Redshaw Cluster Reinforcements

Site Strategy EJP
Version: 1.0
11/12/2024

SP Energy Networks
RIIO-T3 Business Plan

SP Energy Networks

Redshaw Cluster Reinforcements			
Name of Scheme	SPT-RI-2060 Redshaw 400/132kV Substation; SPT-RI-2061 Redshaw 132kV Substation; SPT-RI-2139 Redshaw 400/132kV SGT2; SPT-RI-3060 Redshaw 132kV 'B' Board; SPT-RI-4137 Harmonic Filter on Redshaw 132kV 'A' Board; and SPT-RI-4138 Harmonic Filter on Redshaw 132kV 'B' Board		
Investment Driver	Local Enabling (Entry) Wider Works		
BPDT / Scheme Reference Number	SPT200409; SPT200494; SPT200497; SPT200857; and SPT200874 (parts of)		
Outputs	• 400kV Platform creation – 1 unit • 132kV Platform creation – 1 unit • Flexible AC Transmission Systems (FACTS) – 2 units • 400kV CB (Gas Insulated Busbars) (ID) – 12 units • 132kV CB (Gas Insulated Busbars) (ID) – 10 units • 400kV<500MVA Wound Plant (Transformer) – 4 units • 400kV OHL (Tower Line) Conductor disposal • 400kV OHL (Tower Line) High Temperature Low Sag (HTLS) conductor addition • 400kV tower disposal – 2 units • 400kV tower addition – 4 units		
Cost	SPT-RI-2060 Redshaw 400kV Substation - £60.73m SPT-RI-2061 Redshaw 132kV Substation - £30.17m SPT-RI-2139 Redshaw 400/132kV SGT - £15.61m SPT-RI-3060 Redshaw 132kV 'B' Board - £47.92m SPT-RI-4137 Redshaw Harmonic Filter 'A' board - £9.75m SPT-RI-4138 Redshaw Harmonic Filter 'B' board - £9.75m		
Delivery Year	SPT-RI-2060 Redshaw 400kV Substation - 2027 SPT-RI-2061 Redshaw 132kV Substation - 2027 SPT-RI-2139 Redshaw 400/132kV SGT - 2028 SPT-RI-3060 Redshaw 132kV 'B' Board - 2029 SPT-RI-4137 Redshaw Harmonic Filter 'A' board - 2030 SPT-RI-4138 Redshaw Harmonic Filter 'B' board - 2030		
Applicable Reporting Tables	BPDT (Section 5.1 – Project Meta Data, Section 6.1 – Scheme C&V Load Actuals, and Section 11.10 Contractor Indirects)		
Historic Funding Interactions	N/A		
Interactive Projects	N/A		
Spend Apportionment / TORI	**ET2**	**ET3**	**ET4**
SPT-RI-2060	£16.41m	£44.32m	£0.00m
SPT-RI-2061	£10.80m	£19.37m	£0.00m
SPT-RI-2139	£6.77m (customer contribution £0.04m)	£9.65m (customer contribution £0.08m)	£0.00m
SPT-RI-3060	£10.36m	£37.56m	£0.00m
SPT-RI-4137	£0.04m	£9.71m	£0.00m
SPT-RI-4138	£0.04m	£9.71m	£0.00m

Table of Contents

1. Executive Summary

This engineering justification paper (EJP) sets out the need case for:

- development of a new Redshaw 400/132kV substation adjacent to the existing 400kV ZV route in SP Transmission's (SPT) network in South Lanarkshire (ref. SPT-RI-2060);
- development of a new Redshaw 132kV substation, switchboard 'A' and installation of a new 400/132kV 360MVA super grid transformer (SGT) at Redshaw 132kV, 'A' board (ref. SPT-RI-2061);
- installation of a second 400/132kV 360MVA SGT and a Load Management Scheme (LMS) at Redshaw 132kV, 'A' board (ref. SPT-RI-2139);
- development of a new Redshaw 132kV substation, switchboard 'B', and installation of two 400/132kV 360MVA SGTs and a LMS at Redshaw 132kV 'B' board (ref. SPT-RI-3060);
- installation of one unit of 20MVAr harmonic filter at the new Redshaw 132kV 'A' board (ref. SPT-RI-4137); and
- installation of one unit of 20MVAr harmonic filter at the new Redshaw 132kV 'B' board (ref. SPT-RI-4138).

This submission supports six discrete applications summarised above.

The proposed Redshaw substation will also connect the new circuits heading west towards the planned Glenmuckloch substation in southwest Scotland (SWS). The Glenmuckloch substation and its connection to the proposed Redshaw substation is planned under SPT-RI-236, the scope of which is outside this EJP.

The primary drivers behind this project are: (i) to accommodate the significant amount of renewable generation application received in South Lanarkshire area; (ii) to ensure network compliance with EREC G5/5 in the area; and (iii) the development of Redshaw substation, by facilitating extension of transmission network from the SWS area towards South Lanarkshire, additionally enables connection of contracted renewable generation to the wider electricity system.

The expected project delivery year for the proposed scheme is:

- SPT-RI-2060 - 2027;
- SPT-RI-2061 - 2027;
- SPT-RI-2139 - 2028;
- SPT-RI-3060 - 2029;
- SPT-RI-4137 - 2030; and
- SPT-RI-4138 - 2030.

The estimated project cost breakdown for the proposed scheme is:

- SPT-RI-2060 - £60.73m;
- SPT-RI-2061 - £30.17m;
- SPT-RI-2139 - £17.62m;
- SPT-RI-3060 - £47.92m;
- SPT-RI-4137 - £9.75m; and
- SPT-RI-4138 - £9.75m.

This EJP is submitted for Ofgem's assessment of the need case for the project and the selection of the preferred option in order to provide sufficient funding for pre-construction and early construction activities. It is anticipated that for the projects detailed within this paper, for projects greater than £25m, cost assessment submission(s) will be made to Ofgem at an appropriate time. For projects under £25m it is proposed to use the RIIO-T3 Use It or Lose It (UIOLI) pot accordingly.

2. Introduction

This EJP sets out SP Transmission (SPT)'s plans to:

(i) establish a new Redshaw 400/132kV substation between Coalburn and Elvanfoot substations, on ZV route;
(ii) establish a new 132kV substation with two switchboards, 'A' & 'B' boards;
(iii) install two new 400/132kV 360MVA super grid transformers at 'A' board of the new 132kV substation (i.e., SGT2 & SGT3);
(iv) install two new 400/132kV 360MVA super grid transformers at 'B' board of the new 132kV substation (i.e., SGT1 & SGT4);
(v) install a LMS to monitor the loadings across SGT2 and SGT3 at Redshaw 132kV, 'A' board, under N-1 conditions and issue relevant trip signals to the appropriate generators;
(vi) install a LMS to monitor the loadings across SGT1 and SGT4 at Redshaw 132kV, 'B' board, under N-1 conditions and issue relevant trip signals to the appropriate generators; and
(vii) install two units of 20MVAr harmonic filters (with a site-specific damping resistor) in the new Redshaw 132kV substation, one at each 'A' and 'B' boards.

For reference ZV route is 126km of a L8 construction, 400kV double circuit overhead line (OHL) connecting SPT's Strathaven 400kV substation, southeast of Glasgow, to NGET's Harker 400kV substation, north of Carlisle. This is the west coast onshore interconnector between Scotland and the North of England. The proposed Redshaw substation lies between existing towers ZV108 and ZV112, on the ZV route, and will also take in the new circuits heading west towards a planned new Glenmuckloch substation in SWS. The current schematic configuration of transmission network in the area is shown in Figure 1. The diagram indicating geographical location of the proposed scheme can be found in Figure 2.

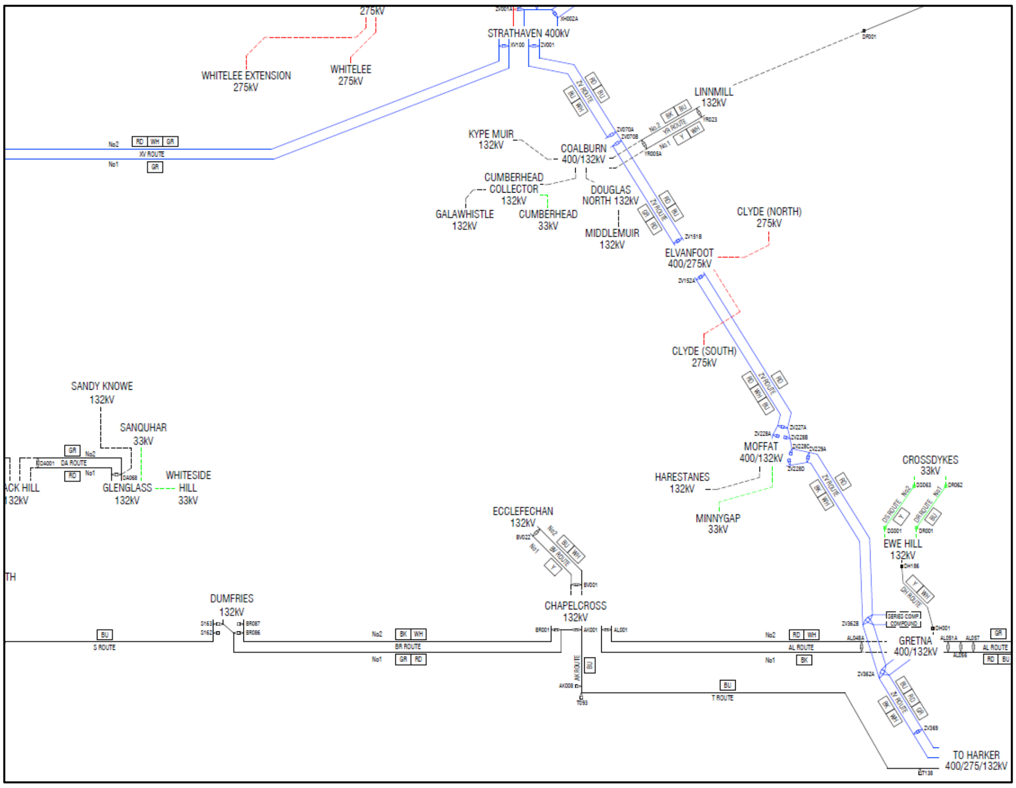


Figure 1: The existing transmission network in the area - extracted from Networks Diagram of the Existing SPT Systems shown in Appendix A (Figure A-1)

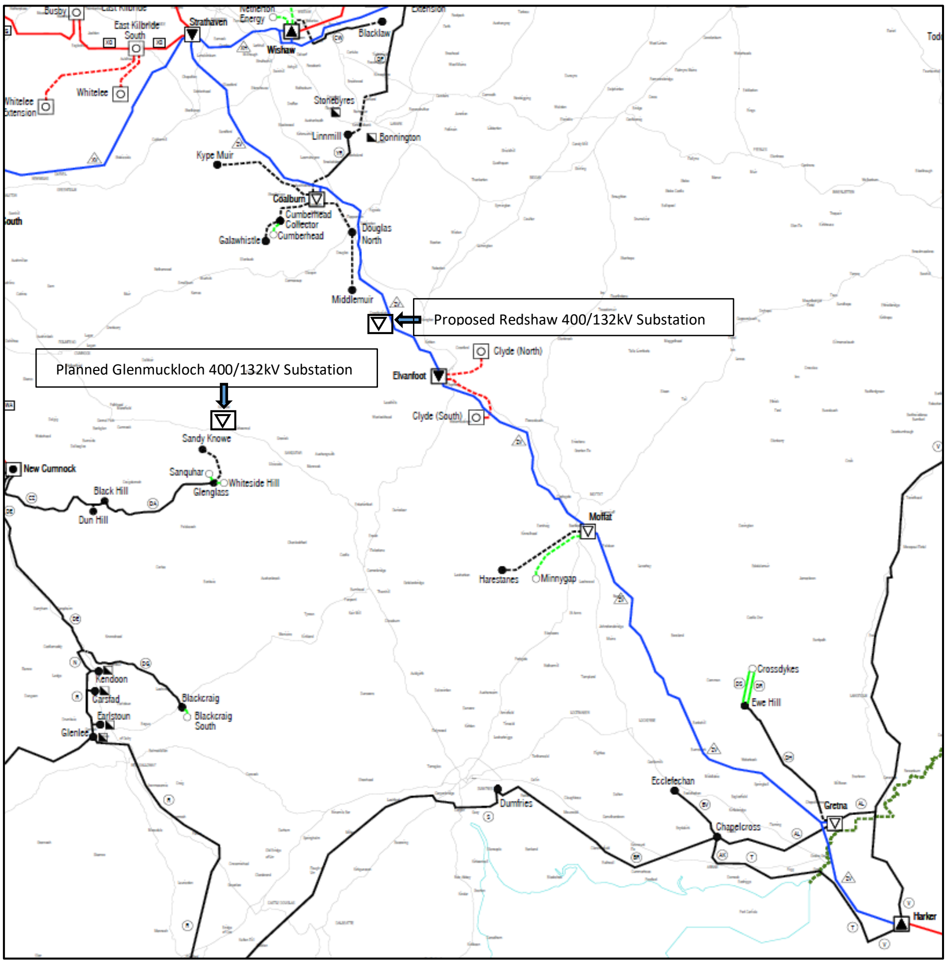


Figure 2: Geographical location of the proposed scheme with respect to the wider network in the area - extracted from Networks Diagram Geographical Layout shown in Appendix A (Figure A-2)

Forming part of the wider reinforcement in South Lanarkshire, this EJP is one needs case application supporting six projects, which namely are -

- SPT-RI-2060 – Redshaw 400kV substation;
- SPT-RI-2061 – Redshaw 132kV substation ('A' board);
- SPT-RI-2139 – Redshaw SGT2;
- SPT-RI-3060 – Redshaw 132kV substation ('B' board);
- SPT-RI-4137 – one 20MVAr harmonic filter at 'A' board; and
- SPT-RI-4138 – one 20MVAr harmonic filter at 'B' board.

The drivers behind the development of Redshaw cluster scheme are:

(i) to accommodate the significant amount of renewable generation applications (majority of which are large wind farms) received into South Lanarkshire. Redshaw 400kV substation will enable the timely and efficient connection of approximately 1.5GW of contracted renewable generation in the local area. The establishment of Redshaw 132kV substation ('A' and 'B' boards) and the provision of additional transformers capacity together facilitates the connection of a further circa 1.1GW of local renewable generation to 132kV network.

(ii) to facilitate connection of additional renewable generation in SWS by enabling creation of a new 'exit route' from a planned Glenmuckloch substation (ref. SPT-RI-236), in the SWS area, towards ZV route. The planned Glenmuckloch 400kV to ZV route project enables the connection of circa 0.9GW renewable generation, the scope of which is outside this EJP.

(iii) to ensure the transmission network in South Lanarkshire area is complaint with harmonic level standards (also known as ENA Engineering Recommendation (EREC) G5/5 [1]).

Both Coalburn and Elvanfoot substations have reached the upper limits in terms of thermal and physical capability to accommodate further connection applications into either substation. The 400/275kV transformers at Elvanfoot substation are committed to 88% of their total thermal capacity and the scope for any further generation capacity at this substation is extremely limited given the topology of the substation, for example, the Elvan Water which sits to the west and south of the substation boundary fence line making further platform extensions challenging.

Similarly, the 400/132kV transformers at Coalburn substation are committed to 98% of their total thermal capacity. Coalburn 400/132kV substation was constructed in 2009 and installed two 400/132kV 240MVA transformers as well as spare 132kV bays to accommodate future connections into this area of the system. These spare bays and transformer capacity quickly became contracted, and a third SGT was triggered in 2013 which required the substation platform to be extended. Still further generation applications came into this part of the system and the Coalburn substation platform had to be extended again to accommodate a fourth SGT. These works are planned under SPT-RI-264 and are outside the scope of this EJP. The SPT-RI-264 project also triggered splitting the 132kV busbars into two boards to manage 132kV fault levels. After two substation platform extensions however Coalburn substation is unable to accommodate any further connections given the nearby Site of Special Scientific Interest (SSSI), Coalburn Moss, which prohibits the substation platform from being extended further.

SPT are, however, establishing a new 400kV substation, Coalburn North, directly north of the existing Coalburn substation, to accommodate circa 1.5GW of generation/battery energy storage system (BESS) connections as well as a 1.4GW demand only connection. The establishing of this new site was triggered by the location of these applications and SPT's inability to connect these parties into the existing Coalburn substation.

In addition to these, circa 2.9GW of generation has been currently contracted for connection in the area between Coalburn and Elvanfoot. With continued renewable generation activity in this area, there is a need for development of the proposed Redshaw 400/132kV substation to accommodate the additional generation.

From a wider system perspective, in the SWS area the transmission system from Kilmarnock South to New Cumnock and the system from New Cumnock to Glenglass are heavily thermally constrained. The new Redshaw 400kV substation can aid with this as it is planned for a new 400kV double circuit from Glenmuckloch substation, in SWS area, to connect into Redshaw. The development of the new 400kV double circuit from Glenmuckloch substation to Redshaw is planned under SPT-RI-236 and it is outside the scope of this EJP. This will create a new power corridor out of the SWS area and enable further renewable generation connections to be made in the region. The single line diagram of the proposed scheme in this EJP with respect to the wider electrical system in the area is shown in Appendix A, Figure A-3.

South Lanarkshire is an area rich in wind energy resource. An increasing number of large wind farm connection applications have been received into the 132kV network in South Lanarkshire. The volume of existing wind farm generators in the area is depicted in Appendix A, Figure A-4. The Figure A-5, in Appendix A, indicates the scale of currently contracted and the existing wind farms. The electricity system in South Lanarkshire area already has a relatively high network impedance and is considered a weak system. The wind farm connections are characterised by the extensive use of arrays of underground cable (i.e., effectively large capacitances in the overall electricity network) which impacts the system's resonance frequency. The combination of these large capacitances with high system impedance leads to emerge of lower resonant frequencies (typically below the 20^{th} harmonic or 1kHz) in the network. There is therefore a high risk that a network resonance coincides with a background harmonic, leading to harmonic voltages above planning and compatibility limits of the EREC G5/5.

Users are normally responsible for harmonic compliance at their connection point. This is based on the premise that harmonic voltages at the connection point are primarily due to harmonic injection from the user's plant (e.g., in the case of a HVDC converter). In such scenarios, the user can install harmonic filters to confine the harmonic injection to acceptable limits. The harmonic injection from most modern wind turbines is very low and high harmonic voltages at the connection point arise primarily due to harmonics that already exist on the network, amplified by a resonant condition. Under such resonant conditions, the harmonic levels at the connection point are a strong function of the network characteristics and hence very difficult for a user to design harmonic filter mitigation. This difficulty is due to followings:

- The final network design is uncertain. The resonant frequencies of the network will move under outage conditions, or as the network is developed and new connections are made.
- The design of future windfarms and their harmonic emissions are unknown.
- Network outages (due to faults or for maintenance or construction) can have a significant impact on harmonic resonance.
- Mitigation designed by a user to deal with harmonic resonance is unlikely to be efficient from a whole-system point of view.
- Harmonic resonances do not only affect windfarm connection points but lead to increased harmonic voltages throughout the network. The best location for a harmonic filter may not be at the connection point, but elsewhere in the transmission network.
- Windfarm array cables contribute to the problem. However, high harmonics are due to the amplification of pre-existing background harmonics and generally not harmonics produced by windfarms.

From a 'whole system' point of view, it is therefore economic and efficient for SPT to design and install harmonic mitigation, consistent with the approach taken in RIIO-T2 and also previously proposed by two SP Energy Networks (SPEN) innovation projects; NIA_SPT_1506 and 1610 [2-4].

At some sites in South Lanarkshire area, the risk of exceeding the EREC G5/5 limits is higher or high harmonic levels have already been reported. The most economic and co-ordinated solution is the installation of standardised 20MVAr damped (C-type) harmonic filters. Previously the need for installation of standardised damped (C-type) harmonic filters at different locations in this area has been justified, as a solution for harmonic issues, in SPT's submissions for the RIIO-T2 price control period [5] and has been approved by Ofgem. These locations namely are Moffat and Linnmill. With the continued growth of onshore wind contracted to connect in South Lanarkshire, the need for installation of further harmonic filtering in the area still exists to ensure system compliance with standard limits. This EJP therefore proposes installation of two 20MVAr harmonic filters at Redshaw 132kV substation, one connected to the 'A' board and the other to the 'B' board.

A schematic of the proposed new Redshaw substation, together with the harmonic filters is depicted in Figure 3, where the work scope of SPT-RI-2060, SPT-RI-2061, SPT-RI-2139, SPT-RI-3060, SPT-RI-4137 and SPT-RI-4138 have been highlighted.

