Management (CBRM) tool.

Insulators and Fittings

Condition information gathered indicates corrosion on fittings and insulators along the XD Route Kincardine Crossing Towers (XD128, 129, 130, 131).

All four towers (XD128, 129, 130, 131) present "brown" type insulators which have been targeted for replacement after insulator failure on the Neilston-East Kilbride South 275kV circuit resulted in the middle phase conductor at tower XQ11 falling onto the bottom phase cross arm. The failure was due to severe corrosion of the insulator cap at a point where the pin of one insulator is connected to the cap of another. A subsequent survey of Transmission OHL circuits with similar insulator type (brown porcelain) was carried out by Transmission Operations and recommended wholesale replacement of all porcelain insulators along XD Route. This recommendation is contained within SPEN Transmission Network OHL-30-001 "Transmission OHL Porcelain Insulator Replacement Programme".

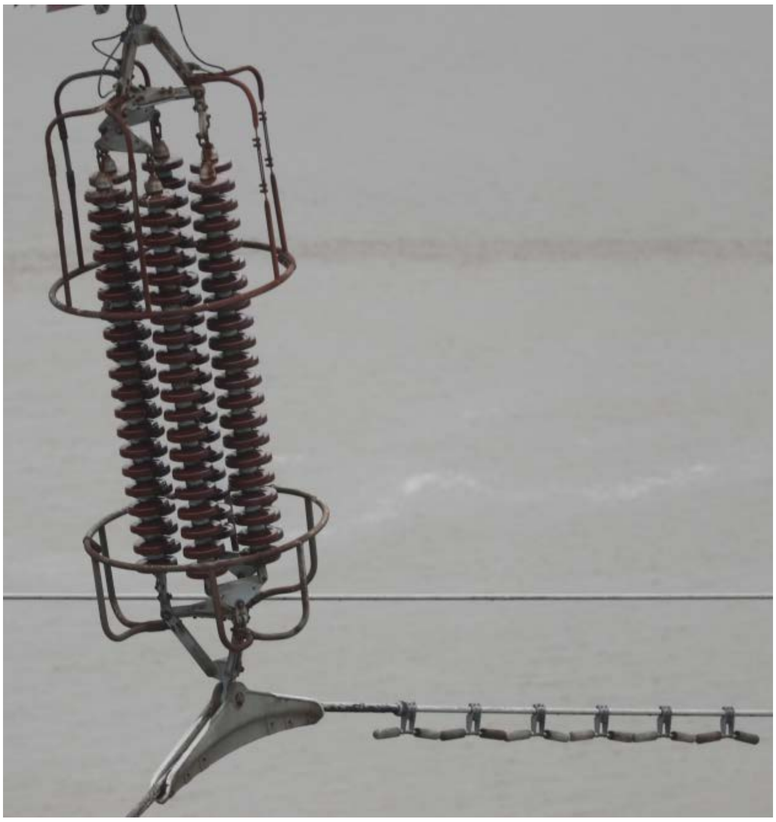

Figure 23: Typical suspension insulator set XD130.

XD130 Foundation

Investigations were carried out on the XD130 foundations in 2017. On the basis of the condition and results found, the tower XD130 foundation has deteriorated and become distressed mainly as a result of generalised re-bar corrosion and requires refurbishment.

Figure 24: piled foundation XD130. Rebar exposed.

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£)*
Fittings XD Route 275kV (128-131)	1962	13.38	37,663,444.37
Steel Tower XD Route 275kV (128-131)	1962	7.53	216,402.29

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

2.9 ZS OHL 400kV Route

ZS Route was constructed in 1985 and is comprised of 178 double circuit steel lattice towers L12 construction.

There are 4 operating circuits on this route:

- TORN-STHA: ZS002-ZS179
- FALL-SMEA: ZS002-ZS103A
- CRYR-FALL: ZS103A-ZS149A
- TORN-CRYR: ZS149A-ZS179

TORN-STHA, FALL-SMEA, CRYR-FALL and TORN-CRYR circuits are of twin bundle formation:

- Phase Conductor Type: AAAC 'Araucaria' installed in 1985.
- Earth wire Conductor Type: AAAC 'Totara' installed in 1985.
- Insulators: all porcelain-grey installed in 1985.