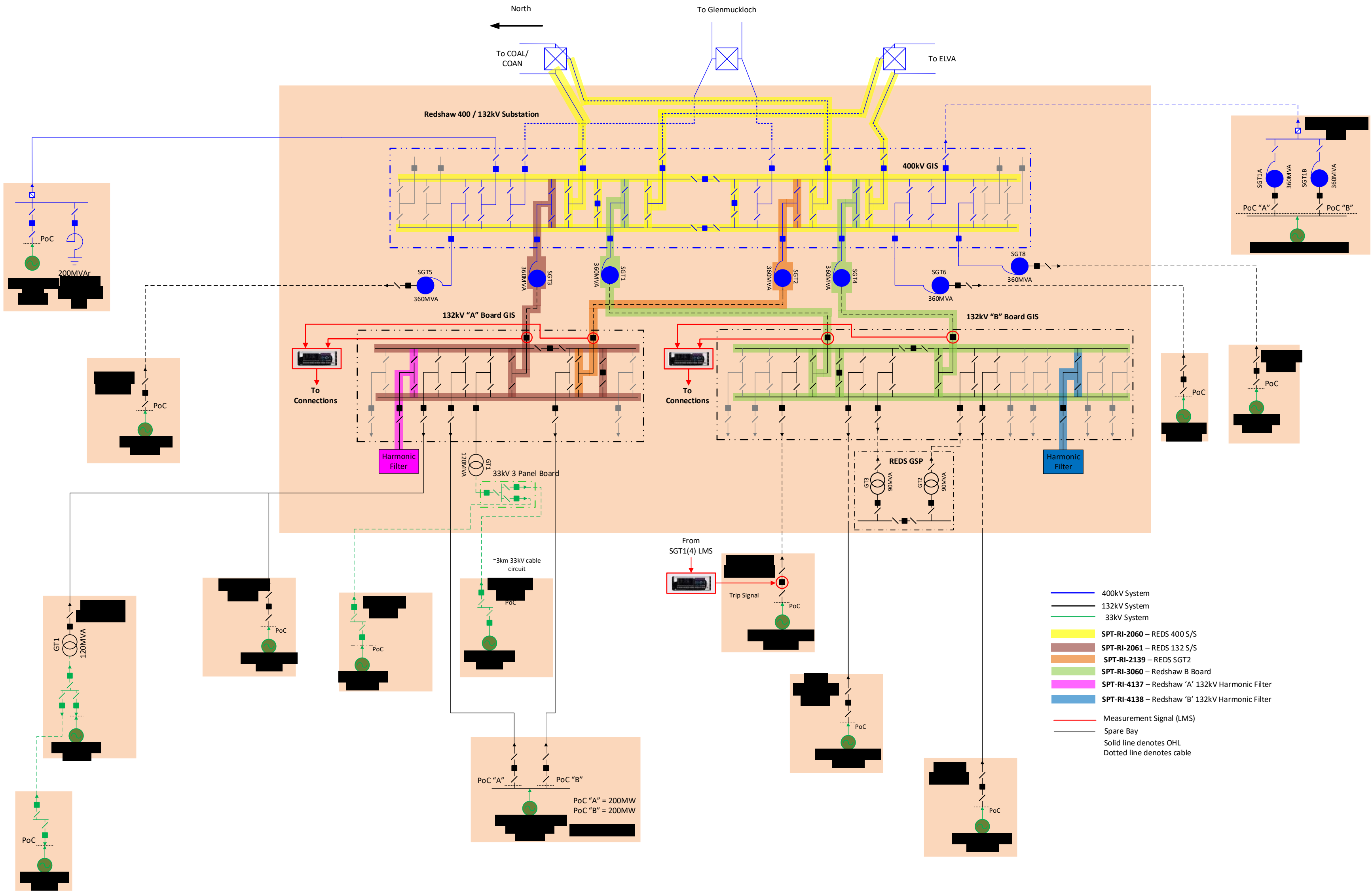


Figure 3: Single Line Diagram of the proposed Redshaw substation cluster. The work scope of SPT-RI-2060, SPT-RI-2061, SPT-RI-2139, SPT-RI-3060, SPT-RI-4137 and SPT-RI-4138 have been depicted with highlights.

A complete description of the needs case for Redshaw cluster project and installation of two harmonic filters (i.e., SPT-RI-2060. SPT-RI-2061, SPT-RI-2139, SPT-RI-3060, SPT-RI-4137 and SPT-RI-4138) as well as full justification for the selected reinforcement option are provided in the following sections. At a high level, however, the proposed scheme will comprise the following:

1. Establish the substation platform for the new Redshaw 400/132kV double busbar substation and install –
    - 6 x 400kV feeder bays towards Coalburn/Coalburn North, Elvanfoot and Glenmuckloch (2 feeders for connection to each direction)
    - 2 x 400kV bus couplers
    - 2 x 400kV bus sections
    - 4 x 400kV bays for connection of 'A' and 'B' board 400/132kV SGTs (2 to each)
    - 5 x 400kV feeder bays for connection of contracted customers
    - 4 x 400kV spare bays (2 at either end of the substation)
2. Establish the substation platform for the new Redshaw 132kV 'A' board[1] and install –
    - 2 x 400/132kV 360MVA SGT
    - 2 x 132kV bays for connection of 400/132kV SGTs (i.e., SGT2 and SGT3)
    - 1 x 132kV feeder bay for connection of the 20MVAr harmonic filter
    - 1 x 132kV bus coupler
    - 1 x 132kV bus section
    - 4 x 132kV feeder bays for connection of contracted customers
    - 2 x 132kV spare bays (1 at either side of the board)
3. Establish the substation platform for the new Redshaw 132kV 'B' board[2] and install –
    - 2 x 400/132kV 360MVA SGT
    - 2 x 132kV bays for connection of 400/132kV SGTs (i.e., SGT1 and SGT4)
    - 1 x 132kV feeder bay for connection of the 20MVAr harmonic filter
    - 1 x 132kV bus coupler
    - 1 x 132kV bus section
    - 2 x 132kV feeder bays for new Redshaw 132/33kV Grid Supply Point (GSP).
    - 3 x 132kV feeder bays for connection of contracted customers
    - 6 x 132kV spare bays (3 at either side of the board for future connections)

The expected project delivery year for development of the proposed scheme is:

- Development of Redshaw 400/132kV substation (SPT-RI-2060) - 2027;
- Development of Redshaw 132kV substation, 'A' board (SPT-RI-2061) - 2027;
- Development of Redshaw SGT2 (SPT-RI-2139) - 2028;
- Development of Redshaw 132kV substation, 'B' board (SPT-RI-3060) - 2029;
- Installation of 132kV harmonic filter at Redshaw 'A' 132kV board (SPT-RI-4137) – 2030;
- Installation of 132kV harmonic filter at Redshaw 'B' 132kV board (SPT-RI-4138) – 2030.

The estimated project cost breakdown is:

- Development of Redshaw 400/132kV substation (SPT-RI-2060) - £60.73m;
- Development of Redshaw 132kV substation, 'A' board (SPT-RI-2061) - £30.17m;

[1] NB – both the 'A' and 'B' boards will be established in the same building.
[2] NB – both the 'A' and 'B' boards will be established in the same building.

- Development of Redshaw SGT2 (SPT-RI-2139) - £17.62m;
- Development of Redshaw 132kV substation, 'B' board (SPT-RI-3060) - £47.92m;
- Installation of Redshaw 132kV harmonic filters (SPT-RI-4137 & SPT-RI-4138) - £9.75m each.

This EJP is submitted for Ofgem's assessment of the need case for the project and the selection of the preferred option in order to provide sufficient funding for pre-construction and early construction activities.

3. Background Information

In this section a background relating to the existing system in the area has been provided indicating scale of the currently contracted and existing renewable developments in the region. Further information on the contracted position at the proposed Redshaw substation has been also provided. Considering the significant volume of connected and contracted wind farm generators in the area the harmonic compliance of the region's electricity network has been also analysed in this section.

3.1. Existing System at ZV Route

The ZV route is a 126km 400kV double circuit OHL route which connects SPT's Strathaven 400kV substation, southeast of Glasgow, to NGET's Harker 400kV substation, north of Carlisle. Constructed in 1993 utilising L8 type steel lattice towers and comprising a twin All Aluminium Alloy Conductor (AAAC) 500mm^2 'Rubus' phase conductor bundle, ZV route forms a strategic north - south power corridor between the south of Scotland and north of England.

Following a recommendation in the 7th Network Options Assessment (NOA7), which supports the Holistic Network Design (HND), two separate but related proposals have received proceed signals for replacement and uprating of the conductor system on ZV route with a High Temperature Low Sag (HTLS) conductor system (ref. NOA7 codes EHRE and VERE). It was further recommended by the Transitional Centralised Network Plan 2 (tCSNP2), or Beyond 2030 report, published by the ESO in March 2024[3].

Approximately 8.0GW of renewable generation is connected/contracted onto the ZV route. The most recent Construction Planning Assumptions (CPA) received from NESO has reduced this value down to circa 4.0GW on the route at any time through the use of probabilistic dispatch across all generators in this corridor however this is still above the thermal rating of the line post EHRE and VERE uprating to HTLS conductor.

3.2. Existing System at Coalburn

The existing Coalburn 400/132kV substation is situated to the south of Lesmahagow in South Lanarkshire and sits north of the proposed Redshaw substation. Coalburn 400/132kV substation forms part of the West Coast onshore interconnection between Scotland and England and serves Linnmill 132/33kV GSP. It utilises Air Insulated Switchgear (AIS) with 400kV and 132kV equipment in a double busbar configuration. Both Linnmill GSP and Coalburn 400/132kV Substations serve as collector sites for onshore wind energy developments.

Coalburn substation has existing and contracted connections at both 400kV and 132kV. Further significant extension of the existing substation platform is not considered feasible due to local considerations, most notably the nearby Coalburn Moss SSSI, which makes both extension of the

[3] Link to ESO Beyond 2030 Report - March 2024.

substation platform and physically achieving connections into the substation extremely challenging from an environmental planning and circuit routing perspective.

At Coalburn substation there is circa 0.9GW of connected/contracted generation enabled via the 132kV double busbar boards here and a further 500MW of battery storage is contracted to connect into the 400kV double busbar substation. This is summarised in Table 1.

Table 1: Contracted Generation into Coalburn 400/132kV Substation

Connecting Substation	Contracted Development	Consent Status	TECA Score[4]	Contracted Energisation Date	Capacity (MW)
[redacted]					

4 Transmission Economic Connections Assessment (TECA) – this assessment represents SPT's best view of the contracted generation landscape to 2036 and forms the basis for evaluating the timely delivery of reinforcement works. This regular assessment activity provides updated projections of renewable development in Scotland, and feeds into SPT's plans, ensuring the investment best meets the needs of users and customers.

Connecting Substation	Contracted Development	Consent Status	TECA Score[4]	Contracted Energisation Date	Capacity (MW)
[redacted]					
Total Capacity (GW)		-	-	-	1.4GW

TECA Legend

TECA Probability	Designated Colour
High	
Medium	
Low	

Given that 1.4GW of generation is due to connect via Coalburn substation it should be noted only a further 354MW of generation could be connected into Coalburn 400/132kV substation without requiring additional reinforcement works. Anything greater than 354MW would result in the generation connections into Coalburn substation exceeding 1800MW which is the infrequent infeed loss risk as per NETS SQSS. Anything greater than this would require SPT to bring a third infeed into Coalburn to maintain compliance with the SQSS.

3.3. Existing System at Coalburn North

The development of Coalburn North 400kV Substation, a planned 400kV AIS double busbar substation to the north of the existing Coalburn compound and on the northern / eastern side of ZV route, is considered feasible, and provides the means of connecting several contracted BESS developments in the area, totalling circa 1.0GW (as per Table 2) as well as a 1.4GW contracted demand facility. The Coalburn North 400kV substation project will be scoped under SPT-RI-2058 and is outside the scope of this EJP.

The continued renewable generation activity in the South Lanarkshire area however, together with the need to accommodate additional generation in southwest Scotland, result in the need for the development of Redshaw 400/132kV Substation, to the south of Coalburn.

The first development to contract for connection directly into Coalburn 400kV Substation was the planned [redacted] Facility. The subsequent connections require the establishment of the planned Coalburn North 400kV Substation (ref. SPT-RI-2058). It is proposed to develop a new Coalburn North 400kV substation due to the need to manage loss of infeed risk and challenges in relation to further extending the existing 400kV compound.

Table 2: Contracted Generation into Coalburn North 400kV Substations

Connecting Substation	Contracted Development	Consent Status	TECA Score	Contracted Energisation Date	Capacity (MW)
[redacted]					
Total Capacity (GW)		-	-	-	**1.0GW**

The generation projects currently contracted to connect into the 400kV busbar at Coalburn North 400kV substation are outlined in Table 2. All direct generation connections into this substation relate to planned BESS developments. In addition to the generation developments detailed in Table 2, a 1.4GW demand facility has also recently accepted an offer for connection via Coalburn North 400kV Substation.

3.4. Existing System at Elvanfoot

Elvanfoot substation is a 400/275kV double busbar substation. Both sides of ZV route are turned into Elvanfoot 400kV substation and, a single 400kV 225MVAr Mechanically Switched Capacitor Damping Network[5] (MSCDN) provides voltage support under high power transfer conditions from Scotland to England.

The substation was established to maintain traction supplies to the West Coast Mainline (via two 400/25kV 80MVA transformers), as well as connect the [redacted] Wind Farm connections (via two 400/275kV 500MVA transformers, one for each connection).

There are currently no connections proposed to connect directly into the 400kV double busbar substation at Elvanfoot. Extension of the substation platform could only be achieved to the west, however space in this direction is extremely limited by virtue of the given the nearby Elvan Water and associated topography.

As noted above, both [redacted] Wind Farms are connected into Elvanfoot via 400/275kV transformers. Further applications for connection have been received in the area; a small compound extension is required to create space for a 275/132kV transformer in order to facilitate

5 Mechanically Switched Capacitor (bank with) Damping Network. Equipment primarily designed as shunt capacitor for reactive compensation, but with an additional damping network to mitigate potential harmonic resonance.

the [redacted] connections.

Table 3 shows the connected and contracted generation connected into Elvanfoot substation.

Table 3: Connected/ Contracted Generation into Elvanfoot 400/275kV Substation

Connecting Substation	Contracted Development	Consent Status	TECA Score	Contracted Energisation Date	Capacity (MW)	Connecting SGT
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	SGT2A
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	SGT2A
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	SGT2A
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	SGT2A
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	SGT2A
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	SGT2A
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	SGT2A
Total Capacity (GW)		-	-	-	**1.0GW**	

At Elvanfoot a total of 1000MVA transformer capacity is available across two 500MVA units. Table 4 indicates the prospective loadings on these units.

Table 4: Elvanfoot SGT Loadings

	Capacity (MVA)	Loading (MVA)	%
Elvanfoot SGT1A	500	394	79%
Elvanfoot SGT2A	500	491	98%

The continued renewable generation activity in the South Lanarkshire area, together with the need to accommodate additional generation in southwest Scotland, result in the need for the development of Redshaw 400/132kV substation, to the north of Elvanfoot.

3.5. Contracted Position at the Proposed Redshaw Substation

Bilateral Connection Agreements are in place between NESO and the developers of renewable generator projects detailed in Table 5 for connection to the new Redshaw substation.

During the process of identifying and evaluating options for each connection offer, due regard was given to the development of an efficient, co-ordinated, and economical system of electricity transmission. As well as determining the most appropriate connection location, the most appropriate method of connection (e.g., OHL, underground cable, wood pole vs. steel tower, connection voltage etc.) was also considered.

Table 5 outlines the contracted projects due to connect into Redshaw substation and the relevant reinforcement scheme (i.e., SPT-RI-2060, SPT-RI-2061, SPT-RI-2139 & SPT-RI-3060) that each project is dependent on.

Table 5: Generation Application into Redshaw 400/132kV Substation

Connecting Substation	Contracted Development	Consent Status	TECA Score	Contracted Energisation Date	Capacity (MW)	SPT-RI-2060	SPT-RI-2061	SPT-RI-2139	SPT-RI-3060
[redacted]						Y			
[redacted]						Y			
[redacted]						Y			
[redacted]						Y			
[redacted]						Y			
[redacted]						Y	Y		
[redacted]						Y	Y		
[redacted]						[redacted]	[redacted]	[redacted]	[redacted]
[redacted]						Y	Y	Y	

Connecting Substation	Contracted Development	Consent Status	TECA Score	Contracted Energisation Date	Capacity (MW)	SPT-RI-2060	SPT-RI-2061	SPT-RI-2139	SPT-RI-3060
[redacted]						Y	Y	Y	
[redacted]						Y	Y	Y	
[redacted]						Y	Y	Y	
[redacted]						Y			Y*
[redacted]						Y			Y*
[redacted]						Y			Y
[redacted]						Y			Y
[redacted]						Y			Y
[redacted]						[redacted] Y			Y*
Total Capacity (GW)		-	-	-	2.9GW	2.9 GW	684 MW	396 MW	422 MW

**Connections are contingent on the establishing of the new Redshaw 132/33kV GSP which will connect into the Redshaw 'B' board.*

3.6. Harmonic Compliance

As part of a regulated business, SPEN evaluates compliance of the connection applications with respect to industry standards including compliance with ENA Engineering Recommendation (EREC) G5/5 for harmonic voltage levels. As outlined in Section 2, users are normally responsible for harmonic mitigation at their point of connection. However, it is expected that the harmonic injection from recent wind farm contracts to be very low due to the modern structural design of their wind turbines. With respect to this and also acknowledging the transmission network in South Lanarkshire area is relatively weak (i.e., has high network impedance), the high harmonic voltages at the connection point arise primarily due to harmonics that already exist on the network. In this case, analyses have shown the most economic and coordinated solution is the installation of standardised damped (C-type) harmonic filters by SPT, consistent with the approach adopted in RIIO-T2 period. A similar approach has been also considered by other transmission owners such as NGET in relation to the connection of large offshore wind farms to a relatively weak 132kV network (i.e., a network with high network impedance) [6]. Employing this approach can also assist with the following problems:

- Harmonic headroom in the network can be managed better and apportioned more fairly.
- Mitigation costs are distributed more equitably between users. For example, a situation where a windfarm (windfarm 'b') avoids filter installation costs because a nearby windfarm (windfarm 'a') has already installed filters, becomes much less likely.
- The risk of late detection of harmonic problems will be reduced.
- The filter redundancy will be improved. A coordinated approach would avoid extensive harmonic problems arising from the failure or unavailability of a single harmonic filter bank. Note that disconnecting the associated windfarm would not necessarily solve the problem.

In depth analyses have been carried out using power system simulations indicting the need to install two identical 132kV 20MVAr damped filters, similar to an MSCDN or also known as a C-type filter, at Redshaw substation, one at Redshaw 'A' board and one at Redshaw 'B' board. The results of these simulations have been included in Appendix C.

3.6.1. Proposed Damped Harmonic Filter

Two identical harmonic filters have been proposed for installation at each Redshaw 'A' and 'B' boards. The layout and parameters of the harmonic filter derived from the power system simulations are shown in Figure 4. These parameters are chosen according to maintain a homogenous criteria with other filters that are going to be installed in the network. To achieve that a 200Ω tunning resistance has been determined resulting in a 350Hz resonance frequency that corresponds to the 7th harmonic of the network.

One of the main advantages of the proposed filter design is that it provides damping to a wide range of harmonic frequencies, rather than being sharply tuned to a specific harmonic. This characteristic is important for this project but comes at the expense of increased losses. In such standardised harmonic filters although the devices are similar, note that a discharge VT as installed on MSCDNs is not required for the harmonic filters. After de-energising a harmonic filter, it is sufficient to enforce a time-delay to allow the capacitors to discharge before the filter can be switched in again.

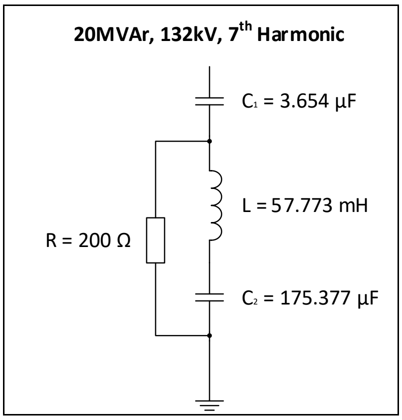


Figure 4: Schematic of the proposed harmonic filter - Filter Layout and Parameters.

Additionally, insulation coordination must be considered in further detail but note that a high-energy surge arrester is likely to be required across the resistor. The switching duty for the associated circuit breaker is not unusually onerous and a standard 132kV circuit breaker rated for capacitive switching duty can be employed.

3.6.2. Losses of the Proposed Damped Harmonic Filter

In an ideal scenario, there won't be any current passing through the filter resistor (i.e., R in Figure 4)[6] at 50Hz frequency, therefore the 50Hz losses are normally very low. In practice, some losses result due to component tolerances or deviation of the system frequency from 50Hz. The filter losses due to harmonic currents depend on the levels of harmonic distortion on the network. If it is assumed that all harmonic voltages are at the maximum compatibility limit allowed by EREC G5/5, the losses could be in excess of 500kW. However, such a condition is extremely unlikely to arise and would not persist for very long. Losses are normally not expected to exceed 60kW – 70kW.

Generally, lower harmonic voltage levels across the network will reduce losses at harmonic frequencies and therefore contribute to a reduction in total network losses. However, extensive network simulations are required to estimate these losses. As harmonic losses are low compared to 50Hz losses, this has not been attempted.

Considering the provided background information on the existing electricity network in the area, the system requirements and design parameters of the proposed scheme are summarised in Table 6.

[6] L and C_2 are tuned to 50 Hz to bypass the resistor.

Table 6: System Requirements and Design Parameters

System Design Table	Circuit/Project	Redshaw Cluster Reinforcements
Thermal and Fault Design	Existing Voltage (if applicable)	N/A
	New Voltage	400kV 132kV ('A' and 'B' boards)
	Existing Continuous Rating (if applicable)	N/A
	New Continuous Rating	N/A
	Existing Fault Rating (if applicable)	N/A
	New Fault Rating	50/55kA (400kV board) 20/25kA (132kV boards)
ESO Dispatchable Services	Existing MVAR Rating (if applicable)	N/A
	New MVAR Rating (if applicable)	20MVAr (2 units)
	Existing GVA Rating (if applicable)	N/A
	New GVA Rating	N/A
System Requirements	Present Demand (if applicable)	N/A
	2050 Future Demand	N/A
	Present Generation (if applicable)	N/A
	Future Generation Count	24
	Future Generation Capacity	2.9GW
Initial Design Considerations	Limiting Factor	N/A
	AIS / GIS	400kV - GIS 132kV 'A' Board - GIS 132kV 'B' Board - GIS
	Busbar Design	Double Busbar (both 400kV and 132kV)
	Cable / OHL / Mixed	OHL
	SI	This scheme enables future development of network in the region, including interconnectivity with future onshore 400kV corridors. The proposed standardised harmonic filters also mitigate the harmonic issues in the 132kV network in South Lanarkshire area.

4. Optioneering

This section provides a description of the options that have been considered to accommodate connection of renewable generation developments in South Lanarkshire area. The considered options for this scheme have been divided into two categories; category A – options considered to accommodate generation connections in the region, and category B – options considered for harmonic mitigation in the area.

Category A – Options Considered to Accommodate Generation Connections

4.1. Option 1: Do Nothing / Delay - Connection of Renewable Generation

A 'Do Nothing' or 'Delay' option is not viable for project and would be inconsistent with SPT's statutory duties and licence obligations, including Licence Conditions D3 and D4A. These require SPT to comply with the NETS SQSS and to offer to enter into an agreement with the system operator upon receipt of an application for connection, in line with the System Operator Transmission Owner Code (STC) and the associated Construction Planning Assumptions provided by NESO. The proposed works are identified as Enabling Works in the connection agreements relating to the projects described in Section 3.

4.2. Option 2: Extend Coalburn 400/132kV Substation

This option is to extend Coalburn 400/132kV substation to facilitate both the future connections in South Lanarkshire area and the future Glenmuckloch to ZV route project (this project is planned under SPT-RI-236 and is outside the scope of this EJP). Section 3.2 outlines that 1.4GW of contracted generation is made into Coalburn substation. As outlined in Section 1 there are multiple reinforcement drivers, including: the connection of the planned 400kV double circuit from the Glenmuckloch area under SPT-RI-236 and the need to connect 2.9GW of contracted generation in the area between Coalburn and Elvanfoot (as per Table 5).

In order to connect in excess of 354MW (as per Section 3.2) at Coalburn substation a third busbar section and third 400kV circuit would need to be connected into the substation such that compliance with clauses 2.6.3 and 2.6.6 of the NETS SQSS can be maintained. An indicative layout arrangement is shown in Figure A-6, in Appendix A, with the new works noted in yellow. This proposal was considered to accommodate the [redacted] and [redacted] Facility applications. The single line diagram shown in Figure A-6, Appendix A, also includes the planned Glenmuckloch 400kV double circuit. It does not however accommodate the contracted [redacted] Farm development or any of the further contracted generation detailed in Table 5 as these were not being considered at this time.

The extent of compound extension to the Coalburn 400kV substation as indicated in Figure A-6, in Appendix A, is not feasible due to the nearby Coalburn Moss SSSI which limits expansion abilities to the west of the site (over and above the platform extension work which has already been carried out).

The planned development of Coalburn North 400kV Substation (which is under SPT-RI-2058 and is outside the scope of this EJP), is described in Section 4.3 below, and mitigates the risk to the SSSI area and the effects on the hydrology of the area associated with extending the existing Coalburn 400kV Substation platform. By establishing the new Coalburn North site the infrequent infeed loss risk remains below 1800MW.

For the reasons above, trying to facilitate the generation connections detailed in Table 5**,** as well as the new Glenmuckloch 400kV connection under SPT-RI-236 (the scope of which is outside this EJP) at Coalburn, is discounted due to the routing and environmental planning challenges coupled with the local works required to maintain compliance with the NETS SQSS.

In summary, this option is discounted in advance of detailed cost estimating exercise due to the following reasons:

- The infrequent infeed loss risk at Coalburn 400kV substation would exceed 1800MW without a substantial extension to the substation for which insufficient space exists; and
- Routing of the new planned Glenmuckloch double circuit (i.e., SPT-RI-236) to Coalburn would be extremely challenging, noting the Coalburn Moss SSSI located to the south of the existing substation, as well as existing wind farm infrastructure.

4.3. Option 3: Connection into Coalburn North Substation

As outlined in Section 4.2 the existing Coalburn 400/132kV substation's ability to facilitate new contracted generation and demand developments leads to the need for the planned Coalburn North 400kV substation (this work is under SPT-RI-2058 and is outside the scope of this EJP) to accommodate the contracted developments in Section 3.2.

This new Coalburn North substation was considered as a location to facilitate:

- the connection of the planned 400kV double circuit from the Glenmuckloch area under SPT-RI-236 (the scope of which is outside this EJP);
- the connection of circa 1.0GW of contracted generation in the Coalburn area (as per Table 2); and
- the connection of circa 2.9GW of contracted generation in the area between Coalburn and Elvanfoot (as per Table 5).

However, this was ultimately discounted in advance of detailed cost estimating exercise for the reasons outlined below:

- Similar to the existing Coalburn 400kV Substation site described in Section 4.2, the ability to route a new 400kV double circuit into Coalburn North proved extremely challenging given the existing wind farm infrastructure in the area, the Coalburn Moss SSSI as well as the existing ZV Route, which any new route would need to cross. Figure A-7, in Appendix A, shows the operational, and planned, transmission windfarm connections into Coalburn substation (note there are other smaller, distribution connections in the area). On the bottom left-hand corner of this figure is the indicative location of the new planned Glenmuckloch 400/132kV substation, the scope of which is outside this EJP.
- From a generation connection application standpoint, given the locations of these developments, routing and construction of 400kV and 132kV circuits from each site towards the Coalburn North substation would result in longer, and more challenging, routes to Coalburn/ Coalburn North given the existing connections/windfarms into this substation as compared to a connection to a new site located in the area between Coalburn and Elvanfoot. Figure A-8, in Appendix A, shows an indicative geographical view of the new connections in this area in addition to those shown in Figure A-7, in Appendix A.

4.4. Option 4: Extend Elvanfoot Substation

As outlined in Section 3.4 in order to accommodate the contracted generation in this area the Elvanfoot 275/132kV transformer reinforcement project is in delivery. This scheme is planned under SPT-RI-226 and is outside the scope of this EJP.

Based on the Elvanfoot 400kV substation layout, there are no spare bays available within the existing substation footprint. The geographical location of the Elvanfoot substation can be found in Appendix A, Figure A-9. At the east side of the substation, the area marked within the yellow lines is reserved for the delivery of the Elvanfoot 275/132kV transformer project (i.e., SPT-RI-226), which is due to complete at the end of 2026 and is outside the scope of this EJP. This area cannot be extended further given the existing 275kV cable circuit serving the customer's connection, and regardless would not serve to extend the 400kV busbars as required. The associated standoff corridors are located further east of the discussed area.

Considering this, the only direction in which the substation could be extended, is to the west of the Elvanfoot substation. Creating space at the west of the substation would require diversion of the Elvan Water to the south which is a significant civil engineering exercise. Additionally, the proximity of the compound to the river and based on experience from previous excavations, the water table is noted to be very high in the area.

Therefore, extending the Elvanfoot substation platform to the west will require dewatering wells and drainage installation which would add significant cost to the solution along with the associated risks with this type of activity. Also, the total level difference between the river and the existing compound is approximately 2.5-3m. Extension of the Elvanfoot substation to the west would need the land to be infilled with a Class 1 imported fill. Slope design for this would further increase the overall intake by an extra 9m toward west, which means the extended substation would be at capacity with no room for further extension. Given the civil engineering and associated environmental planning challenges this option is discounted in advance of detailed cost estimating exercise.

In addition to this, the location of Elvanfoot is also some distance south of where the generation applications in this area are, thus longer 400kV and 132kV circuits would require to be routed towards this location, which would add cost and potential programme disadvantages relative to the proposed solution.

4.5. Option 5: Creation of Redshaw 400/132kV Substation

Recognising the requirement for the location of a 400kV substation to enable the planned Glenmuckloch 400kV double circuit OHL (i.e., SPT-RI-236) to be routed into the area, as well as the ability to establish 400/132kV infrastructure to facilitate the connection of 2.9GW of contracted generation in the area between Coalburn and Elvanfoot (as per Table 5), this option proposes the development of Redshaw 400/132kV Substation. Noting the inability to connect further new generation into either Coalburn or Elvanfoot substations as outlined in the previous sections, Redshaw 400/132kV substation is proposed to be located approximately 12km south from Coalburn and 15km north from Elvanfoot.

Through the early development phases of this option, four sub-options were evaluated, weighing up the relative advantages and disadvantages of using AIS or Gas Insulated Switchgear (GIS) for both the 400kV and 132kV installations; hence, the sections detailing Options 5a, 5b, 5c and 5d below.

4.5.1. Option 5a – AIS Solution for 400kV and 132kV Substations

The use of AIS equipment was considered for use across both substation voltages. Initially an eight bay 400kV AIS development was considered. These 8 bays were allocated as follows:

- 2 x 400kV bays for Coalburn/Coalburn North circuits
- 2 x 400kV bays for Elvanfoot circuits
- 2 x 400kV bays for Glenmuckloch circuits
- 1 x 400kV bus section circuit breaker
- 1 x 400kV bus coupler circuit breaker

A double busbar 'wraparound' solution, as shown in Figure A-10 in Appendix A, was considered as part of the initial Redshaw design options, as this enables the incoming circuits into the substation to enter at the same point, however the wraparound configuration allows these to be split across the 400kV bus section without busbar or cable crossings as the circuits can run under the Main/Reserve busbars. This kind of arrangement can be advantageous as no crosses are required to split the circuits across the bus section circuit breaker. It was considered that the site could be set up with a Coalburn, Elvanfoot and Glenmuckloch circuit selected to the Main 1 busbar with the other Coalburn, Elvanfoot and Glenmuckloch circuit selected to the Reserve busbar. This would mean that under the scenario of a fault outage on either the bus section breaker or bus coupler breaker, a 'North-South' power corridor would remain intact. The 400/132kV SGTs would also be split across these two busbars as the site developed.

Upon receiving significant connection applications in this area; however, it became apparent that a 132kV substation would be required. Learning lessons from other substations across the system it was anticipated that this new 132kV board may ultimately require in excess of two 400/132kV transformers and as such at the early stages provision for four 400/132kV transformers was planned, together with a second bus section and bus coupler. This increased the number of 400kV bays from 8 to 12. For the 132kV substation this was also initially considered to utilise AIS equipment. Figure A-11, in Appendix A, shows an initial single line diagram of Redshaw 400kV and 132kV substations. Note the inclusion of the [redacted] Wind Farm 132kV bay, as this was one of the first connection applications received requiring the establishment of Redshaw 132kV substation.

The estimated total cost for this option is approximately £180.76m.

4.5.2. Option 5b – GIS Solution for 400kV and AIS 132kV Substation

Following on from Section 4.5.1 the use of GIS equipment for the 400kV substation is considered in this option, with the 132kV substation continuing to utilise AIS equipment. The spatial length of the substation was determined by the number of 400/132kV SGTs (since the length of the substation would need to accommodate, at least, four transformers, a 132kV AIS double busbar substation could occupy the same width).

Figure A-12, in Appendix A, shows an indicative layout drawing produced for this option. This shows the 400kV GIS substation connecting the three 400kV double circuit overhead line routes, as well as provision for up to four 400/132kV SGT connections to a 132kV AIS substation. At the time this drawing was produced (noting the subsequent evolution in the contracted generation background) the platform size was [redacted].

The estimated total cost for this option is approximately £162.50m.

4.5.3. Option 5c – GIS Solution for 400kV and 132kV Substation

As outlined in Section 4.5.2 the initial design and development of Redshaw considered a 400kV GIS substation and an accompanying 132kV AIS substation, however given the continued generation applications received and evolution of the contracted generation background, a change to a 132kV GIS configuration is considered appropriate. Figure A-13, in Appendix A, shows the layout drawing created when considering both the 400kV and 132kV substations being constructed utilising GIS equipment. At the time when this drawing was produced the platform size was [redacted], which represents a circa 34% reduction in platform size and contributes to a more economic, efficient, and coordinated solution relative to that in Option 5b.

The Figure A-13, Figure A-14 and Figure A-15, in Appendix A, outline the evolution of the substation design, incorporating a future 'B' 132kV substation alongside the 400kV substation under SPT-RI-2060 and the 'A' substation under SPT-RI-2061 and SPT-RI-2139. Figure A-13, in Appendix A, shows the layout when considering both the 400kV and 132kV substations as GIS installations.

Noting the continued generation activity in the Redshaw area, there is a need to plan for a 132kV 'B' substation. For similar reasons to the above, a future 'B' Board was considered initially as an AIS solution. A layout drawing was created for this arrangement and is shown in Figure A-14, in Appendix A, outlining the 132kV 'A' board as a GIS installation and the future 'B' board as an AIS installation.

Civil platform savings can be achieved however if both the 132kV 'A' board and future 132kV 'B' board ultimately utilise GIS equipment and are located within the same building, as indicated in Appendix A, Figure A-15.

What is clear from the progression of the layout drawings is the number of 400/132kV SGTs. It is noteworthy that four SGTs are indicated for new 132kV board(s) required at Redshaw. The additional transformers shown in Figure A-14 and Figure A-15, in Appendix A, are related to connections coming into Redshaw at the 132kV voltage level but will be connected via a dedicated 400/132kV transformer. The reason for this is some of schemes, given the capacity they are connecting, would take up a large portion of the shared SGT capacity across the 132kV board(s) and this would prevent other (smaller) connections proceeding, as additional transformers would be required to be connected to each board, but this is not possible given the fault level constraints these transformer connections would create.

The estimated total cost for this option is approximately £154.43m.

4.5.4. Option 5d – AIS Solution for 400kV and GIS 132kV Substation

For completeness the final iteration was evaluated which considered establishing Redshaw 400kV substation utilising AIS equipment, with the 132kV substations utilising GIS equipment. This solution was explored but discounted in line with the Option 5a due to the land requirements and economics associated with establishing a 400kV AIS substation. Considering this, Option 5d is discounted in advance of detailed cost estimating exercise.

4.5.5. Option Assessment – Redshaw Cluster Development

In Sections 4.1 – 4.5, eight options have been evaluated to accommodate contracted and future generation connection in the area. A summary of each option considered for development of Redshaw Cluster is described in Table 7, while the system requirements and design parameters for the considered options are outlined in Table 8.

Four options have been considered to establish the optimum switchgear technology type to be utilised at Redshaw, considering AIS and GIS across the two voltage levels (i.e., 400kV and 132kV). SPT undertook an exercise whereby the equipment cost, platform size and total costs were evaluated and compared. Given the number of 400kV bays required at the new substation this would have led to an extremely large 400kV compound being required if AIS equipment was to be used; however, the use of 400kV GIS equipment means that a smaller overall platform is required, leading to significantly lower overall costs when compared with the AIS alternative.

Similarly, for the 132kV equipment both technology types were considered. The design and development options for Redshaw 132kV substation initially considered the use of AIS equipment. Similar to the 400kV substation; however, the use of GIS equipment leads to significantly lower overall costs, driven by the reduced substation platform size required. As such it is proposed to develop Redshaw 400kV and 132kV substations utilising GIS equipment, as per Option 5c.

In the following sections (i.e., Sections 4.6 – 4.11) different options to mitigate harmonic issue in the Redshaw area have been considered with respect to the need to accommodate the contracted and future generation.

Table 7: Summary of Considered Options to Accommodate Contracted and Future Generation Connection

Options	Map	Layout of Substation/ Connection	Layout of all Route Works	Relevant Survey Works	Narrative Consenting Risks	Narrative Preferred Option	Narrative Rejection
Preferred – Option 5c: GIS solution for 400kV and 132kV substations	Refer to Figure A-15, Appendix A	Refer to Figure 3	N/A	N/A	Early engagement with landowners, environmental bodies and employing low bearing pressure ground vehicles and trackway where possible to minimise extents of stone tracks.	Eight options have been reviewed in terms of scope feasibility, cost, delivery timescales, land requirements, system limitations and restoring SQSS compliant limit with option 5a demonstrating a network capacity reinforcement whilst affording the least project deliverability risk.	N/A
Rejected – Option 1: Do Nothing / Delay	N/A	N/A	N/A	N/A	N/A	N/A	Inconsistent with SPT's various statutory duties and licence obligations.
Rejected – Option 2: Extend Coalburn 400/132kV substation	N/A	Refer to Figure A-6, Appendix A	N/A	N/A	N/A	N/A	The extension required is not feasible due to the platform encroaching on a nearby Coalburn Moss SSSI. This option was discounted in advance of detailed cost estimating exercise.
Rejected – Option 3: Connection into Coalburn North substation	N/A	N/A	N/A	N/A	N/A	N/A	The location of Coalburn North substation does not enable a feasible connection for the contracted generation in the area. It also does not enable connection of Glenmuckloch substation into the ZV route as it would lead to longer overhead line circuits needing to be routed. This option was discounted in advance of detailed cost estimating exercise.
Rejected – Option 4: Extend Elvanfoot substation	N/A	N/A	N/A	N/A	N/A	N/A	It is not possible to extend the Elvanfoot 400kV substation due to the layout of the substation, terrain, and new/existing equipment at the

							substation (MSCDN, cables and new connections). This option was discounted in advance of detailed cost estimating exercise.
Rejected – Option 5a: Redshaw substation – AIS solution for 400kV & 132kV substations	Refer to Figure A-11, Appendix A	N/A	N/A	N/A	N/A	N/A	The construction of a 400kV AIS substation and two 132kV AIS boards would result in a very large substation platform being required. Hence, it will be more expensive and challenging to consent in comparison with the proposed scheme. The estimated cost of this option is £180.76m.
Rejected – Option 5b: Redshaw substation – GIS solution for 400kV & AIS 132kV substations	Refer to Figure A-12, Appendix A	N/A	N/A	N/A	N/A	N/A	The space required to establish two 132kV AIS boards would result in a very large substation platform being required. Hence, it will be more expensive and challenging to consent in comparison with the proposed scheme. The estimated cost of this option is £162.50m.
Rejected – Option 5d: Redshaw substation – AIS solution for 400kV & GIS 132kV substations	N/A	N/A	N/A	N/A	N/A	N/A	Construction of a 400kV AIS substation would require a very large platform to be established which leads to significantly higher cost in comparison to a GIS substation. This option was discounted in advance of detailed cost estimating exercise.

Table 8: System Requirements and Design Parameters for the considered Options to Accommodate Contracted and Future Generation Connection

System Design Table	Circuit/Project	**Preferred – Option 5c:** GIS solution for 400kV and 132kV substations	**Rejected – Option 1:** Do Nothing / Delay	**Rejected – Option 2:** Extend Coalburn 400/132kV substation	**Rejected – Option 3:** Connection into Coalburn North substation
Thermal and Fault Design	Existing Voltage (if applicable)	N/A	N/A	400kV	400kV
	New Voltage	400kV 132kV	N/A	400kV	400kV
	Existing Continuous Rating (if applicable)	N/A	N/A	N/A	N/A
	New Continuous Rating	N/A	N/A	N/A	N/A
	Existing Fault Rating (if applicable)	N/A	N/A	50/55kA	50/55kA
	New Fault Rating	50/55kA 20/25kA	N/A	50/55kA	50/55kA
ESO Dispatchable Services	Existing MVAR Rating (if applicable)	N/A	N/A	N/A	N/A
	New MVAR Rating (if applicable)	N/A	N/A	N/A	N/A
	Existing GVA Rating (if applicable)	N/A	N/A	N/A	N/A
	New GVA Rating	N/A	N/A	N/A	N/A
System Requirements	Present Demand (if applicable)	N/A	N/A	N/A	N/A
	2050 Future Demand	N/A	N/A	N/A	N/A
	Present Generation (if applicable)	N/A	N/A	N/A	N/A
	Future Generation Count	24	24	24	24
	Future Generation Capacity	2.9GW	2.9GW	2.9GW	2.9GW
	Limiting Factor	N/A	N/A	It is not possible to extend Coalburn substation due to limited land availability.	The location of Coalburn North substation does not enable a feasible connection for the

Initial Design Considerations					contracted generation in the area.
	AIS / GIS	GIS	N/A	AIS	AIS
	Busbar Design	Double Busbar	N/A	Double Busbar	Double Busbar
	Cable / OHL / Mixed	OHL	N/A	OHL	OHL
	SI	This scheme enables future development of network in the region.	N/A	It does not enable the efficient electricity system in the area. Additionally, it does not enable connection of Glenmuckloch substation into the ZV route.	It does not enable the efficient electricity system in the area. Additionally, it does not enable connection of Glenmuckloch substation into the ZV route.

System Design Table	**Circuit/Project**	**Rejected – Option 4:** Extended Elvanfoot substation	**Rejected – Option 5a:** Redshaw substation – AIS solution for 400kV & 132kV substations	**Rejected – Option 5b:** Redshaw substation – GIS solution for 400kV & AIS 132kV substations	**Rejected – Option 5d:** Redshaw substation – GIS solution for 400kV & AIS 132kV substations
Thermal and Fault Design	Existing Voltage (if applicable)	400kV	N/A	N/A	N/A
	New Voltage	400kV	400kV 132kV	400kV 132kV	400kV 132kV
	Existing Continuous Rating (if applicable)	N/A	N/A	N/A	N/A
	New Continuous Rating	N/A	N/A	N/A	N/A
	Existing Fault Rating (if applicable)	N/A	N/A	N/A	N/A
	New Fault Rating	50/55kA	50/55kA 20/25kA	50/55kA 20/25kA	50/55kA 20/25kA
ESO Dispatchable Services	Existing MVAR Rating (if applicable)	N/A	N/A	N/A	N/A
	New MVAR Rating (if applicable)	N/A	N/A	N/A	N/A
	Existing GVA Rating (if applicable)	N/A	N/A	N/A	N/A
	New GVA Rating	N/A	N/A	N/A	N/A

System Requirements	Present Demand (if applicable)	N/A	N/A	N/A	N/A
	2050 Future Demand	N/A	N/A	N/A	N/A
	Present Generation (if applicable)	N/A	N/A	N/A	N/A
	Future Generation Count	24	24	24	24
	Future Generation Capacity	2.9GW	2.9GW	2.9GW	2.9GW
Initial Design Considerations	Limiting Factor	It is not possible to extend the Elvanfoot 400kV substation due to the layout of substation, terrain and new/existing equipment at the substation.	N/A	N/A	N/A
	AIS / GIS	GIS	AIS	GIS/AIS	GIS/AIS
	Busbar Design	Double Busbar	Double Busbar	Double Busbar	Double Busbar
	Cable / OHL / Mixed	OHL	OHL	OHL	OHL
	SI	This scheme enables future development of network in the region.	This scheme enables future development of network in the region.	This scheme enables future development of network in the region.	This scheme enables future development of network in the region.

Category B – Options Considered to Accommodate Harmonic Mitigation

4.6. Option 6: Do Nothing / Delay - Harmonic Mitigation

With respect to harmonic filter installation, a 'Do Nothing' or 'Delay' option would lead to increasing harmonic levels on the transmission network, causing a disturbance to users and transmission equipment. Due to resonant conditions, harmonic levels are likely to exceed the EREC G5/5 compatibility levels.

4.7. Option 7: Installation of harmonic filters only in wind farms

This option was the employed approach prior to the RIIO-T2 price control period. As discussed in section 2, this option is neither economic nor efficient from a whole-system point of view. Also, it will not eliminate excessive harmonic voltages in all areas of the network. Considering these reasons, this option was discounted in advance of detailed cost estimating exercise.