Data Collection

As part of the SPT OHL inspection regime, aerial photographic information in conjunction with site specific investigations have been employed to provide a detailed condition analysis of the OHL components.

- Aerial photographic inspection.

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 SPT Condition Based Risk Management (CBRM) tool.

<u>Spacers</u>

A number of incidents related to wind induce effects have been reported along ZS Route:

- ZS121-122: spacer damping rubber at the hinge supporting one of the legs failed – top phase.
- ZS121-122: spacer damping rubber at the hinge supporting one of the legs failed – middle phase.

These evidences are in line with the spacers being beyond of their anticipated life of 30-40 years. It is also to be highlighted that external damages on AAAC conductors cause a higher reduction in strength than on ACSR conductors increasing the risk of the assets if the conductor gets further damage along the route.

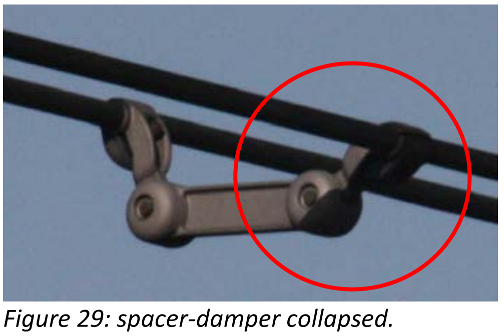

Figure 29: spacer-damper collapsed.

<u>Tower steelwork</u>

ZS route exhibits steelwork rust discolouration through deterioration of the galvanised outer layer protection to the different steelwork sections.

Figure 30: level of rust through towers along ZS Route.

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 ZS Route 400kV	1985	9.40	35,903,548.38
Steel Tower ZS Route 400kV	1985	15.00	48,167,931.62

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

2.10 ZT OHL 400kV Route

ZT Route was constructed in 1985 and is comprised of 108 double circuit steel lattice towers L12 construction.

There are 2 operating circuits on this route:

- TORN-ECCL-1: ZT001-ZT108.
- TORN-ECCL-2: ZT001-ZT108.

TORN-ECCL -1 and 2 circuits are of twin bundle formation:

- Phase Conductor Type: AAAC 'Araucaria' installed in 1985.
- Earth wire Conductor Type: AAAC 'Totara' installed in 1985.
- Insulators: all porcelain-grey installed in 1985.

Data Collection

As part of the SPT OHL inspection regime, aerial photographic information in conjunction with site specific investigations have been employed to provide a detailed condition analysis of the OHL components.

- Aerial photographic inspection.

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 SPT Condition Based Risk Management (CBRM) tool.

Spacers

A number of incidents related to wind induce effects have been reported along ZT Route:

- ZT059-060: conductor damage reported in 2019.
- ZT059-060: slipped spacer reported in 2018.
- ZT108-109: slipped spacers reported in 2018.

These evidences are in line with the spacers being beyond of their anticipated life of 30-40 years. It is also to be highlighted that external damages on AAAC conductors cause a higher reduction in strength than on ACSR conductors increasing the risk of the assets if the conductor gets further damage along the route.

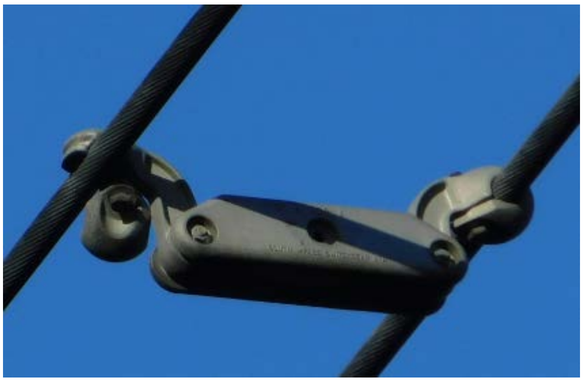

Figure 27: spacer damage.