4.8. Option 8: Installation of 33kV standard harmonic filters

This is a variation of the Option 7 (i.e., installing a standardised filter at wind farms' 33kV connection points). This would lead to the installation of a high number of filters (between 15 and 20 installations), but these would not be effective in controlling harmonic voltages in all areas of the network. Further detail on this option has been provided in the SPEN NIA project; NIA_SPT_1506 [2-3]. Considering this reason, this option was discounted in advance of detailed cost estimating exercise.

4.9. Option 9: Installation of active harmonic filters

This option is to use power electronic converters and a suitable control system to provide harmonic filtering. This technology is often deployed as part of an equipment such as STATCOM (i.e., a system that provides reactive compensation and harmonic filtering). The capital and operational costs for this option are very high, and the technology is effective only at low harmonic orders. The availability of the active harmonic filters is significantly lower than that of a passive filter. Also, their losses and noise emissions are high. Considering these reasons, this option was discounted in advance of detailed cost estimating exercise.

4.10. Option 10: Installation of bespoke harmonic filter for each site

It could be possible to design bespoke filters for each site in South Lanarkshire area. This would provide more efficient filtering at specific harmonics with a reduced filter rating. However, such filters could themselves become part of an unintended resonant condition. They would be very sensitive to network changes and may require re-tuning or extension in future. Also, these filters will not be very efficient to procure as each site requires a different type of filter. Considering these reasons, this option was discounted in advance of detailed cost estimating exercise.

4.11. Option 11: Installation of 132kV standard harmonic filters

This approach was shown to provide the best technical solution, able to mitigate harmonic levels in the 132kV network in an economic and efficient manner by NIA projects; NIA_SPT_1506 and 1610 [2-4]. The proposed standardised 132kV filter design provides damping across the full range of harmonic frequencies. This ensures a high level of immunity to network outages or changes. The use of a standard design should also assist in achieving efficiencies in procurement, delivery, spares holding, etc.

A proposed layout for the considered harmonic filter installation is shown in Figure 4 and fully described in Section 3. A large number of power system simulation studies have been carried out, with considering connected and contracted wind farms in the proposed Redshaw substation and the wider South Lanarkshire area, under intact and under different system outage scenarios to investigate the mitigation effect of installing 132kV harmonic filters in the area. These in-depth studies can be found in Appendix C. In these studies, ETYS 2023 networks for Year 9 (2031-32) are assessed.

The below nine options have been investigated to ensure the network's compliance with EREC G5/5.

4.11.1. Option 11a – Installation of two 20MVAr standard harmonic filters at Redshaw 132kV substation, one at each 'A' and 'B' boards

Various harmonic studies were carried out across South Lanarkshire network near the Redshaw area for both intact and outage conditions to firstly determine if a harmonic issue is present based on the contracted position and subsequently to determine the optimal location for the harmonic filter installation.

The intact Redshaw network without a harmonic filter was assessed to determine the potential harmonic issues in the area. Table 9 includes the results when all wind turbine generators have infinite impedance and do not contribute to the damping of the network harmonic resonances. This is a pessimistic assumption, but it is a realistic scenario for the low (or very high) wind conditions when the wind turbines are not generating, with the collector cable networks remain energised. Table 10 includes results where the wind turbine impedances were considered in the network model. Harmonic issues are prominent at multiple harmonic orders across the Redshaw 132kV and downstream network. It is to be noted that the harmonic violations at [redacted] Windfarm [redacted] and [redacted] are resulting from the connection assets of the users and the assumed wind farm cable arrays' capacitances behind the users' point of connections. Significant G5/5 planning, and compatibility limit breaches are present across the Redshaw network under outage conditions as well, highlighting the need for harmonic mitigation in the Redshaw area. The main problems arise because of the interaction between the connections assets for the wind farms and the main network resulting in resonances around the 7th, 8th, 9th, 11th, 13th, 23rd and 25th harmonic orders.

Table 9: Redshaw Substation Harmonic Distortions (Intact System, Low Wind Conditions)

[redacted]

Table 10: Redshaw Substation Harmonic Distortions (Intact System, WTG Impedance Included)

[redacted]

Additional studies were carried out to determine which connection in the Redshaw queue would trigger the required harmonic mitigation. The first connection in the queue, [redacted] Renewable Energy Project, exceeded the G5/5 planning limits at the 25th harmonic so the filters would need to be installed at the early stages of establishing Redshaw substation. The full suite of harmonic analysis results can be found in Appendix C.

Based on the harmonic analysis results it has been determined that the optimal solution is the installation of a two 132kV 20MVAr harmonic filters – one at the 132kV 'A' board and one at the 132kV 'B' board.

4.11.2. Option 11b – Installation of a single 20MVAr standard harmonic filter at [redacted] ([redacted]) 132kV substation

This option involves installing one 20MVAr harmonic filter at [redacted] (established for the connection of [redacted]) 132kV substation. [redacted] substation is a new customer substation contracted for connection to Redshaw 132kV 'A' board, the scope of which is outside this EJP.

Based on the studies shown in Appendix C, this option is ineffective at harmonic mitigation on Redshaw 'B' 132kV network compared to Option 11a. Additionally, there is risk associated with the installation of harmonic filter at a developer's substation.

4.11.3. Option 11c – Installation of a single 20MVAr standard harmonic filter at [redacted] Wind Farm 132kV substation

This option involves installing one 20MVAr harmonic filter at [redacted] wind farm 132kV substation. [redacted] wind farm substation is a new customer substation contracted for connection to Redshaw 132kV 'A' board, the scope of which is outside the proposed scheme in this EJP.

Based on the studies shown in Appendix C, this option is ineffective at harmonic mitigation on Redshaw 'B' 132kV network compared to Option 11a. Additionally, there is risk associated with the installation of harmonic filter at a developer's substation.

4.11.4. Option 11d – Installation of a single 20MVAr standard harmonic filter at [redacted] Wind Farm 132kV substation

This option involves installing one 20MVAr harmonic filter at [redacted] wind farm 132kV substation. [redacted] wind farm substation is a new customer substation contracted for connection to Redshaw 400kV substation, the scope of which is outside the proposed scheme in this EJP.

Based on the studies shown in Appendix C, this option is overall ineffective at harmonic mitigation compared to Option 11a. Additionally, there is risk associated with the installation of harmonic filter at a developer's substation.

4.11.5. Option 11e – Installation of a single 20MVAr standard harmonic filter at Redshaw 'A' 132kV substation

This option involves installing one 20MVAr harmonic filter at Redshaw 132kV substation, 'A' board. Based on the studies shown in Appendix C, this option is ineffective on the Redshaw 'B' 132kV network compared to Option 11a.

4.11.6. Option 11f – Installation of a single 20MVAr standard harmonic filter at Redshaw 'B' 132kV substation

This option involves installing one 20MVAr harmonic filter at Redshaw 132kV substation, 'B' board. Based on the studies shown in Appendix C, this option is ineffective on the Redshaw 'A' 132kV network compared to Option 11a.

4.11.7. Option 11g – Installation of two 20MVAr standard harmonic filters, one at Redshaw 'A' 132kV substation and one at [redacted] wind farm 132kV substation

This option involves installing one 20MVAr harmonic filter at Redshaw 132kV substation, 'A' board and one 20MVAr harmonic filter at [redacted] wind farm 132kV substation.

Based on the studies shown in Appendix C, this option is ineffective at harmonic mitigation on the Redshaw 'B' 132kV network compared to Option 11a. There is also risk associated with the installation of harmonic filter at a developer's substation (i.e., [redacted] wind farm). This option is economically inefficient as the filter at [redacted] cannot provide mitigation beyond the user's point of connection.

4.11.8. Option 11h – Installation of two 40MVAr standard harmonic filters, one at Redshaw 'A' 132kV substation and one at Redshaw 'B' 132kV substation

This option involves installing one 40MVAr harmonic filter at Redshaw 132kV substation, 'A' board and one 40MVAr harmonic filter at Redshaw 132kV substation, 'B' board.

Based on the studies shown in Appendix C, this option does not provide significant improvements in harmonic performance compared to Option 11a. Additionally the cost associated with the higher rated harmonic filters is higher, making this option economically inefficient.

4.12. Option Assessment – Harmonic Mitigation

In Sections 4.6 – 4.11, thirteen options have been evaluated to mitigate the harmonic issues in South Lanarkshire network in Redshaw area. A summary of each option considered for Redshaw harmonic mitigation is described in Table 11, while the system requirements and design parameters for the considered options are outlined in Table 12.
Following extensive power system studies, shown in Appendix C, the most optimum solution to mitigate the harmonic problem in the area is to install two 20MVAr standard harmonic filters at Redshaw 132kV substation, one at each 'A' and 'B' boards.

4.13. Selected Option – Development of Redshaw 400kV GIS substation and Redshaw 132kV GIS ‘A’ and ‘B’ boards and installation of two 20MVAr harmonic filters, one at each Redshaw 132kV ‘A’ and ‘B’ boards (Options 5c & 11a)

Given the overall cost and ability to meet project objectives, the most appropriate option to enable the economic, efficient, and co-ordinated connection of the proposed renewable generation developments and mitigate the harmonic issues in the Redshaw area in South Lanarkshire is to establish a new Redshaw 400kV GIS substation, develop new Redshaw 132kV GIS ‘A’ and ‘B’ boards (i.e., Option 5c) and install two 20MVAr harmonic filters at the Redshaw 132kV substation, one at each ‘A’ and ‘B’ boards (i.e., Option 11a).

The Redshaw 400/132kV substation will be established near the existing ZV route, as shown in Figure 2. The final substation platform size is [redacted] with an approximate OS coordinate of [redacted] as shown in Appendix A, Figure A-15.

4.14. Whole System Outcomes

Our optioneering approach has identified ‘Whole System’ interactions with other electricity network in the area, i.e., SP Distribution (SPD), in the development of our proposed solution and has considered the appropriate ‘Whole System’ outcome. As part of the Redshaw Cluster project we are establishing Redshaw GSP, which will provide 180MVA of non-firm generation capacity to the SPD system, as per SPT-TOCO-2975.

Our optioneering approach has additionally considered the appropriate ‘Whole System’ outcome by proposing a technology solution which manages network characteristics (i.e., harmonic issues).

Table 11: Summary of Considered Options to Mitigate Harmonic Issues

Options	Map	Layout of Substation/ Connection	Layout of all Route Works	Relevant Survey Works	Narrative Consenting Risks	Narrative Preferred Option	Narrative Rejection
Preferred – Option 11a: Installation of two 20MVAr standard harmonic filters at Redshaw 132kV substation, one at each ‘A’ and ‘B’ boards	Refer to Figure A-15, Appendix A	Refer to Figure 3	N/A	N/A	Early engagement with landowners, environmental bodies and employing low bearing pressure ground vehicles and trackway where possible to minimise extents of stone tracks.	Considering Option 5c, in Table 7 as the most optimum solution to enable connection of contracted generation in the area, thirteen additional options have been considered with respect to wider scheme proposed in this EJP to mitigate the harmonic issues in the region. These thirteen options have been reviewed in terms of scope feasibility, cost, delivery timescales, land requirements, system limitations and restoring SQSS compliant limit with option 11a demonstrating a network capacity reinforcement whilst affording the least project deliverability risk.	N/A
Rejected – Option 6: Do Nothing / Delay	N/A	N/A	N/A	N/A	N/A	N/A	It makes the network incompliant with harmonic standard (EREC G5/5).
Rejected – Option 7: Installation of harmonic filters only in wind farms	N/A	N/A	N/A	N/A	N/A	N/A	It is neither economic nor efficient from a ‘whole system’ perspective. It also will not eliminate excessive harmonic voltages in all areas of the network.
Rejected – Option 8: Installation of 33kV standard harmonic filters	N/A	N/A	N/A	N/A	N/A	N/A	This option would lead to the installation of high number of filters but would not be effective in controlling harmonic voltages in all areas of the network.

Rejected – Option 9: Installation of active harmonic filters	N/A	N/A	N/A	N/A	N/A	N/A	The active harmonic filters technology is effective only at low harmonic orders. Their availability is significantly lower than that of a passive filter. Also, their losses and noise emissions are high.
Rejected – Option 10: Installation of bespoke harmonic filter for each site	N/A	N/A	N/A	N/A	N/A	N/A	Having bespoke filters for each site can itself become part of an unintended resonant condition. These filters would be very sensitive to network changes and may require re-tuning or extension in future. Additionally, these filters will not be very efficient to procure as each site requires a different type of filter.
Rejected – Option 11b: Installation of a single 20MVAr standard harmonic filter at [redacted] 132kV substation	N/A	N/A	N/A	N/A	N/A	N/A	Ineffective at harmonic mitigation on the Redshaw 'B' 132kV network compared to proposed option. Additionally, there is risk associated with the installation at a developer's substation.
Rejected – Option 11c: Installation of a single 20MVAr standard harmonic filter at [redacted] Wind Farm 132kV substation	N/A	N/A	N/A	N/A	N/A	N/A	Ineffective at harmonic mitigation on the Redshaw 'B' 132kV network compared to proposed option. Additionally, there is risk associated with the installation at a developer's substation.
Rejected – Option 11d: Installation of a single 20MVAr standard harmonic filter at [redacted] Wind Farm 132kV substation	N/A	N/A	N/A	N/A	N/A	N/A	Overall ineffective at harmonic mitigation compared to proposed option. Additionally, there is risk associated with the installation at a developer's substation.
Rejected – Option 11e: Installation of a single 20MVAr standard harmonic	N/A	N/A	N/A	N/A	N/A	N/A	Ineffective at harmonic mitigation on the Redshaw 'B' 132kV network compared to proposed option.

filter at Redshaw 'A' 132kV substation							
Rejected – Option 11f: Installation of a single 20MVAr standard harmonic filter at Redshaw 'B' 132kV substation	N/A	N/A	N/A	N/A	N/A	N/A	Ineffective at harmonic mitigation on the Redshaw 'A' 132kV network compared to proposed option.
Rejected – Option 11g: Installation of two 20MVAr standard harmonic filters, one at Redshaw 'A'132kV substation and one at [redacted] wind farm 132kV substation	N/A	N/A	N/A	N/A	N/A	N/A	Ineffective at harmonic mitigation on the Redshaw 'B' 132kV network compared to proposed option. Additionally, there is risk associated with the installation at a developer's substation. Economically inefficient as the filter at [redacted] cannot provide mitigation beyond the user's point of connection.
Rejected – Option 11h: Installation of two 40MVAr standard harmonic filters, one at Redshaw 'A'132kV substation and one at Redshaw 'B' 132kV substation	N/A	N/A	N/A	N/A	N/A	N/A	Insignificant improvements in harmonic performance compared to the proposed option. The 20MVAr units in the proposed option are supposed to keep the Redshaw network G5/5 compliant. Higher cost associated with the higher rated harmonic filters.

Table 12: System Requirements and Design Parameters for the considered Options to Mitigate Harmonic Issues

System Design Table	Circuit/Project	**Preferred – Option 11a:** Installation of two 20MVAr standard harmonic filters at Redshaw 132kV substation, one at each 'A' and 'B' boards	**Rejected – Option 6:** Do Nothing / Delay	**Rejected – Option 7:** Installation of harmonic filters only in wind farms	**Rejected – Option 8:** Installation of 33kV standard harmonic filters	**Rejected – Option 9:** Installation of active harmonic filters
Thermal and Fault Design	Existing Voltage (if applicable)	N/A	N/A	N/A	N/A	N/A
	New Voltage	132kV	N/A	N/A	132kV	132kV
	Existing Continuous Rating (if applicable)	N/A	N/A	N/A	N/A	N/A
	New Continuous Rating	N/A	N/A	N/A	N/A	N/A
	Existing Fault Rating (if applicable)	N/A	N/A	N/A	N/A	N/A
	New Fault Rating	20/25kA	N/A	N/A	20/25kA	20/25kA
ESO Dispatchable Services	Existing MVAR Rating (if applicable)	N/A	N/A	N/A	N/A	N/A
	New MVAR Rating (if applicable)	20MVAr (2 units)	N/A	N/A	N/A	N/A
	Existing GVA Rating (if applicable)	N/A	N/A	N/A	N/A	N/A
	New GVA Rating	N/A	N/A	N/A	N/A	N/A
System Requirements	Present Demand (if applicable)	N/A	N/A	N/A	N/A	N/A
	2050 Future Demand	N/A	N/A	N/A	N/A	N/A
	Present Generation (if applicable)	N/A	N/A	N/A	N/A	N/A
	Future Generation Count	24	24	24	24	24
	Future Generation Capacity	2.9GW	2.9GW	2.9GW	2.9GW	2.9GW
	Limiting Factor	N/A	Inconsistent with SPT's various	It's neither economic nor efficient from a whole system	It is not effective in controlling harmonic	They are effective only at low harmonic orders. They

Initial Design Considerations			statutory duties and licence obligations. It makes the network incompliant with harmonic standard (EREC G5/5).	perspective. It also does not eliminate excessive harmonic voltages in all areas of the network.	voltages in all areas of the network.	have high losses and noise emission.
	AIS / GIS	GIS	N/A	N/A	N/A	N/A
	Busbar Design	Double Busbar	N/A	N/A	N/A	N/A
	Cable / OHL / Mixed	N/A	N/A	N/A	N/A	N/A
	SI	The proposed standardised harmonic filter mitigates the harmonic levels in the 132kV network in the area.	N/A	N/A	N/A	N/A

System Design Table	**Circuit/Project**	**Rejected – Option 10:** Installation of bespoke harmonic filter for each site	**Rejected – Option 11b:** Installation of a single 20MVAr standard harmonic filter at [redacted] 132kV substation	**Rejected – Option 11c:** Installation of a single 20MVAr standard harmonic filter at [redacted] Wind Farm 132kV substation	**Rejected – Option 11d:** Installation of a single 20MVAr standard harmonic filter at [redacted] Wind Farm 132kV substation
Thermal and Fault Design	Existing Voltage (if applicable)	N/A	N/A	N/A	N/A
	New Voltage	132kV	132kV	132kV	132kV
	Existing Continuous Rating (if applicable)	N/A	N/A	N/A	N/A
	New Continuous Rating	N/A	N/A	N/A	N/A
	Existing Fault Rating (if applicable)	N/A	N/A	N/A	N/A
	New Fault Rating	20/25kA	20/25kA	20/25kA	20/25kA
ESO Dispatchable Services	Existing MVAR Rating (if applicable)	N/A	N/A	N/A	N/A
	New MVAR Rating (if applicable)	N/A	20MVAr	20MVAr	20MVAr

	Existing GVA Rating (if applicable)	N/A	N/A	N/A	N/A
	New GVA Rating	N/A	N/A	N/A	N/A
System Requirements	Present Demand (if applicable)	N/A	N/A	N/A	N/A
	2050 Future Demand	N/A	N/A	N/A	N/A
	Present Generation (if applicable)	N/A	N/A	N/A	N/A
	Future Generation Count	24	24	24	24
	Future Generation Capacity	2.9GW	2.9GW	2.9GW	2.9GW
Initial Design Considerations	Limiting Factor	Having bespoke filters for each site can itself become part of an unintended resonant condition. They would be very sensitive to network changes and may require re-tuning or extension in future. Also, they will not be very efficient to procure as each site requires a different type of filter.	Ineffective at harmonic mitigation on the Redshaw 'B' 132kV network compared to proposed option. Additionally, there is risk associated with the installation at a developer's substation.	Ineffective at harmonic mitigation on the Redshaw 'B' 132kV network compared to proposed option. Additionally, there is risk associated with the installation at a developer's substation.	Overall ineffective at harmonic mitigation compared to proposed option. Additionally, there is risk associated with the installation at a developer's substation.
	AIS / GIS	N/A	AIS/GIS	AIS/GIS	AIS/GIS
	Busbar Design	N/A	Double Busbar	Double Busbar	Double Busbar
	Cable / OHL / Mixed	N/A	N/A	N/A	N/A
	SI	N/A	The proposed standardised harmonic filter mitigates the harmonic levels in the 132kV network in the area.	The proposed standardised harmonic filter mitigates the harmonic levels in the 132kV network in the area.	The proposed standardised harmonic filter mitigates the harmonic levels in the 132kV network in the area.

System Design Table	Circuit/Project	**Rejected – Option 11e:** Installation of a single 20MVAr standard harmonic filter at Redshaw 'A' 132kV substation	**Rejected – Option 11f:** Installation of a single 20MVAr standard harmonic filter at	**Rejected – Option 11g:** Installation of two 20MVAr standard harmonic filters, one at Redshaw 'A'132kV substation and one at	**Rejected – Option 11h:** Installation of two 40MVAr standard harmonic filters, one at Redshaw 'A'132kV substation and one at Redshaw 'B' 132kV substation

			Redshaw 'B' 132kV substation	[redacted] wind farm 132kV substation	
Thermal and Fault Design	Existing Voltage (if applicable)	N/A	N/A	N/A	N/A
	New Voltage	132kV	132kV	132kV	132kV
	Existing Continuous Rating (if applicable)	N/A	N/A	N/A	N/A
	New Continuous Rating	N/A	N/A	N/A	N/A
	Existing Fault Rating (if applicable)	N/A	N/A	N/A	N/A
	New Fault Rating	20/25kA	20/25kA	20/25kA	20/25kA
ESO Dispatchable Services	Existing MVAR Rating (if applicable)	20MVAr	20MVAr	20MVAr (2 units)	40MVAr (2 units)
	New MVAR Rating (if applicable)	N/A	N/A	N/A	N/A
	Existing GVA Rating (if applicable)	N/A	N/A	N/A	N/A
	New GVA Rating	N/A	N/A	N/A	N/A
System Requirements	Present Demand (if applicable)	N/A	N/A	N/A	N/A
	2050 Future Demand	N/A	N/A	N/A	N/A
	Present Generation (if applicable)	N/A	N/A	N/A	N/A
	Future Generation Count	24	24	24	24
	Future Generation Capacity	2.9GW	2.9GW	2.9GW	2.9GW
	Limiting Factor	Ineffective at harmonic mitigation on the Redshaw 'B' 132kV network compared to proposed option.	Ineffective at harmonic mitigation on the Redshaw 'A' 132kV network compared to proposed option.	Ineffective at harmonic mitigation on the Redshaw 'B' 132kV network compared to proposed option. Additionally, there is risk associated with the	Insignificant improvements in harmonic performance compared to the proposed option. The 20MVAr units in the proposed option are supposed

Initial Design Considerations				installation at a developer's substation. Economically inefficient as the filter at [redacted] cannot provide mitigation beyond the user's point of connection.	to keep the Redshaw network G5/5 compliant. Higher cost associated with the higher rated harmonic filters.
	AIS / GIS	AIS/GIS	AIS/GIS	AIS/GIS	AIS/GIS
	Busbar Design	Double Busbar	Double Busbar	Double Busbar	Double Busbar
	Cable / OHL / Mixed	N/A	N/A	N/A	N/A
	SI	The proposed standardised harmonic filter mitigates the harmonic levels in the 132kV network in the area.	The proposed standardised harmonic filter mitigates the harmonic levels in the 132kV network in the area.	The proposed standardised harmonic filter mitigates the harmonic levels in the 132kV network in the area.	The proposed standardised harmonic filter mitigates the harmonic levels in the 132kV network in the area.