Figure 28: slipped spacer.

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 ZT Route 400kV	1985	9.34	26,165,154.04

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

3. Optioneering

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

Option	Status	Reason for rejection
Baseline - Do Minimum: • Phase conductor, earthwire and insulators replacement in RIIO-T3 (2031).	Considered	This option is unacceptable due to the overall condition of the OHL fittings/insulators and spacers being at their end of life and no intervention will add considerable risk to the SPT Network. In addition, deferring the investment will accelerate the continual deterioration of the OHL components; in particular the OHL conductor which will require an early replacement.
Option 1 - Minor Refurbishment: • Spacer, insulator and earth wire fitting replacement in RIIO-T2 (2026). • Phase conductor and earthwire replacement beyond RIIO-T3.	Proposed and Considered	-
Option 2 – Major Refurbishment: • Conductor, earthwire and insulator replacement in RIIO-T2 (2026).	Rejected	Replacement of the existing OHL conductor (fully greased) is unacceptable due to its current condition and anticipated remaining life. Replacing spacer and fittings will avoid its earlier degradation due to fatigue.
Option 3 – Full Replacement: • OHL Tower replacement in RIIO-T2 (2026).	Rejected	Replacement of the existing OHL towers in RIIO-T2 is unacceptable due to its condition and anticipated remaining life left. 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 fittings/insulators, spacer 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 ZD and ZC(S) OHL 275kV Routes: Option 1 - Minor Refurbishment

The following works shall form the basis of Option 1 intervention:

- Replace all phase conductor spacers (Andre) along ZD and ZC(S) routes, including jumpers along ZC(S) if required.
- Replace all suspension and tension insulators including tower and line end fittings along ZC(S) Route.
- Replace all phase vibration dampers along ZC(S) Route.
- Replace tower muff foundations as required per condition.
- Carry out tower painting along ZD Route.
- Replace heavily corroded or damaged steelwork (above category 4).
- Update all OHL records to reflect the works carried out.
- Provide report to the Asset manager to include condition of spacers and steelwork.

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

- Special requirements when replacing quad insulator sets considered.
- Conductor repairs due to damage under spacers.

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

- Access routes to be addressed through early engagement with landowners, employing low bearing pressure ground vehicles and trackway.
- Resources and management to provide a programme with multiple gangs (2) working concurrently in order to minimise access and constraints on the network.

4.2 ZC(N) OHL 275kV Route: Option 1 - Minor Refurbishment

The following works shall form the basis of Option 1 intervention:

- Replace all phase conductor spacers (Andre), including jumpers.
- Replace all suspension and tension insulators including tower and line end fittings.
- Replace all phase vibration dampers.
- Replace tower muff foundations as required per condition.
- Replace heavily corroded or damaged steelwork (above category 4).
- Update all OHL records to reflect the works carried out.
- Provide report to the Asset manager to include condition of spacers and steelwork.

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

- Special requirements when replacing quad insulator sets considered.
- Conductor repairs due to damages under spacers.

The following specific risks have been identified for this option:

- Access routes to be addressed through early engagement with landowners, employing low bearing pressure ground vehicles and trackway.
- Resources and management to provide a programme with multiple gangs (2) working concurrently in order to minimise access and constraints on the network.

4.3 ZP OHL 400kV Route (Circuits 1 & 2): Option 1 - Minor Refurbishment

The following works shall form the basis of Option 1 intervention:

- Replace all phase conductor spacers, including jumpers if required.
- Replace all suspension and tension insulators including tower and line end fittings.
- Replace all phase and earth wire vibration dampers.
- Replace earth wire fittings and tower connections.
- Carry out tower painting along ZP Route.
- Replace tower muff foundations as required per condition.
- Replace heavily corroded or damaged steelwork (above category 4).
- Update all OHL records to reflect the works carried out.
- Provide report to the Asset manager to include condition of spacers and steelwork.

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

- Special requirements when replacing quad insulator sets considered.
- Conductor repairs due to damage under spacers.
- Steelwork modifications to accommodate new earth wire fittings.
- Study reason behind poor performance of XB Route after re-conductoring in 2008.

The following specific risks have been identified for this option:

- Access routes to be addressed through early engagement with landowners, employing low bearing pressure ground vehicles and trackway where possible.
- Resources and management to provide a programme with multiple gangs (2) working concurrently in order to minimise access and constraints on the network.

4.4 ZE OHL 275kV Route: Option 1 - Minor Refurbishment

The following works shall form the basis of Option 1 intervention:

- Replace all earth wire attachment configuration fittings.
- Replace all phase, earth wire conductor vibration dampers.
- Replace all insulators and fittings.
- Replace tower muff foundations as required per condition.
- Replace heavily corroded or damaged steelwork (above category 4).
- Update all OHL records to reflect the works carried out.
- Provide report to the Asset manager to include condition of spacers and steelwork.

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

- Potential failures/cracks on porcelain insulators which difficult replacement tasks.
- Steelwork modifications to accommodate new earth wire fittings.
- Wrap fibre on earth wire will difficult replacement of earth wire fittings.

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

- Access routes to be addressed through early engagement with landowners, employing low bearing pressure ground vehicles and trackway where possible.

4.5 ZF OHL 400kV Route: Option 1 - Minor Refurbishment

The following works shall form the basis of Option 1 intervention:

- Replace all phase conductor spacers, including jumpers.
- Replace all suspension and tension insulators including tower and line end fittings.
- Replace all phase and earth wire vibration dampers.
- Replace earth wire fittings.
- Replace tower muff foundations as required per condition.
- Replace heavily corroded or damaged steelwork (above category 4).
- Update all OHL records to reflect the works carried out.
- Provide report to the Asset manager to include condition of spacers and steelwork.

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

- Conductor repairs due to damage under spacers.
- Steelwork modifications to accommodate new earth wire fittings.
- Study reason behind poor performance of XC Route after re-conductoring in 2008.

The following specific risks have been identified for this option:

- Access routes to be addressed through early engagement with landowners, employing low bearing pressure ground vehicles and trackway where possible.

- Resources and management to provide a programme with multiple gangs (2) working concurrently in order to minimise access and constraints on the network.

4.6 YK OHL 275kV Route: Option 1 - Minor Refurbishment

The following works shall form the basis of Option 1 intervention:

- Replace all phase conductor spacers, including jumpers.
- Replace all phase and earth wire vibration dampers.
- Replace earth wire fittings.
- Carry out tower painting.
- Replace tower muff foundations as required per condition.
- Replace heavily corroded or damaged steelwork (above category 4).
- Update all OHL records to reflect the works carried out.
- Provide report to the Asset manager to include condition of spacers and steelwork.

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

- Conductor repairs due to damage under spacers.
- Steelwork modifications to accommodate new earth wire fittings.

The following specific risks have been identified for this option:

- Access routes to be addressed through early engagement with landowners, employing low bearing pressure ground vehicles and trackway where possible.

4.7 YQ OHL 275kV Route: Option 1 - Minor Refurbishment

The following works shall form the basis of Option 1 intervention:

- Inspect and replace all phase conductor spacers, including jumpers.
- Replace all phase and earth wire vibration dampers.
- Measure the resistance between terminal joints and jumper ends and replace/repair as required.
- Replace tower muff foundations as required per condition.
- Replace heavily corroded or damaged steelwork (above category 4).
- Update all OHL records to reflect the works carried out.
- Provide report to the Asset manager to include condition of spacers and steelwork.

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

- Conductor repairs due to damages under spacers.
- Steelwork modifications to accommodate new earth wire fittings.

The following specific risks have been identified for this option:

- Access routes to be addressed through early engagement with landowners, employing low bearing pressure ground vehicles and trackway where possible.