5. Proposed Works & Associated Cost

5.1. Project Summary

As discussed above, the proposed scheme in this scheme entails establishment of the new Redshaw 400/132kV substation in the South Lanarkshire area which shall connect into the existing 400kV double circuit (ZV route). Figure 5 below shows an indicative view of the proposed location for Redshaw 400/132kV substation in relation to the existing 400kV double circuit in this area. A corridor will be established for the incoming Glenmuckloch 400kV double circuit OHLs as shown in red, which is outside the scope of this EJP.

[redacted]

Figure 5: Indicative View of Positioning of Redshaw Substation and ZV Route OHL Diversion Works

Forming part of the wider Redshaw 400/132kV substation development in South Lanarkshire this EJP relates to six discrete applications as outlined in the previous sections (i.e., SPT-RI-2060, SPT-RI-2061, SPT-RI-2139, SPT-RI-3060, SPT-RI-4137 & SPT-RI-4138).

The sections below outline the key element required to complete each of these six projects.

5.2. SPT-RI-2060 – Redshaw 400kV Substation

Given the planned reinforcements and contracted generation applications into Redshaw substation it is proposed that the Redshaw 400kV substation is constructed initially to be capable of expansion to a 21 bay 400kV development, as shown in Figure 3.

<u>Substation Works</u>

Substation works required for SPT-RI-2060 include the following 400kV GIS bays:

- 2 x 400kV feeder bays pointing north towards Coalburn/Coalburn North
- 2 x 400kV feeder bays pointing south towards Elvanfoot

- 2 x 400kV feeder bays pointing west towards the planned double circuit OHLs from Glenmuckloch (funded via SPT-RI-236, the scope of which is outside this EJP)
- 2 x 400kV bus section circuit breakers
- 2 x 400kV bus couplers
- 2 x 400kV transformer bays for 'A' board SGTs (i.e., SGT2 & SGT3) – funded via SPT-RI-2061 & SPT-RI-2139
- 2 x 400kV transformer bays for 'B' board SGTs (i.e., SGT1 & SGT4) – funded via SPT-RI-3060
- 1 x feeder bay for [redacted] SGT (i.e., SGT8) – part of associated connection works
- 1 x feeder bay for [redacted] WF SGT (i.e., SGT6) – part of associated connection works
- 1 x feeder bay for [redacted] Farm SGT (i.e., SGT5) – part of associated connection works
- 1 x feeder bay for [redacted] connection
- 1 x feeder bay for [redacted] Energy Park connection
- 4 x spare bays total (2 x either end of the substation)
- Associated protection and control works
- Associated civil works

As outlined in the previous sections, given the number if bays required in the new 400kV substation, the use of GIS is proposed given the project specific relative economic advantages and smaller overall footprint this technology provides compared with AIS.

<u>OHL Works</u>

Diversion of the existing 400kV ZV Route double circuit is required to enable the turning in of these circuits into the new substation. Figure 5 shows an indicative view of the positioning of the new Redshaw substation outlined in pink. The existing 400kV double circuit which passes by is shown in blue and as noted, existing spans will need to be diverted to enable their turn into the new Redshaw substation. This will require the installation of three new 400kV towers and the associated OHL conductor between each span. The OHL route coming in from the left-hand side of the image is the planned Glenmuckloch to Redshaw 400kV double circuit route, which is scoped in SPT-RI-236 and is outside the scope of this EJP.

<u>Cable Works</u>

No cable works are identified as part of SPT-RI-2061.

<u>Civil Works</u>

Works will be required to establish the new 400kV substation platform as well as the construction of the 400kV GIS building required to house the new switchgear, protection and control panels and other associated equipment.

5.3. SPT-RI-2061 – Redshaw 132kV 'A' Board and SPT-RI-2139 – Redshaw 400/132kV SGT2

As outlined in the previous sections it is proposed to establish both 132kV boards at Redshaw using GIS equipment and it is proposed to house both GIS boards (i.e., 'A' and 'B' boards) in the same building to limit the overall footprint of the site as well as make the schemes more economically efficient.

<u>Substation Works</u>

As shown in Figure 3, the substation works for SPT-RI-2061 and SPT-RI-2139 include:

- 2 x 400/132kV 360MVA SGTs (i.e., SGT2 & SGT3)
- 1 x 400kV transformer feeder bay connecting to SGT2
- 1 x 400kV transformer feeder bay connecting to SGT3
- 1 x 132kV transformer feeder bay connecting to SGT2

- 1 x 132kV transformer feeder bay connecting to SGT3
- 1x 132kV bus coupler bay
- 1 x 132kV bus section bay
- 1 x 132kV feeder bay for [redacted] wind farm connections
- 1 x 132kV feeder bay for GT1 (to connect [redacted] wind farms)
- 2 x 132kV feeder bays for the [redacted] connection
- 1 x 132kV feeder bay for harmonic filter – funded via SPT-RI-4137
- 2 x spare bays (one at each end)
- Associated protection and control works
- Associated civil works

<u>OHL Works</u>
No OHL works are identified as part of SPT-RI-2061 & SPT-RI-2139.

<u>Cable Works</u>
No cable works are identified as part of SPT-RI-2061 & SPT-RI-2139.

<u>Civil Works</u>
Works will be required to establish the new 132kV substation platform as well as the construction of the 132kV GIS building required to house the new 132kV GIS switchgear, protection and control panels and other associated equipment.

5.4. SPT-RI-3060 – Redshaw 132kV 'B' Board

The new 'B' board to be established at Redshaw will use GIS equipment and as also outlined in previous sections, it is proposed to house both GIS boards (i.e., 'A' and 'B' boards) in the same building to limit the overall footprint of the site as well as make the schemes more economically efficient.

<u>Substation Works</u>
As shown in Figure 3, the substation works for SPT-RI-3060 include:

- 2 x 400/132kV 360MVA SGTs (i.e., SGT1 & SGT4)
- 1 x 400kV transformer feeder bay connecting to SGT1
- 1 x 400kV transformer feeder bay connecting to SGT4
- 1 x 132kV transformer feeder bay connecting to SGT1
- 1 x 132kV transformer feeder bay connecting to SGT4
- 1x 132kV bus coupler bay
- 1 x 132kV bus section bay
- 1 x 132kV feeder bay for [redacted] wind farm
- 1 x 132kV feeder bay for [redacted] wind farm
- 1 x 132kV feeder bay for [redacted]
- 1 x 132kV feeder bay for [redacted] wind farm
- 2 x 132kV feeder bay for Redshaw GSP
- 1 x 132kV feeder bay for harmonic filter – funded via SPT-RI-4138
- 2 x spare bays (one at each end)
- Associated protection and control works
- Associated civil works

<u>OHL Works</u>
No OHL works are identified as part of SPT-RI-3060.

<u>Cable Works</u>
No cable works are identified as part of SPT-RI-3060.

<u>Civil Works</u>
Works will be required to establish the new 132kV substation platform as well as the construction of the 132kV GIS building required to house the new 132kV GIS switchgear, protection and control panels and other associated equipment.

5.5. SPT-RI-4137 – Redshaw ‘A’ 132kV Harmonic Filter

The proposed scope of works involved with the Redshaw ‘A’ 132kV harmonic filter can be found in the following.

<u>Substation Works</u>
As shown in Figure 3, the substation works for SPT-RI-4137 include:

- 1 x 132kV feeder bay with the associated switchgear at the Redshaw 132kV ‘A’ board
- 1 x 132kV 20MVAr Harmonic Filter at the Redshaw 132kV ‘A’ board
- Associated protection and control works
- Associated civil works

<u>OHL Works</u>
No OHL works are identified as part of SPT-RI-4137.

<u>Cable Works</u>
No cable works are identified as part of SPT-RI-4137.

<u>Civil Works</u>
Works will be required to establish the new 132kV 20MVAr harmonic filter protection and control panels and associated equipment at the Redshaw 132kV ‘A’ board.

5.6. SPT-RI-4138 – Redshaw ‘B’ 132kV Harmonic Filter

The proposed scope of works involved with the Redshaw ‘B’ 132kV harmonic filter can be found in the following.

<u>Substation Works</u>
As shown in Figure 3, the substation works for SPT-RI-4138 include:

- 1 x 132kV feeder bay with the associated switchgear at the Redshaw 132kV ‘B’ board
- 1 x 132kV 20MVAr Harmonic Filter at the Redshaw 132kV ‘B’ board
- Associated protection and control works
- Associated civil works

<u>OHL Works</u>
No OHL works are identified as part of SPT-RI-4138.

<u>Cable Works</u>
No cable works are identified as part of SPT-RI-4138.

<u>Civil Works</u>
Works will be required to establish the new 132kV 20MVAr harmonic filter protection and control panels and associated equipment at the Redshaw 132kV ‘B’ board.

5.7. Project Cost

5.7.1. Estimated Total Project Cost

Redshaw 400kV Substation (SPT-RI-2060)

A Business Plan provision and estimated cost of the Redshaw 400kV substation project is indicated in the following table. Costs provided below include direct, indirect, and contingency costs.
Project costs for Redshaw 400kV substation are summarised in the cost breakdown in Table 13:

Table 13: Project Cost Breakdown – SPT-RI-2060

Item	Description	Estimated CAPEX (£m 23/24)
[redacted]		

Expenditure incidence is summarised in Table 14:

Table 14: Summary of Expenditure Incidence – SPT-RI-2060

Energisation Year	Yr. 2023: CAPEX	Yr. 2024: CAPEX	Yr. 2025: CAPEX	Yr. 2026: CAPEX	Yr. 2027: CAPEX	Yr. 2028: CAPEX	RIIO-T2 Total: CAPEX	RIIO-T3 Total: CAPEX	Total: CAPEX
2027	£0.07m	£0.45m	£2.28m	£13.61m	£35.48m	£8.84m	£16.41m	£44.32m	£60.73m

Redshaw 132kV substation, 'A' board (SPT-RI-2061)

A Business Plan provision and estimated cost of the Redshaw 132kV substation, 'A' board, project is indicated in the following table. Costs provided below include direct, indirect, and contingency costs.
Project costs for Redshaw 132kV substation, 'A' board, are summarised in the cost breakdown in Table 15:

Table 15: Project Cost Breakdown – SPT-RI-2061

Item	Description	Estimated CAPEX (£m 23/24)
[redacted]		

Expenditure incidence is summarised in Table 16:

Table 16: Summary of Expenditure Incidence – SPT-RI-2061

Energisation Year	Yr. 2023: CAPEX	Yr. 2024: CAPEX	Yr. 2025: CAPEX	Yr. 2026: CAPEX	Yr. 2027: CAPEX	Yr. 2028: CAPEX	RIIO-T2 Total: CAPEX	RIIO-T3 Total: CAPEX	Total: CAPEX
2027	£0.01m	£0.77m	£1.83m	£8.19m	£15.65m	£3.72m	£10.80m	£19.37m	£30.17m

Redshaw SGT2 (SPT-RI-2139)

A Business Plan provision and estimated cost of the Redshaw SGT2 project is indicated in the following table. Costs provided below include direct, indirect, and contingency costs.
Project costs for Redshaw SGT2 are summarised in the cost breakdown in Table 17:

Table 17: Project Cost Breakdown – SPT-RI-2139

Item	Description	Estimated CAPEX (£m 23/24)
[redacted]		
[redacted]		
[redacted]		
[redacted]		

Expenditure incidence is summarised in Table 18:

Table 18: Summary of Expenditure Incidence – SPT-RI-2139

Energisation Year 2027	Yr. 2022: CAPEX	Yr. 2023: CAPEX	Yr. 2024: CAPEX	Yr. 2025: CAPEX	Yr. 2026: CAPEX	Yr. 2027: CAPEX	Yr. 2028: CAPEX	RIIO-T2 Total: CAPEX	RIIO-T3 Total: CAPEX	Total: CAPEX
Allowance	£0.00m	£0.00m	£0.56m	£1.42m	£4.75m	£8.26m	£2.63m	£6.73m	£10.89 m	£17.62 m
Cost	£0.00m	£0.00m	£0.56m	£1.43m	£4.78m	£8.32m	£2.65m	£6.77m	£10.97 m	£17.74 m
Variance (customer contribution)	£0.00m	£0.00m	£0.00m	-£0.01m	-£0.03m	-£0.06m	-£0.02m	-£0.04m	-£0.08m	-£0.12m

Redshaw 132kV substation, ‘B’ board (SPT-RI-3060)

A Business Plan provision and estimated cost of the Redshaw 132kV substation, ‘B’ board, project is indicated in the following table. Cost provided below include direct, indirect, and contingency costs.
Project cost for Redshaw 132kV substation, ‘B’ board, is summarised in the cost breakdown in Table 19:

Table 19: Project Cost Breakdown – SPT-RI-3060

Item	Description	Estimated DCAPEX (£m 23/24)
[redacted]		

Expenditure incidence is summarised in Table 20:

Table 20: Summary of Expenditure Incidence – SPT-RI-3060

Energisation Year	Yr. 2024: CAPEX	Yr. 2025: CAPEX	Yr. 2026: CAPEX	Yr. 2027: CAPEX	Yr. 2028: CAPEX	Yr. 2029: CAPEX	RIIO-T2 Total: CAPEX	RIIO-T3 Total: CAPEX	Total: CAPEX
2028	£0.00m	£0.50m	£9.86m	£21.95m	£11.93m	£3.69m	£10.36m	£37.56m	£47.92m

5.7.2. Allocation of Harmonic Filter Costs

As outlined in the previous sections, users are normally responsible for harmonic mitigation and therefore the full cost of mitigation. For users that are significant sources of harmonic emissions, this is consistent with a 'polluter pays' approach. However, most windfarms are not a significant source of harmonics (i.e., they are not by themselves polluters). In some parts of the SPT's 132kV network, they simply form part of a wider resonant system that amplifies background harmonics caused by a range of sources, including consumer devices and equipment. This suggests that part of the cost of harmonic mitigation should be socialised, rather than penalising individual Users for resonant conditions that are largely out of their control.

It is anticipated that the harmonic filter installation proposed in this paper will be funded fully via the RIIO-T3 price review. However:

1. The responsibility for harmonic compliance should not be removed from users to ensure that they remain liable if they connect polluting equipment to the network.
2. User choice could have a significant impact on harmonic resonance (e.g., the use of cable instead of an overhead line connection). In such cases, where there is deemed to be an increased risk of harmonic resonance, a harmonic filter should be included in the offer as a one-off cost.

This approach is consistent with the 'polluter pays' principle while ensuring that harmonic compliance is managed in an economic and efficient manner across the transmission system.

Redshaw Harmonic Filter ('A' board)

The estimated cost of the Redshaw Harmonic Filter ('A' board), project is indicated in the following table. Cost provided below include direct, indirect, and contingency costs.
Project cost for Redshaw Harmonic Filter ('A' board) is summarised in the cost breakdown in Table 21:

Table 21: Project Cost Breakdown – Harmonic Filter Installation – SPT-RI-4137

Item	Description	Estimated CAPEX (£m 23/24)
[redacted]		
[redacted]		
[redacted]		
[redacted]		
[redacted]		
[redacted]		

Expenditure incidence is summarised in Table 22:

Table 22: Summary of Expenditure Incidence – SPT-RI-4137

Energisation Year	Yr. 2025: CAPEX	Yr. 2026: CAPEX	Yr. 2027: CAPEX	Yr. 2028: CAPEX	Yr. 2029: CAPEX	Yr. 2030: CAPEX	RIIO-T2 Total: CAPEX	RIIO-T3 Total: CAPEX	Total: CAPEX
2029	£0.00m	£0.04m	£1.49m	£4.21m	£3.85m	£0.16m	£0.04m	£9.71m	£9.75m

Redshaw Harmonic Filter (‘B’ board)

The estimated cost of the Redshaw Harmonic Filter (‘B’ board), project is indicated in the following table. Cost provided below include direct, indirect, and contingency costs.
Project cost for Redshaw Harmonic Filter (‘B’ board) is summarised in the cost breakdown below:

Table 23: Project Cost Breakdown – Harmonic Filter Installation – SPT-RI-4138

Item	Description	Estimated CAPEX (£m 23/24)
[redacted]		
[redacted]		
[redacted]		
[redacted]		
[redacted]		
[redacted]		

Expenditure incidence is summarised in Table 24:

Table 24: Summary of Expenditure Incidence – SPT-RI-4138

Energisation Year	Yr. 2025: CAPEX	Yr. 2026: CAPEX	Yr. 2027: CAPEX	Yr. 2028: CAPEX	Yr. 2029: CAPEX	Yr. 2030: CAPEX	RIIO-T2 Total: CAPEX	RIIO-T3 Total: CAPEX	Total: CAPEX
2029	£0.00m	£0.04m	£1.49m	£4.21m	£3.85m	£0.16m	£0.04m	£9.71m	£9.75m

5.8. Regulatory Outputs

Redshaw 400kV Substation (SPT-RI-2060)

The indicative primary asset outputs for the Redshaw 400kV substation project are identified in Table 25:

Table 25: Indicative Primary Asset Outputs – SPT-RI-2060

Asset Category	Asset Sub-Category Primary	Voltage	Intervention	Forecast Addition[7]	Forecast Disposal[8]
Substation Platform	Platform Creation	400kV	Addition	1 unit	-
Circuit Breaker	CB (Gas Insulated Busbars) (ID)	400kV	Addition	8 units	-
Overhead Tower Line	Tower	400kV	Addition	4 units	-
Overhead Tower Line	Tower	400kV	Disposals	-	2 units
Overhead Tower Line	OHL (Tower Line) Conductor	400kV	Disposals	-	2.36 km
Overhead Tower Line	OHL (Tower Line) HTLS Conductor	400kV	Addition	2.2 km	-

Redshaw 132kV 'A' board (SPT-RI-2061)

The indicative primary asset outputs for the Redshaw 132kV 'A' board project are identified in Table 26:

Table 26: Indicative Primary Asset Outputs – SPT-RI-2061

Asset Category	Asset Sub-Category Primary	Voltage	Intervention	Forecast Addition[9]	Forecast Disposal
Substation Platform	Platform Creation	132kV	Addition	1 unit	-
Circuit Breaker	CB (Gas Insulated Busbars) (ID)	132kV	Addition	3 units	-
Circuit Breaker	CB (Gas Insulated Busbars) (ID)	400kV	Addition	1 unit	-
Wound Plant	Transformer	400kV<500MVA	Addition	1 unit	-

Redshaw 400/132kV SGT2 (SPT-RI-2139)

The indicative primary asset outputs for the Redshaw 400/132kV SGT2 project are identified in Table 27:

Table 27: Indicative Primary Asset Outputs – SPT-RI-2139

Asset Category	Asset Sub-Category Primary	Voltage	Intervention	Forecast Addition[10]	Forecast Disposal
Circuit Breaker	CB (Gas Insulated Busbars) (ID)	132kV	Addition	1 unit	-
Circuit Breaker	CB (Gas Insulated Busbars) (ID)	400kV	Addition	1 unit	-

7 Forecast Additions are indicative pending further detail design.
8 Forecast Disposals are indicative pending further detail design.
9 Forecast Additions are indicative pending further detail design.
10 Forecast Additions are indicative pending further detail design.

Wound Plant	Transformer	400kV<500MVA	Addition	1 unit	-

Redshaw 132kV 'B' board (SPT-RI-3060)

The indicative primary asset outputs for the Redshaw 132kV 'B' board project are identified in Table 28:

Table 28: Indicative Primary Asset Outputs – SPT-RI-3060

Asset Category	Asset Sub-Category Primary	Voltage	Intervention	Forecast Addition[11]	Forecast Disposal
Substation Platform	Platform Creation	132kV	Addition	1 unit	-
Circuit Breaker	CB (Gas Insulated Busbars) (ID)	132kV	Addition	4 units	-
Circuit Breaker	CB (Gas Insulated Busbars) (ID)	400kV	Addition	2 units	-
Wound Plant	Transformer	400kV<500MVA	Addition	2 units	-

Redshaw 'A' 132kV Harmonic Filter (SPT-RI-4137)

The indicative primary asset outputs for the Redshaw 'A' 132kV harmonic filter project are identified in Table 29:

Table 29: Indicative Primary Asset Outputs – SPT-RI-4137

Asset Category	Asset Sub-Category Primary	Voltage	Intervention	Forecast Addition[12]	Forecast Disposal
Circuit Breaker	CB (Gas Insulated Busbars) (ID)	132kV	Addition	1 unit	-
Flexible AC Transmission Systems (FACTS)	FACTS Equipment	132kV	Addition	1 unit	-

Redshaw 'B' 132kV Harmonic Filter (SPT-RI-4138)

The indicative primary asset outputs for the Redshaw 'B' 132kV harmonic filter project are identified in Table 30:

Table 30: Indicative Primary Asset Outputs – SPT-RI-4138

Asset Category	Asset Sub-Category Primary	Voltage	Intervention	Forecast Addition[13]	Forecast Disposal
Circuit Breaker	CB (Gas Insulated Busbars) (ID)	132kV	Addition	1 unit	-
Flexible AC Transmission Systems (FACTS)	FACTS Equipment	132kV	Addition	1 unit	-

11 Forecast Additions are indicative pending further detail design.
12 Forecast Additions are indicative pending further detail design.
13 Forecast Additions are indicative pending further detail design.

5.9. Environmental and Consents Works

Section 37 consent will be sought from the Scottish Ministers to install the required length of the double circuit OHLs. Deemed planning permission will be sought for the 400kV OHL and the proposed Redshaw substation, as well as the ancillary development. Relevant landowner agreements will also need to be put in place where required.

The Section 37 application to the Energy Consents Unit will be accompanied by an Environmental Impact Assessment Report (EIA Report). The information contained in the EIA Report fulfils the requirements of the EIA Regulations and will enable Scottish Ministers as the decision-making authority, to make their decisions on the application for Section 37 consent and deemed planning permission.

The EIA Report details the findings of the assessment of the likely significant effects of the proposals on the environment in terms of its construction and operation. The assessment forms part of the wider process of EIA, which is undertaken to ensure that the likely significant effects, both positive and negative of certain types of development are considered in full by the decision maker prior to the determination of an application for Section 37 consent and for deemed planning permission.

The main strategy for minimising adverse environmental effects of the proposals will be through careful OHL routeing. While some environmental effects can be avoided through careful routeing, other effects are best mitigated through local deviations of the route, the refining of tower locations and appropriate construction practices. Additionally, in certain cases, specific additional mitigation measures will be required, and these have been identified through the EIA process.

Consultation has taken place with statutory stakeholders including SEPA and Nature Scot in relation to the proposals. Consultation was also undertaken with all other relevant stakeholders including the wider public and landowners.

6. Deliverability

We have applied SPT project management approach to ensure that this project work is delivered safely, and in line with the agreed time, cost, and quality commitments. We have a proven track record of delivering essential transmission network upgrade projects and will draw upon this knowledge and experience to effectively manage these works. We work closely with our supply chain partners and this relationship is critical to the successful delivery of our plans. Our supply chain provides the support and agility to respond to changes in workload over the course of a price review. Further information is contained within our Workforce & Supply Chain Resilience Annex. We have assigned a dedicated Project Manager to the works at every stage who is responsible for overall delivery of the scope and is the primary point of contact for all stakeholders. The project manager responsibilities, albeit not limited, include:

- Handing over the project from development phase to delivery phase and ensuring minimum requirements of the SPT project handover are met.
- System and customer updates to reflect transfer of ownership.
- Leading tender activities during development phase.
- Provision of a comprehensive resource plan to encompass all contractor and SPT operational activities.
- Booking outages and risks of trip with operational planning.
- Ensure all offline works are completed prior to any outage being taken to reduce system risk.
- Co-ordinate all site commissioning issues.

- Chair commissioning panel meetings.
- Chair progress meetings.
- Maintain the site quality plan.

Some further responsibilities of the project manager are discussed in the following sub-sections.

6.1. Delivery Schedule

A standard approach has been applied to the planning phase of these works and that will continue for the reporting and the application of processes and controls throughout the lifecycle. Table 31 summarises the key milestones within the delivery schedule of this project. Complete detail on the energisation dates and delivery schedules for the proposed scheme can be found in Appendix B.

Table 31: Summary of Key Milestones within the Project Delivery Schedule

Item	Project Milestone	Estimated Completion Date
1	Town & Country Planning Application	February 2025
2	Issue of ITT	March 2025
3	Town & Country Planning	July 2025
4	Site Mobilisation	November 2025
5	Earthworks	December 2026
6	Civil Works	March 2027
7	400kV & 132kV GIS Building Works	June 2027
8	Final OHL Connection to Redshaw Substation	October 2027
9	400kV Plant Commissioning	October 2027
10	132kV ‘A’ Board Plant Commissioning	October 2027
11	132kV ‘B’ Board Plant Commissioning	November 2028
12	132kV ‘A’ & ‘B’ Board Harmonic Filter Commissioning	June 2029

SPEN for its procurement process follows a generic global process (INS 00.08.04) for supplier pre-qualification, product technical assessment, manufacturing factory capability assessment and quality audit. The SPEN’s equipment approval procedure is to:

- identify and select candidate equipment.
- ensuring the candidate equipment is assessed to meet the specific requirements of SPEN.
- ensuring a structured and consistent approach is adopted for the approval of candidate equipment prior to energisation.
- Ensuring no equipment is installed on SPEN’s network without first having been examined in accordance with the procedure and issued with a formal internal approval.

ASSET-02-002 specifies the SPEN’s approval process inclusive of assessment scope and business processes for various equipment.

Regular meetings with the project and construction management teams will be undertaken to assess the ongoing effectiveness of the project management interfaces.

The Project Manager will facilitate internal project team meetings, in which project progress and deliverables will be reviewed and any arising risks or issues will be discussed and addressed.

6.2. Risk and Mitigation

A Project Risk Register has been developed, collaboratively, during the initial project kick-off meeting to identify any risks to the delivery plan. Mitigation strategies have been developed to manage the risks identified and these will be implemented by the Project Manager. The risk register shall remain a live document and will be updated by the project team on an ongoing basis. The top scheme risks as currently identified are as follows:

Table 32: Main Scheme Risks and Mitigation Plans

Risk Title	Risk Description	Mitigation Plan
Planning Consent	Delay in submission of Section 37 application and receiving approvals from Scottish Ministers may delay the project delivery plans.	Regular meetings will be held with developers and/or landowners to satisfy the stakeholders requirements, manage an in-time submission of Section 37 application and frequent follow ups with Scottish Ministers to ensure receiving the approvals on time.
Compulsory Purchase Order (CPO)	CPO may require to be sought due to being unable to secure voluntary land rights for 400kV substation platform and parts of the circuit route.	Regular meetings will be held with SPEN's planning and permission team to ensure SPEN's OHL route principles have been met. Continued engagement with relevant landowners.
System Access for Construction Outages	Delay in gaining system access for construction outages, including outages associated with diversion of the ZV OHL route to enable commencement of substation civil platform works, may delay the project delivery plans.	Frequent site visits and regular meetings will be held with the project stakeholders (internal and external) to identify the project delivery requirements in advance and ensure in-time commencement of substation civil works.
Procurement of Harmonic Filter	Learning from RIIO-T2 experience on harmonic filter installations, there is a limited market availability for harmonic filter procurement.	Regular meetings will be held with SPEN's Mega Scheme team to ensure SPEN's principles have been met.

6.3. Quality Management

SPT adopts a 'life cycle' approach to Quality Management in major project delivery. Our Management Systems are certified to ISO 9001, ISO 14001 and ISO 45001. The key quality management areas are detailed below:

6.3.1. Quality Requirements During Project Development

Any risk or opportunity that may affect the quality of the product is detailed in the Project Risk Register. The suppliers of main equipment may also receive a Factory Acceptance Test Inspection when the asset is being built.

6.3.2. Quality Requirements in Tenders

Each contract that SPT issues has a standard format. Specifically in relation to quality, this will include a Contractors' Quality Performance Requirement (CQPR). This CQPR represents a specification that details roles and responsibilities for all parties during the works, frequency, and format of reporting. It will also specify the document management process to be adhered to during the delivery of the project. In addition to the CQPR, each project has a contract specific Quality Management Plan, detailing the inspection and testing regime for works as well as the records to be maintained.

6.3.3. Monitoring and Measuring During Project Delivery

SPT Projects undertake regular inspections on projects to monitor and measure compliance with SPT Environmental, Quality and Health and Safety requirements, as detailed in the contract specifications for the work. This also includes oversight of contractors. All inspections are visual, with the person undertaking the inspection ensuring that evidence of the inspection and any actions raised are documented.

The following inspections are completed:

- Quality Inspections (monthly).
- Environmental Inspections (monthly, with weekly review by third party Environmental Clerk of Works).
- Safety Assessments & Contractor Safety Inspection (daily, with full time Site Manager).
- Project Management Tours (monthly).

The scope of audits and inspections is set to ensure compliance with the following:

- Procedures & Guides.
- Planned arrangements for ISO 9001, 14001 & 18001.
- Legal and other requirements.

6.3.4. Post Energisation

SPT Projects and SPT Operations carry out a Defect Liability Period Inspection within the Contract Defect Liability Period with the aim of identifying any defects and rectifying them with the contractors.

6.4. Environmental Sustainability

IMS-01-001 encompasses all activities undertaken within and in support of SPEN's three Licences. This includes operational and business support functions concerned with management of SP Transmission, SP Distribution and associated regulatory and commercial interfaces, products, services, and their associated environmental, social, and economic impacts. The policy makes the following commitments which shall be respected in any works associated with this scheme.

SP Energy Networks will incorporate environmental, social, and economic issues into our business decision-making processes, ensuring compliance with or improvement upon legislative, industry, regulatory and other compliance obligations. We will deliver this by being innovative and demonstrating leadership on the issues which are important to us and our stakeholders, and will:

- Ensure the reliability and availability of our Transmission and Distribution network whilst creating value and delivering competitiveness by increasing efficiency and minimising losses.
- Reduce greenhouse gas emissions in line with our Net Zero Science Based GHG target, which is a target of 90% reduction in GHG emissions by 2035 (TBC) from a 2018/19 baseline.
- Integrate climate change adaptation requirements into our asset management and operations processes to support business resilience and reduce the length and time of service interruptions.

- Consider whole life cycle impacts to reduce our use of resources to sustainable levels, improve the efficiency of our use of energy and water and aim for zero waste.
- Improve land, air, and watercourse quality by preventing pollution and contamination and protecting and enhancing biodiversity in our network areas.
- Improve our service to local communities, supporting their economic and social development, protecting vulnerable customers, and respecting human rights.

ENV-04-014 gives specific guidance on the management of incidents with environmental consequence, or potential for environmental consequences, over and above the general requirements for the management of incidents.

The proposed design solution is also resilient to future climate change risks, such as substation flooding or potential faults from vegetation along the route.

SPEN policy to eliminate risk of substation flooding entails:

- Substations shall be designed such that there is no loss of supply or damage to strategic equipment during a 0.1% annual exceedance probability (AEP) flood event. Access routes to the substation shall also be considered to ensure access will be available during flood conditions and consideration of staff access to the key plant and buildings during the 0.1% annual flood event.
- In those instances where there is a compelling reason to locate a substation inside this zone and this is accepted by SPEN Network Planning & Regulation the substation design shall eliminate or mitigate against the risk of such a flood impacting the operation of the substation (access requirements, loss of supply, or damage to equipment).
- The 400kV substation platforms shall be constructed at a minimum level of 600mm above the 0.1% designed flood level, the 600mm freeboard allows for uncertainties in data and modelling. The designed flood level shall include an allowance for climate change for a 50-year design life, in accordance with the requirements of the relevant national environment agency. Where climate change guidance is not available then a minimum of 200mm shall be applied. The flood design should consider Pluvial, Fluvial, Coastal and Reservoir flooding, as well as combinations of these.

SUB-01-018 gives detailed specific guidance on SPEN's substation flood resilience policy.

Also, SPEN policy to reduce the number of vegetation related OHL faults entails:

In SPEN to reduce the number of vegetation related OHL faults, the route will be surveyed, consented, and cut on a per kilometre basis. The cutting specification entails:

- Falling distance plus 5m (i.e., Vicinity Zone) to the conductor and maintain 5 years clear from that distance.
- Clearance as 5.3m to be achieved from conductor positioned at 45° blowout and maximum sag condition. Maintain 5 years clear from that distance.

- All vegetation directly below the OHL with the potential to breach the Vicinity Zone before the next cut cycle shall be removed.
- Hedgerows shall be maintained. Species identified with no threat to breach the Vicinity Zone at any point in the future shall continue to be managed as part of the 3-year vegetation management programme.

- Tower bases shall be kept free of all scrub to a distance of 5m from the base.

OHL-03-080 gives detailed specification for OHL vegetation management in SPEN.

Additionally, the preferred OHL route for the project needs to be identified after extensive evaluation of the length of route, biodiversity and geological conservation, landscape and visual amenity (including recreation and tourism), cultural heritage, land use, forestry, and flood risk.

If routing the OHLs in areas of forestry the guideline is to -

- Avoid areas of landscape sensitivity;
- Not follow the line of sight of important views;
- Be kept in valleys and depressions;
- Not divide a hill in two similar parts where it crosses over a summit;
- Cross skylines or ridges where they dip to a low point;
- Follow alignments diagonal to the contour as far as possible, and;
- Vary in the alignment to reflect the landform by rising in hollows and descending on ridges.

The overall project design objective is to minimise the extent of felling required and woodland areas and individual trees are to be avoided where possible during the routeing phase. Where routeing through woodland has been unavoidable, a 'wayleave' corridor is required for safety reasons to ensure that trees do not fall onto the line and for health and safety of forestry operatives. SPEN has statutory powers to control tree clearance within the wayleave corridor. Where possible the design of the new OHLs and associated infrastructure must be sought to avoid/minimise felling where possible, when balancing with other technical and environmental objectives.

6.5. Stakeholder Engagement

SPT is committed to delivering optimal solutions in all the projects it undertakes. A key part of this is engaging with relevant stakeholders throughout the project-development and delivery process. SPT's stakeholder engagement plan for this reinforcement project will be closely aligned to our wider stakeholder engagement commitment as outlined in our RIIO-T3 business plan. Stakeholders includes customers, regulatory bodies and other statutory consultees, national and local government, landowners, community groups, and local residents and their representatives (e.g., MPs, MSPs and councillors). Community impacts associated with construction activities are considered at project initiation by completion of a Community Communications Plan, which details the stakeholders relevant to the project, the communication channels that will be used to engage with them, the information that will be provided to and sought from them, and the timescales over which this will happen. It considers any sensitivities that may require increased stakeholder consultation and details specific events that will be held with stakeholders during the development of the project.

As part of this project, SPT will engage with statutory consultees associated with the planning application for these works - the Local Authority, SEPA and Nature Scot - and the third-party landowner.

Due to the location and nature of this project, no particular sensitivities or community impact issues have been identified, but a general level of interest from local representatives has been noted and we will continue to engage with them throughout the project. Stakeholder engagement to date has informed the details of the construction and permanent drainage details for the works.

7. Eligibility for Competition

Under the RIIO-T3 Business Plan Guidance, Ofgem has requested that projects that are above £50m and £100m should be flagged as being eligible for being suitable for early and late competition respectively. When bundled, this group of projects is above both thresholds, however, is not suitable due to:

- Being significantly developed, with elements already out to tender, therefore not suitable for early or late competition.
- A number of new connections projects are dependent on the completion date, therefore delays through any project tender exercise will delay these projects.
- OHL works into the existing ZV Route are integral to the existing route, and therefore this section of works is not separable.

8. Conclusion

This EJP demonstrates the need to -

(i) establish a new Redshaw 400kV substation;
(ii) establish a new Redshaw 132kV substation with two switchboards (‘A’ & ‘B’ boards);
(iii) install two new 400/132kV 360MVA SGTs at ‘A’ board of the new 132kV substation;
(iv) install two new 400/132kV 360MVA SGTs at ‘B’ board of the new 132kV substation;
(v) install a LMS to monitor the loading across SGT1 and SGT4 at Redshaw ‘B’ 132kV substation, under N-1 conditions; and
(vi) install two unites of 20MVAr harmonic filters in the new Redshaw 132kV substation, one at each ‘A’ and ‘B’ boards.

This submission supports six discrete applications summarised above.

Redshaw 400kV Substation (ref. SPT-RI-2060) will enable the timely and efficient connection of approximately 2.9GW of contracted generation in the local area and will also facilitate the future extension of the transmission network from the planned Glenmuckloch substation to Redshaw 400kV substation (planned under SPT-RI-236, the scope of which is outside this EJP), enabling the connection of a further circa 0.9GW of contracted renewable generation capacity in SWS area.

The establishment of Redshaw 132kV Substation (‘A’ Board) (ref. SPT-RI-2061) and the provision of additional inter-bus transformer capacity (ref. SPT-RI-2139) together facilitate the connection of a further 684MW with the Redshaw 132kV substation (‘B’ Board) (ref. SPT-RI-3060) connecting a further 422MW of renewable generation to the system as well as providing a new GSP to the DNO (SP Distribution Ltd) in this area.

The increasing number of large wind farm connections into South Lanarkshire area is leading to amplification of background harmonics to levels above the EREC G5/5 planning levels. This issue can be mitigated by the installation of standardised harmonic filters to provide a coordinated and efficient solution. Installation of Redshaw 132kV 20MVAr damped (C-type) harmonic filters at Redshaw 132kV ‘A’ and ‘B’ boards (one at each board) as proposed in this EJP are proven to ensure our network compliance with harmonic standards, EREC G5/5, in the area.

The main conclusions of this EJP are:

- It is necessary to invest in transmission infrastructure at Redshaw area to enable the connection of circa 2.9GW of contracted renewable generation in South Lanarkshire area, as well as enabling connection of circa 0.9GW in SWS area. This has been identified as the most economic and efficient option.

- To ensure network compliance with EREC G5/5 it's necessary to install two 132kV 20MVAr damped (C-type) harmonic filters at the new Redshaw 132kV substation, one at each 'A' and 'B' boards.
- The proposed reinforcement scheme plays a vital role in reaching legislated net zero targets and is aligned with SPT's RIIO-T3 strategic goals.

We ask that Ofgem approve the need for the projects as set out within this EJP to enable pre-construction and early enabling works funding. Cost assessment submissions will be made to Ofgem at an appropriate time within the RIIO-T3 period via the Load Related Reopener mechanism for those projects which are applicable. For projects less than £25.00m, it is expected these will be funded using the UIOLI pot.

9. Appendices

Appendix A – Maps and Diagrams

Appendix B – Reference to Supporting Documents

[redacted]

[redacted]

Appendix A: Maps and Diagrams

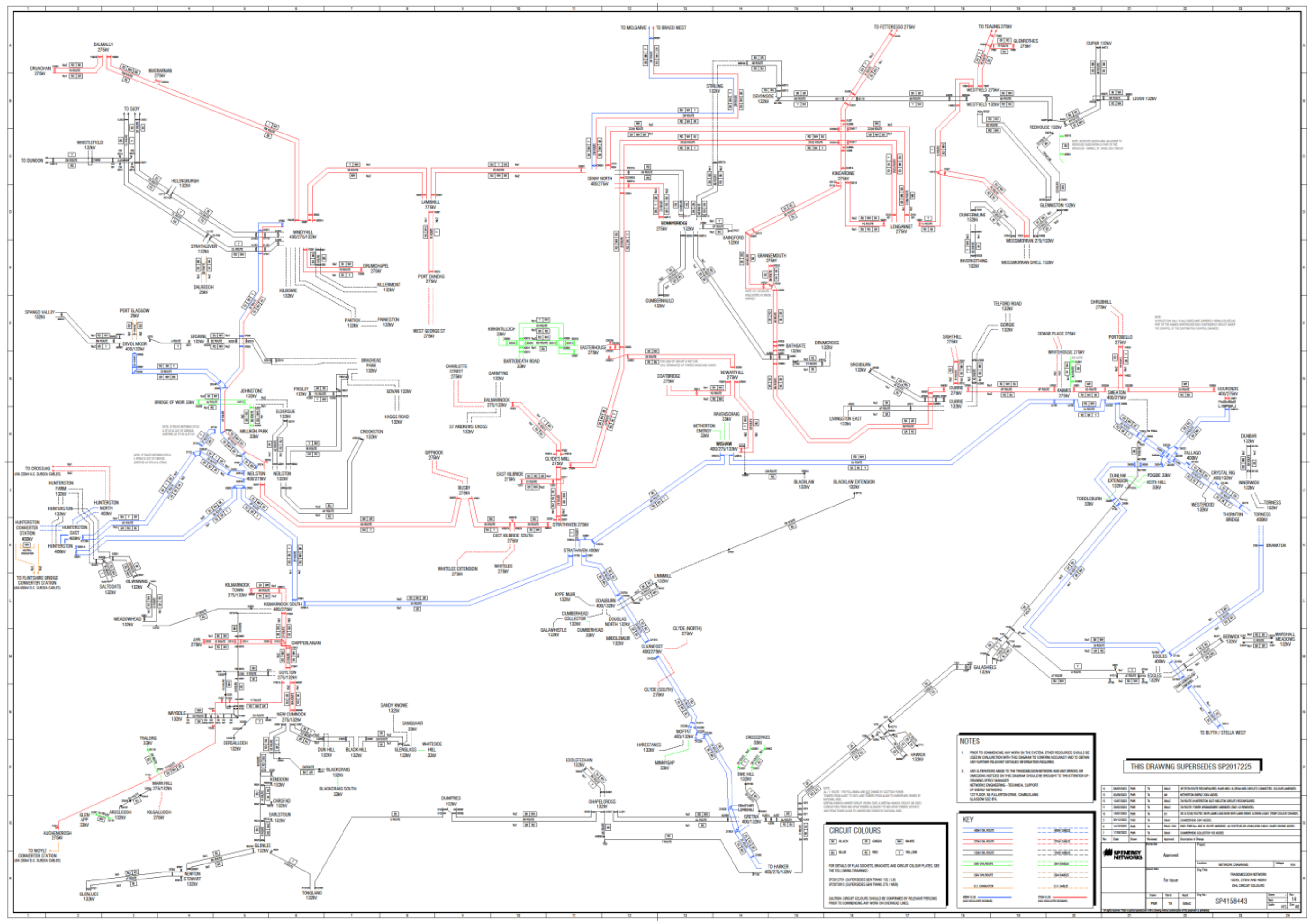


Figure A-1: Networks diagram of the existing SPT systems – Single Line Diagram.