4.8 XD 275kV Route: Kincardine Crossing Towers: Option 1 - Minor Refurbishment

The following works shall form the basis of Option 1 intervention:

- Replace all suspension and tension insulators including tower and line end fittings on XD129, 129, 130, 131.
- Replace all phase and earth wire vibration dampers along XD129, 129, 130, 131.
- Foundation upgrades works at tower XD130.
- Carry out tower painting.
- Replace tower muff foundations as required per condition.
- Replace heavily corroded or damaged steelwork (above category 4).
- Update all OHL records to reflect the works carried out.
- Provide report to the Asset manager to include condition of spacers and steelwork.

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

- Special requirements for replacing suspension sets at the crossing and anchor towers.
- Special requirements on the remedial works at the piled foundation on XD 130 (crossing tower).

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

- Access routes to be addressed through early engagement with landowners, employing low bearing pressure ground vehicles and trackway where possible.
- Special requirements for working on the crossing and anchor towers.

4.9 ZS OHL 400kV Route: Option 1 - Minor Refurbishment

The following works shall form the basis of Option 1 intervention:

- Replace all phase conductor spacers, including jumpers.
- Replace phase and earth wire vibration dampers as required per condition.
- Replace earth wire fittings as required per condition.
- Replace tower muff foundations as required per condition.
- Carry out tower painting.
- Replace heavily corroded or damaged steelwork (above category 4).
- Update all OHL records to reflect the works carried out.
- Provide report to the Asset manager to include condition of spacers and steelwork.

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

- Conductor repairs due to damages under spacers.
- Potential failures/cracks on porcelain insulators which require some insulator replacements.
- Steelwork modifications to accommodate new earth wire fittings.

The following specific risks have been identified for this option:

- Access routes to be addressed through early engagement with landowners, employing low bearing pressure ground vehicles and trackway where possible.
- Resources and management to provide a programme with multiple gangs (2) working concurrently in order to minimise access and constraints on the network.

4.10 ZT OHL 400kV Route: Option 1 - Minor Refurbishment

The following works shall form the basis of Option 1 intervention:

- Replace all phase conductor spacers, including jumpers.
- Replace phase and earth wire vibration dampers as required per condition.
- Replace earth wire fittings as required per condition.
- Replace tower muff foundations where deemed required.
- Replace heavily corroded or damaged steelwork (above category 4).
- Update all OHL records to reflect the works carried out.
- Provide report to the Asset manager to include condition of spacers and steelwork.

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

- Conductor repairs due to damages under spacers.
- Potential failures/cracks on porcelain insulators which require some insulator replacements.
- Steelwork modifications to accommodate new earth wire fittings.

The following specific risks have been identified for this option:

- Access routes to be addressed through early engagement with landowners, employing low bearing pressure ground vehicles and trackway where possible.
- Resources and management to provide a programme with multiple gangs (2) working concurrently in order to minimise access and constraints on the network.

4.11 Selected Option

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

CBA analysis has been developed for the "SPNLT201 – ZC(N) Route 275kV Minor Refurbishment" scheme and results extrapolated to the rest of the schemes within the "OHL Minor Refurbishment Programme" since optioneering, interventions and investment cycles are common across the proposals.

SPNLT201 – ZC(N) Route 275kV Minor Refurbishment				
Option No.	**Description Of Option**	**Preferred Option**	**Total NPV** *(Incl. Monetised Risk)*	**Delta** *(Option to baseline)*
Baseline	Baseline	N	£ 301.53	£ -
1	Minor Refurbishment	Y	£ 352.80	£ 51.27

5. Conclusion

The two options proposed have been reviewed in terms of scope feasibility, cost, timescales and construction risks with Option 1 demonstrating the primary objective of refurbishment of conductor (spacer replacement) and towers and fittings 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 is the selected option:

5.1 ZD and ZC(S) OHL 275kV Routes: Option 1 - Minor Refurbishment

- Scheme Total Cost: £8.4M
- Timing of investment: 2021 – 2025
- Declared outputs:

Asset	Type of Activity	Disposal (cct. Km/sets/each)	Addition/Activity (cct. Km/sets/each)
275kV OHL (Tower Line) Conductor	Repair	-	103 cct. Km
275kV OHL Fittings	Replacement	298 set	298 each
275kV Tower	Refurbishment Major	-	149 each

- Long term risk benefit (LR£m):

Asset Description	Long Term Risk Benefit (LR£m)
ZD Route: 275kV OHL (Tower Line) Conductor	249.36
ZD Route: 275kV Tower	72.50
ZC(S)001-ZC(054A) Route: 275kV OHL (Tower Line) Conductor	141.80
ZC(S)001-ZC(054A) Route: 275kV OHL Fittings	2,042.04

- Price control period of outputs: 2025

5.2 ZC(N) OHL 275kV Route: Option 1 - Minor Refurbishment

- Scheme Total Cost: £4.3M
- Timing of investment: 2023 – 2026
- Declared outputs:

Asset	Type of Activity	Disposal (cct. Km/sets/each)	Addition/Activity (cct. Km/sets/each)
275kV OHL (Tower Line) Conductor	Repair	-	37.6 cct. Km
275kV OHL Fittings	Replacement	108 set	108 set
275kV Tower	Refurbishment Major	-	54 each

- Long term risk benefit (LR£m):

Asset Description	Long Term Risk Benefit (LR£m)
275kV OHL (Tower Line) Conductor	25.83
275kV OHL Fittings	396.36

- Price control period of outputs: 2026

5.3 ZP OHL 400kV Route (Circuits 1 & 2): Option 1 - Minor Refurbishment

- Scheme Total Cost: £9.0M
- Timing of investment: 2023 – 2027
- Declared outputs:

Asset	Type of Activity	Disposal (cct. Km/sets/each)	Addition/Activity (cct. Km/sets/each)
400kV OHL (Tower Line) Conductor	Repair	-	55 cct. Km
400kV OHL Fittings	Replacement	162 sets	162 sets
400kV Tower	Refurbishment Major	-	81 each

- Long term risk benefit (LR£m):

Asset Description	Long Term Risk Benefit (LR£m)*
400kV OHL (Tower Line) Conductor	165.19
400kV OHL Fittings	2,945.75
400kV OHL Tower	146.42

(*) Long term risk benefit values correspond to circuit 1 to be delivered in T2. Circuit 2 will be delivered outside T2, in 2027, and therefore do not contribute to the Baseline Risk Outputs.

- Price control period of outputs: 2027

5.4 ZE OHL 275kV Route: Option 1 - Minor Refurbishment

- Scheme Total Cost: £1.8M
- Timing of investment: 2023 – 2026
- Declared outputs:

Asset	Type of Activity	Disposal (cct. Km/sets/each)	Addition/Activity (cct. Km/sets/each)
275kV OHL (Tower Line) Conductor	Repair	-	20.8 cct. Km
275kV OHL Fittings	Replacement	60 sets	60 sets
275kV Tower	Refurbishment Major	-	30 each

- Long term risk benefit (LR£m):

Asset Description	Long Term Risk Benefit (LR£m)
275kV OHL (Tower Line) Conductor	42.65
275kV OHL Fittings	605.24

- Price control period of outputs: 2026

5.5 ZF OHL 400kV Route: Option 1 - Minor Refurbishment

- Scheme Total Cost: £2.7M
- Timing of investment: 2020 – 2022
- Declared outputs:

Asset	Type of Activity	Disposal (cct. Km/sets/each)	Addition/Activity (cct. Km/sets/each)
400kV OHL (Tower Line) Conductor	Repair	-	37.6 cct. Km
400kV OHL Fittings	Replacement	98 sets	98 sets
400kV Tower	Refurbishment Major	-	49 each

- Long term risk benefit (LR£m):

Asset Description	Long Term Risk Benefit (LR£m)
400kV OHL (Tower Line) Conductor	191.78
400kV OHL Fittings	2,545.71