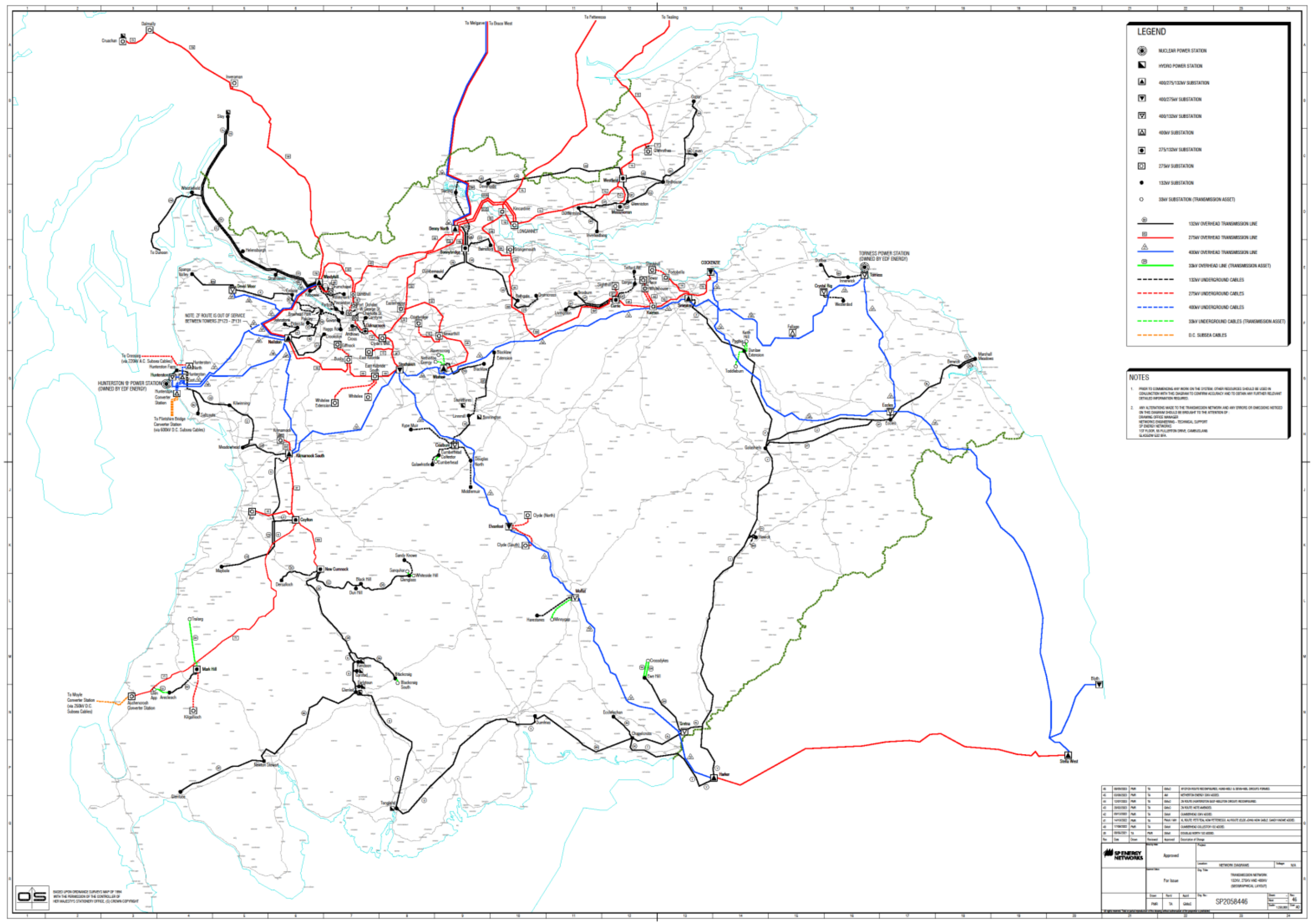


Figure A-2: Networks diagram of the existing SPT system - Geographical Layout.

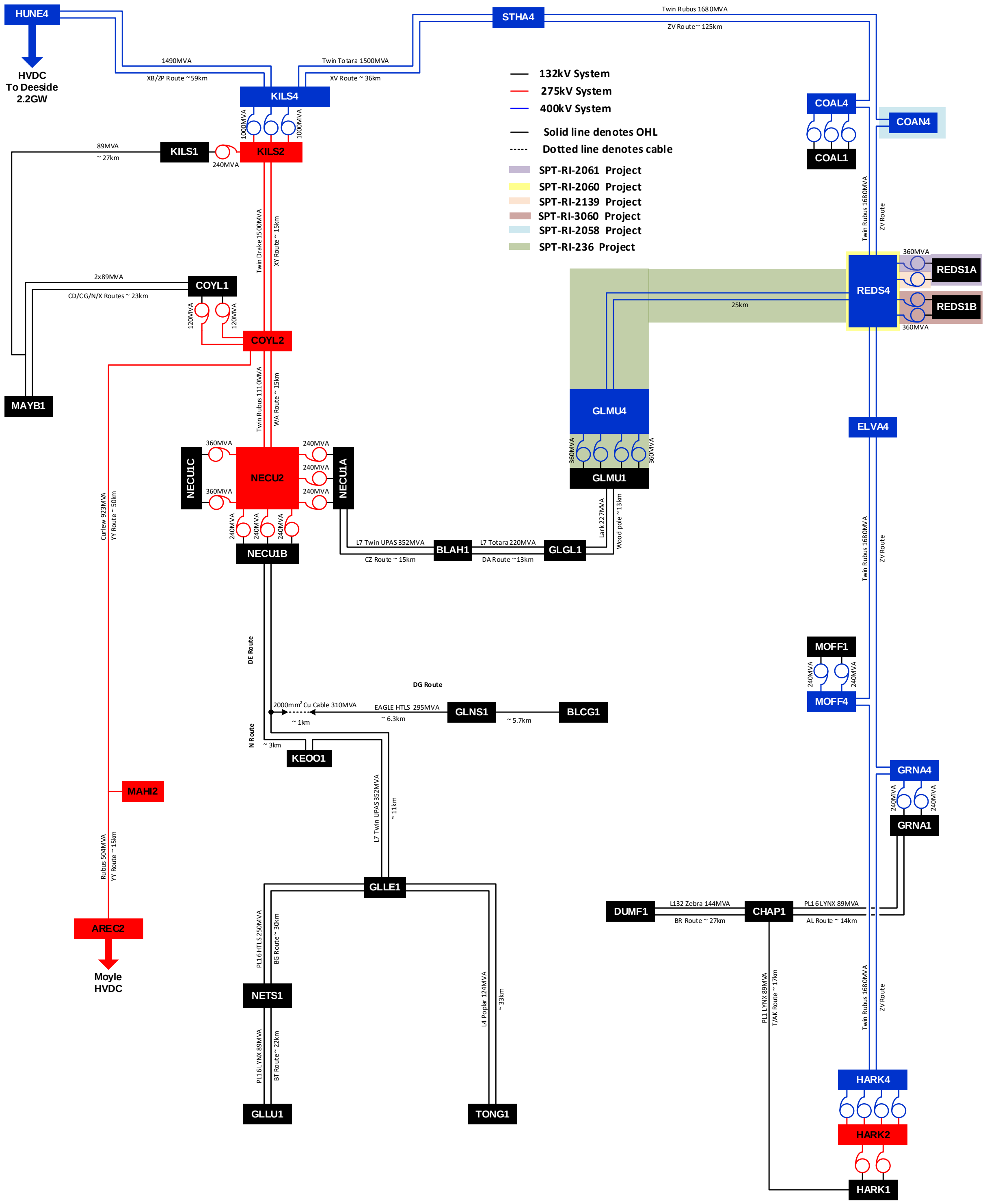


Figure A-3: Single Line Diagram of the electricity network in the area.*

*NB – The Focus of this diagram is the Redshaw cluster project. The rest of the network shown in subject to change as driven by other network needs. The reinforcement projects SPT-RI-236 and SPT-RI-2058 will be justified through separate need cases. In this diagram, the Kilmarnock South, New Cumnock, Glenglass, Coalburn, Coalburn North, Glenmuckloch and Redshaw substations are indicated as KILS, NECU, GLGL, COAL, COAN, GLMU and REDS, respectively.

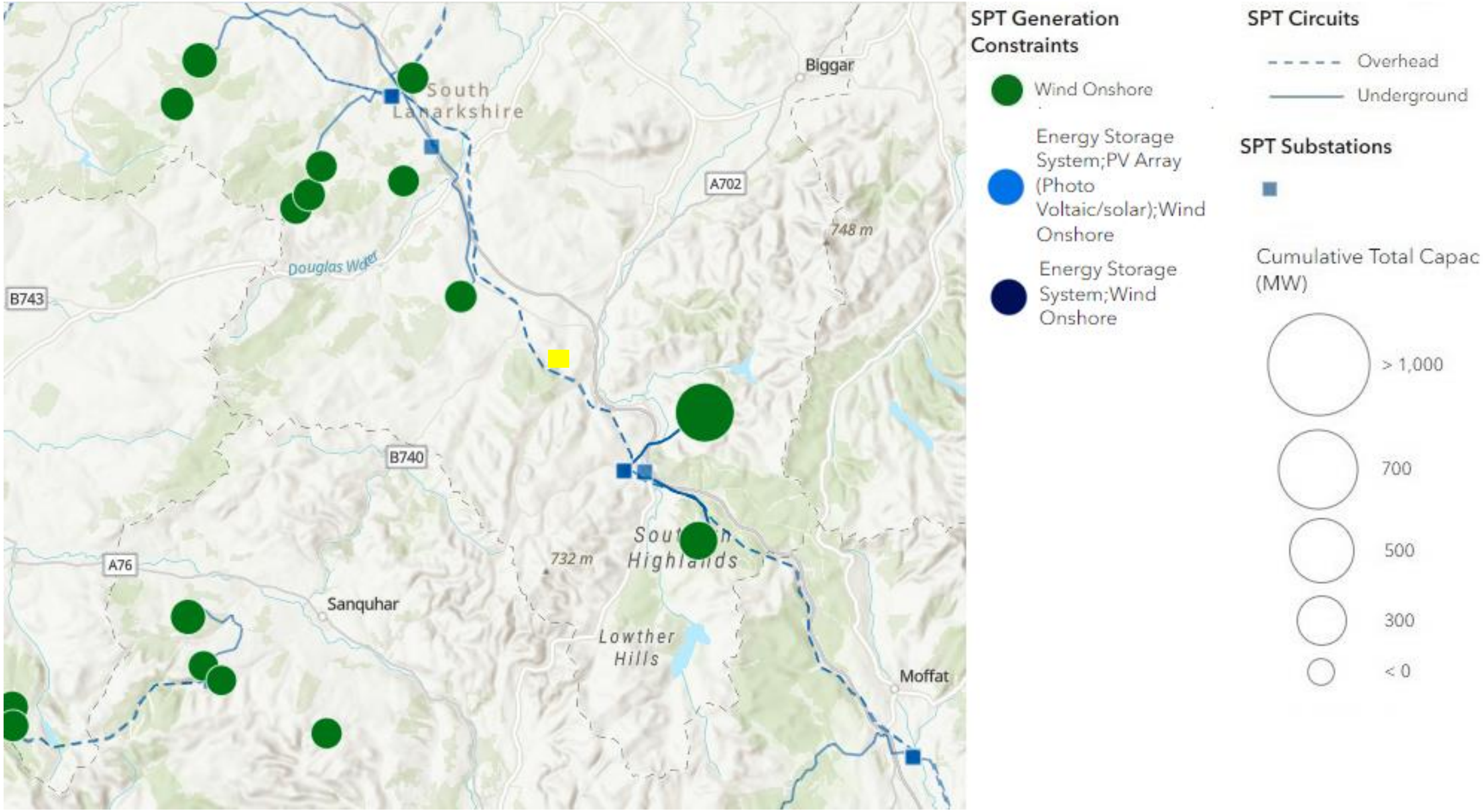


Figure A-4: Currently Connected Renewable Developments, with wind power generation technology, in Redshaw area as a scale to indicate the network's background harmonic level – Extracted from Transmission Generation Heat Map.*

*NB – The proposed new Redshaw substation, where the Redshaw 'A' 132kV and Redshaw 'B' 132kV harmonic filters will be connected to, has been highlighted in yellow.

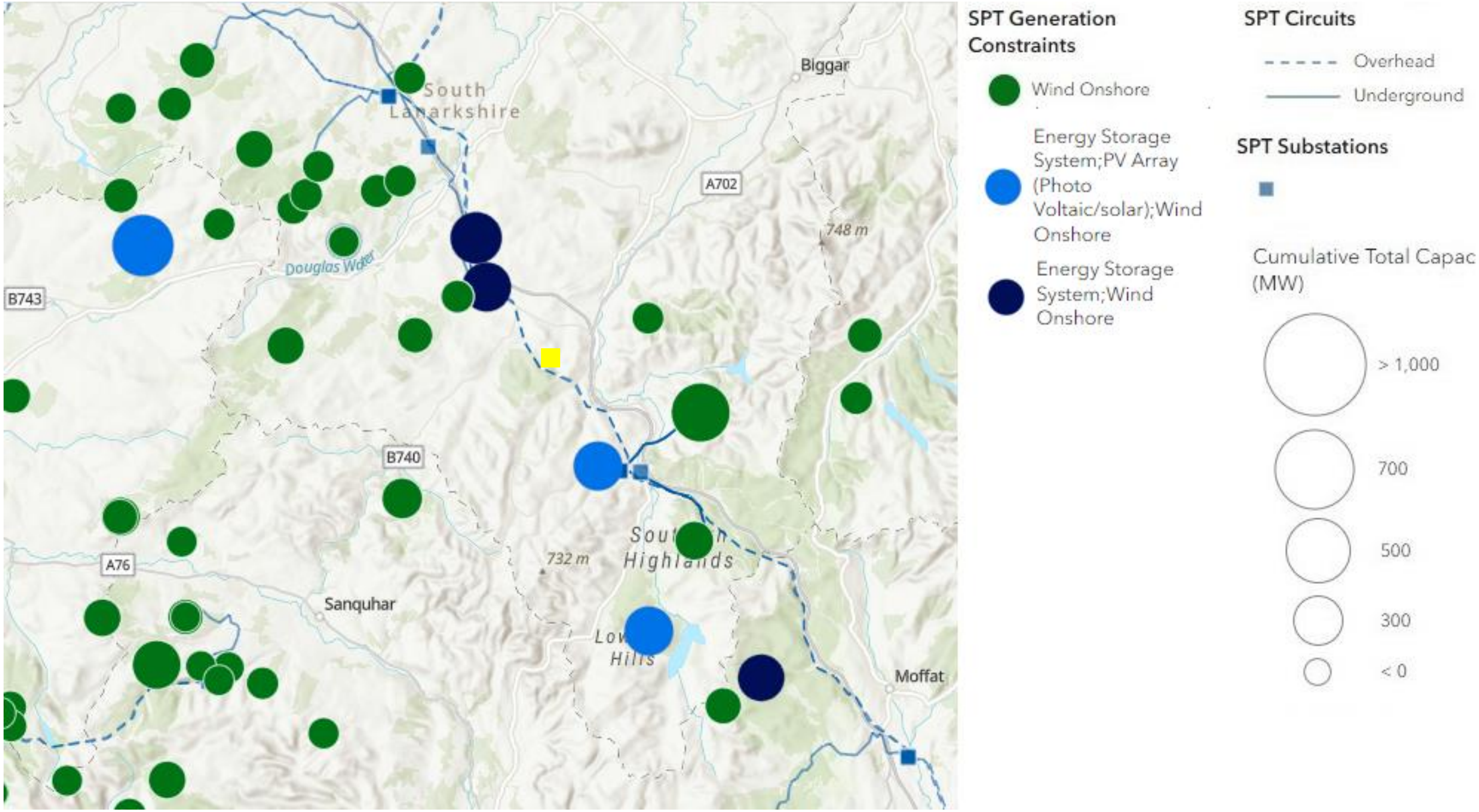


Figure A-5: Contracted and Connected Renewable Developments, with wind power generation technology, in Redshaw area as a scale to indicate the network's background harmonic level – Extracted from Transmission Generation Heat Map.*

*NB – The proposed new Redshaw substation, where the Redshaw 'A' 132kV and Redshaw 'B' 132kV harmonic filters will be connected to, has been highlighted in yellow.

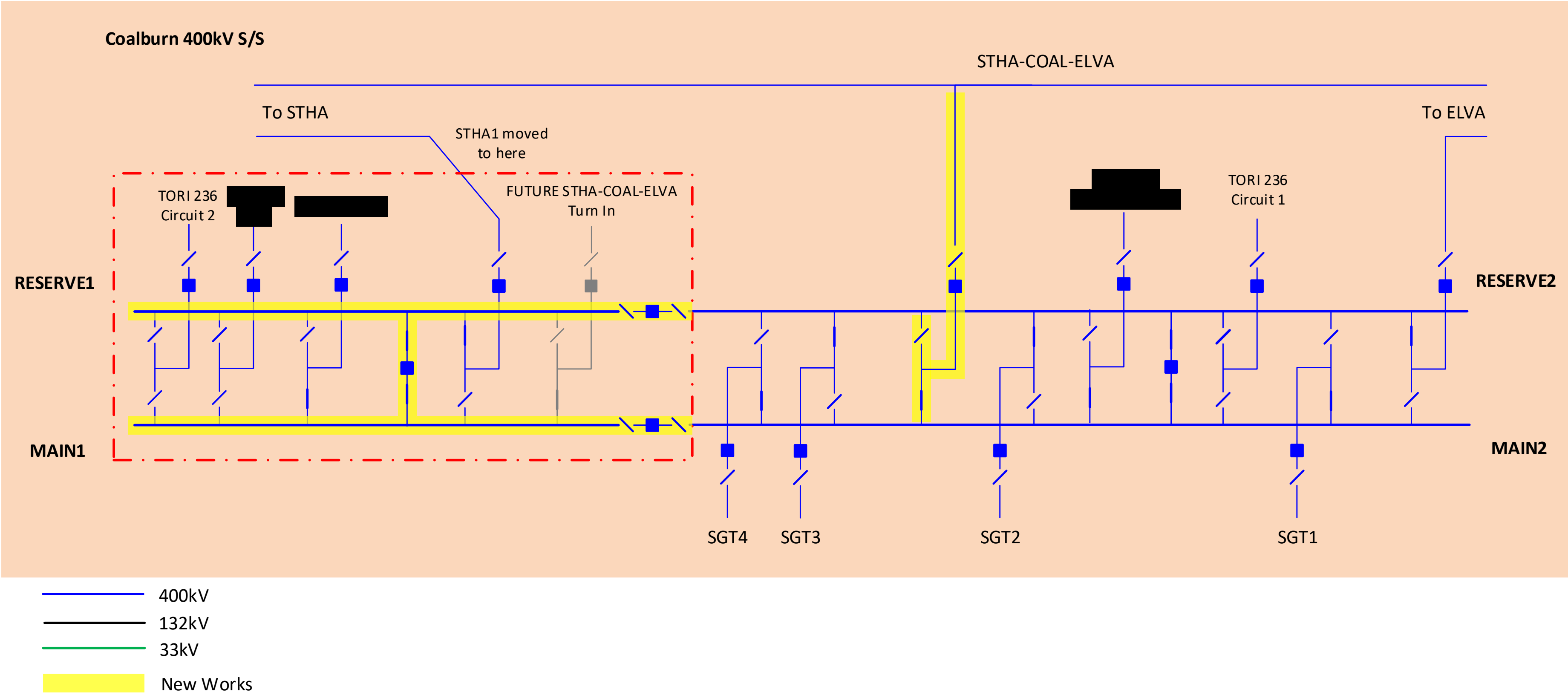


Figure A-6: Coalburn 400kV substation extension single line diagram (i.e., Option 2).

[redacted]

Figure A-7: Connected/contracted connections in Coalburn/Redshaw/Glenmuckloch area.

[redacted]

Figure A-8: Indicative geographical view showing Coalburn and Redshaw connections.

[redacted]

FigureA-9: Geographical location of Elvanfoot substation.

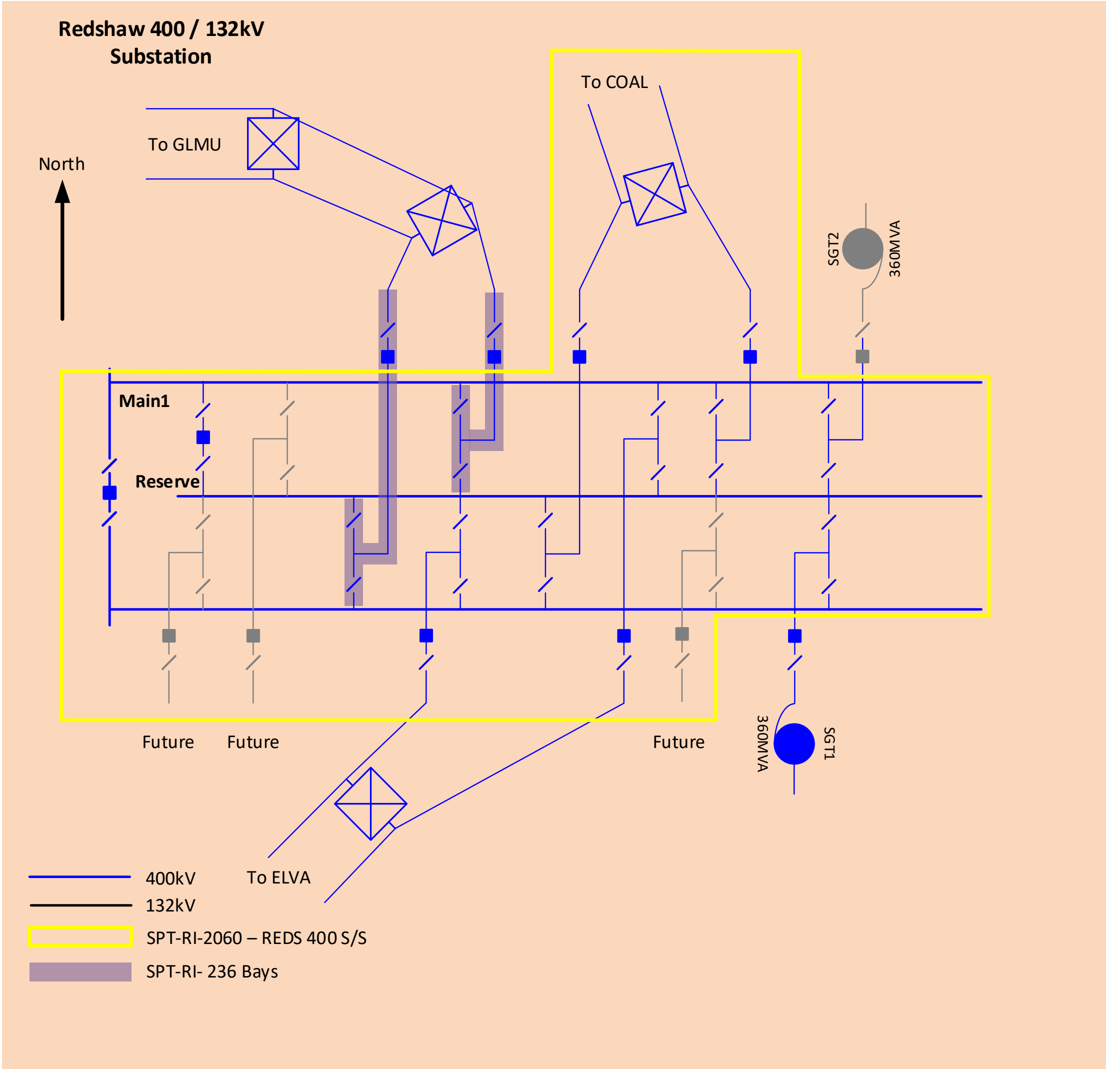


Figure A-10: Single line diagram of a double busbar 'wraparound' solution for Redshaw 400kV substation (i.e., Option 5a).*

*NB - The bays highlighted as 'SPT-RI-236 Bays' are planned under Glenmuckloch 400kV double busbar circuit project which is outside the scope of this EJP.