- Price control period of outputs: 2022

5.6 YK OHL 275kV Route: Option 1 - Minor Refurbishment

- Scheme Total Cost: £0.7M
- Timing of investment: 2021 – 2024
- Declared outputs:

Asset	Type of Activity	Disposal (cct. Km/sets/each)	Addition/Activity (cct. Km/sets/each)
275kV OHL (Tower Line) Conductor	Repair	-	8.1 cct. Km
275kV Fittings	Replacement *(spacers)*	30 sets	30 sets
275kV Tower	Refurbishment Major	-	15 each

- Long term risk benefit (LR£m):

Asset Description	Long Term Risk Benefit (LR£m)
275kV OHL (Tower Line) Conductor	21.02
275kV OHL Towers	590.36

- Price control period of outputs: 2024

5.7 YQ OHL 275kV Route: Option 1 - Minor Refurbishment

- Scheme Total Cost: £0.4M
- Timing of investment: 2023 – 2026
- Declared outputs:

Asset	Type of Activity	Disposal (cct. Km/sets/each)	Addition/Activity (cct. Km/sets/each)
275kV OHL (Tower Line) Conductor	Repair	-	6.9 cct. Km
275kV Fittings	Replacement *(spacers)*	24 sets	24 sets
275kV Tower	Refurbishment Major	-	12 each

- Long term risk benefit (LR£m):

Asset Description	Long Term Risk Benefit (LR£m)
275kV OHL (Tower Line) Conductor	29.20

- Price control period of outputs: 2026

5.8 XD 275kV Route: Kincardine Crossing Towers: Option 1 - Minor Refurbishment

- Scheme Total Cost: £5.2M
- Timing of investment: 2020 – 2023
- Declared outputs:

Asset	Type of Activity	Disposal (cct. Km/sets/each)	Addition/Activity (cct. Km/sets/each)
275kV OHL Fittings	Replacement	8 sets	8 sets
275kV Tower	Refurbishment Major	-	4 each

- Long term risk benefit (LR£m):

Asset Description	Long Term Risk Benefit (LR£m)
275kV OHL Fittings	306.21
275kV OHL Towers	3.39

- Price control period of outputs: 2023

5.9 ZS OHL 400kV Route: Option 1 - Minor Refurbishment

- Scheme Total Cost: £8.6M
- Timing of investment: 2022 – 2025
- Declared outputs:

Asset	Type of Activity	Disposal (cct. Km/sets/each)	Addition/Activity (cct. Km/sets/each)
400kV OHL (Tower Line) Conductor	Repair	-	108.1 cct. Km
400kV OHL Fittings	Replacement *(spacers)*	356 sets	356 sets
400kV Tower	Refurbishment Major	-	178 each

- Long term risk benefit (LR£m):

Asset Description	Long Term Risk Benefit (LR£m)
400kV OHL (Tower Line) Conductor	772.40
400kV OHL Towers	458.62

- Price control period of outputs: 2025

5.10 ZT OHL 400kV Route: Option 1 - Minor Refurbishment

- Scheme Total Cost: £2.8M
- Timing of investment: 2022 – 2025
- Declared outputs:

Asset	Type of Activity	Disposal (cct. Km/sets/each)	Addition/Activity (cct. Km/sets/each)
400kV OHL (Tower Line) Conductor	Repair	-	68.5 cct. Km
400kV OHL Fittings	Replacement *(spacers)*	216 sets	216 sets
400kV Tower	Refurbishment Major	-	108 each

- Long term risk benefit (LR£m):

Asset Description	Long Term Risk Benefit (LR£m)
400kV OHL (Tower Line) Conductor	612.67

- Price control period of outputs: 2025

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

SPNLT2015 – YK Route 275kV Minor Refurbishment:

YK was included as a ‘best view’ scheme in RIIO-T1. There have been a small number of substitutions of the overhead line portfolio and YK route was deferred as part of this. The overall position for overhead lines is that the schemes substituted in are forecast to meet the targets for this category. The full funding allocated to YK route in RIIO-T1 has been transferred to other schemes through substitution.