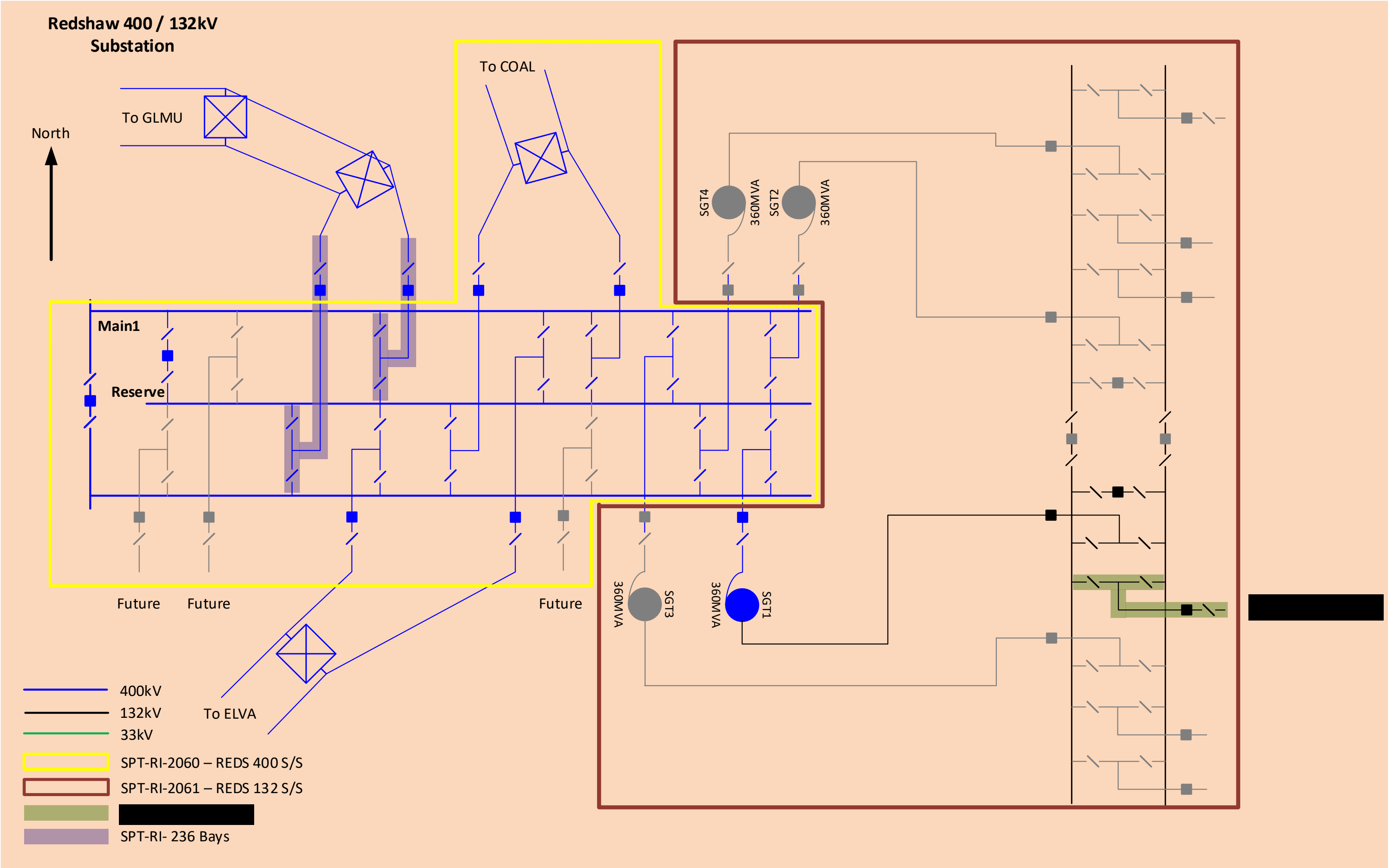


Figure A-11: Single line diagram of Redshaw 400/132kV substation considering AIS 400kV and 132kV equipment (i.e., Option 5a)*.

*NB – The bays highlighted as 'SPT-RI-236 Bays' are planned under Glenmuckloch 400kV double busbar circuit project which is outside the scope of this EJP. Also, the [redacted] Bay will be funded by the customer.

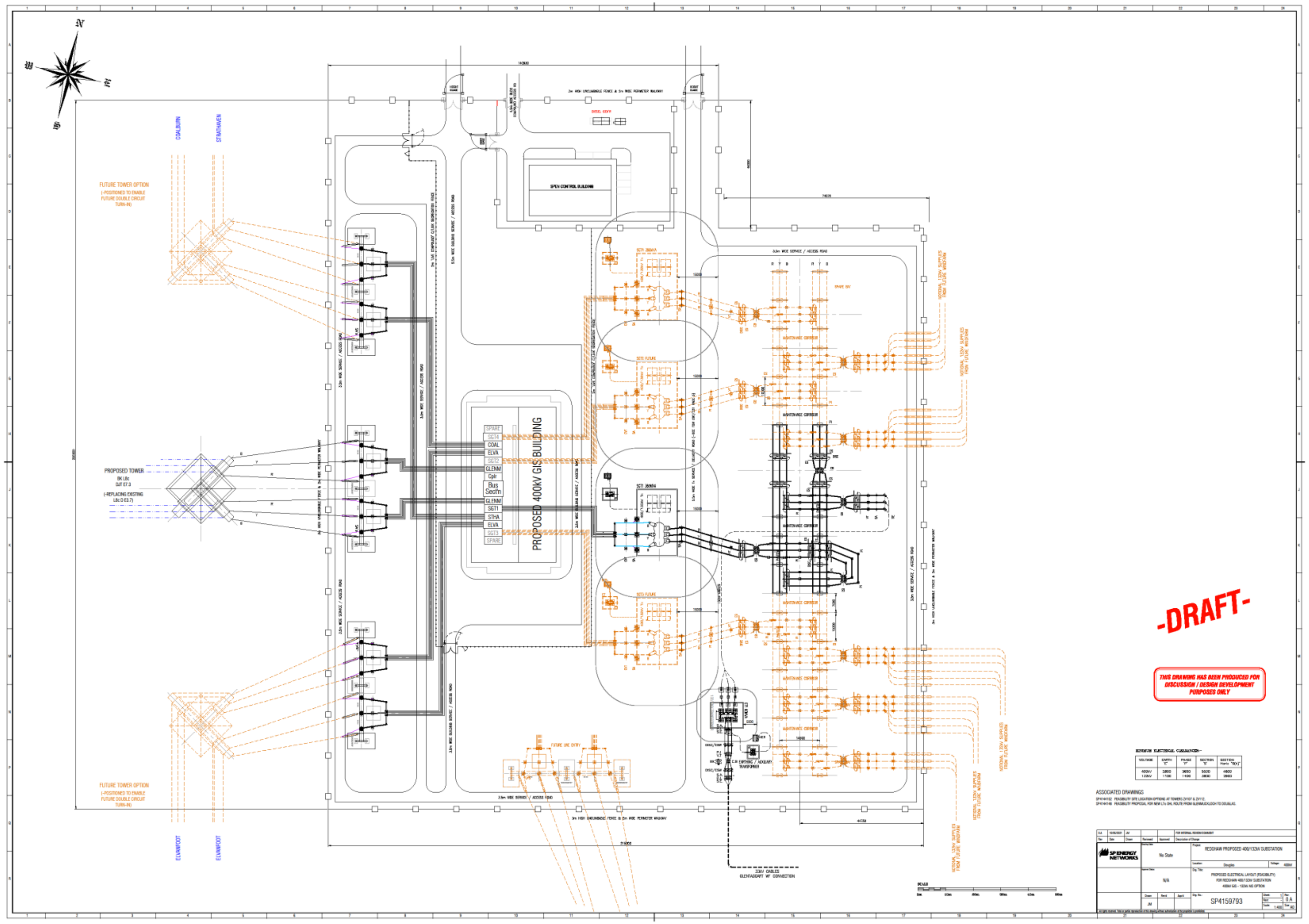
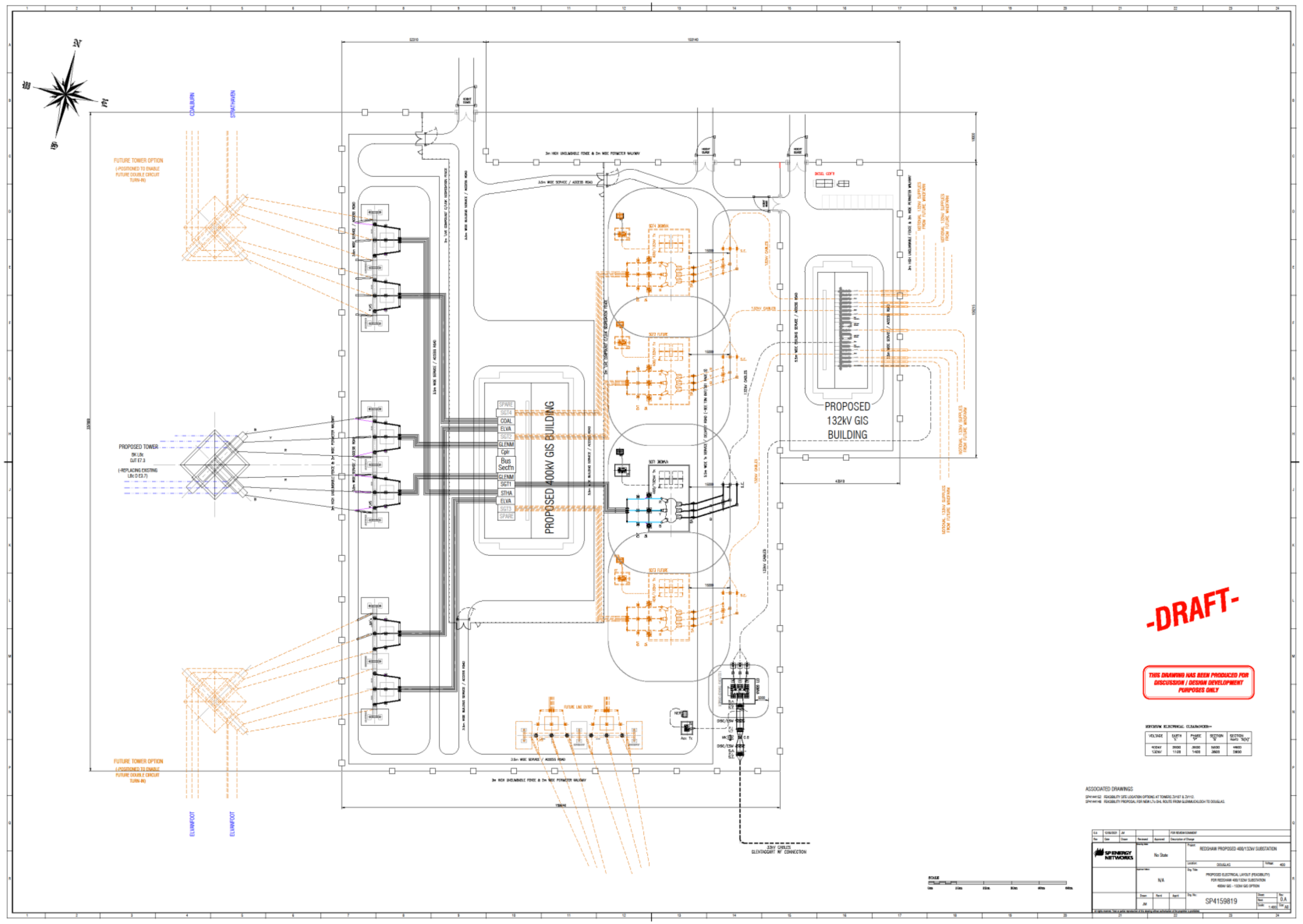
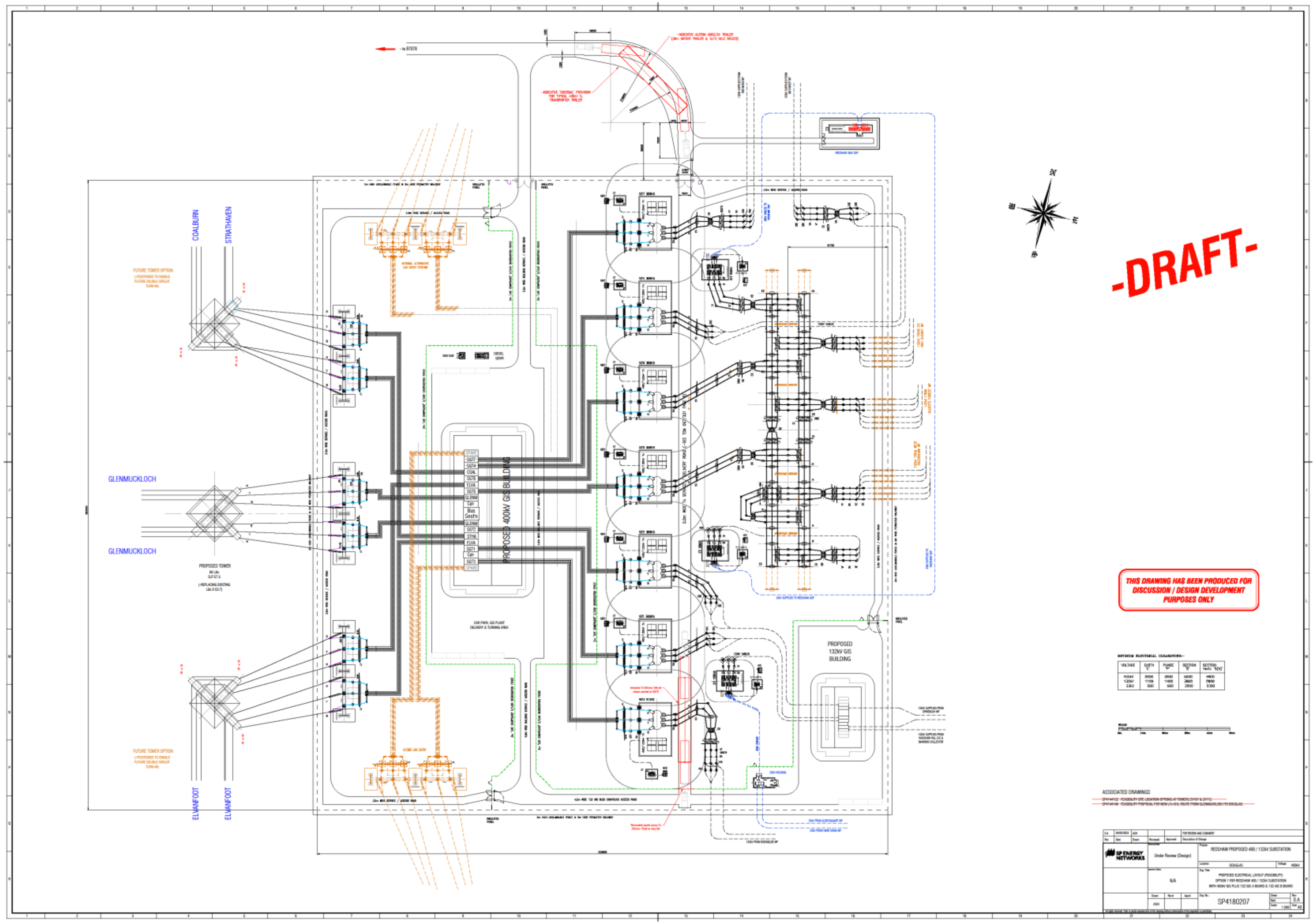


Figure A-12: Redshaw 400/132kV substation - GIS 400kV substation and AIS 132kV substation (i.e., Option 5b).



FigureA-13: Redshaw 400/132kV substation - GIS 400kV substation and GIS 132kV substation.



FigureA-14: GIS 400kV substation and GIS 'A' 132kV board and AIS 'B' board.

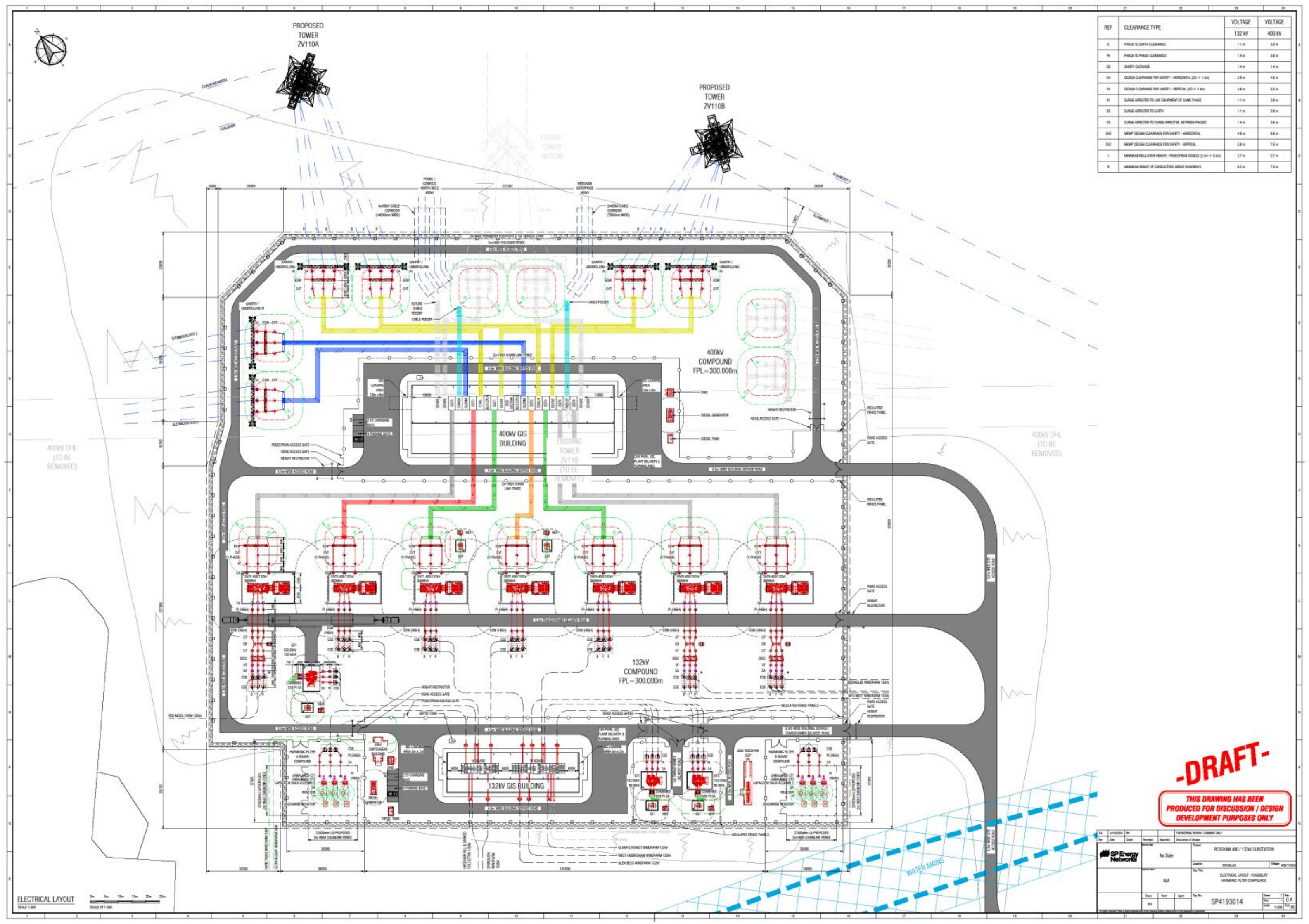


Figure A-15: Redshaw 400/132kV substation - GIS 400kV substation and GIS 132kV 'A' and 'B' board (i.e., Option 5c).

Appendix B: Reference to Supporting Documents

1. ENA Engineering Recommendation G5 "Harmonic voltage distortion and the connection of harmonic sources and/or resonant plant to transmission systems and distribution networks in the United Kingdom", Issue 5, 2020.

2. WSP Parsons Brinckerhoff, "Development of a Standard 33kV Harmonic Filter – Stage 1", June 2016 (NIA project NIA_SPT_1506, Development of a Standard 33kV Damped Harmonic Filter Design).

3. WSP Parsons Brinckerhoff, "Development of a Standard 33kV Harmonic Filter – Stage II", February 2017 (NIA project NIA_SPT_1506, Development of a Standard 33kV Damped Harmonic Filter Design).

4. Electric Power Research Institute (EPRI), "South West Scotland Harmonics Study – Filter Design and Analysis Results", July 2017 (NIA project NIA_SPT_1610, Innovative Approach for Transmission Harmonics Issues).

5. Dr Brozio C.C, IP1 "Harmonic Filters for 132kV Network", RIIO-T2 Works, January 2020.

6. NIA_NGTO018 (Harmonic compliance management),

   https://www.smarternetworks.org/project/nia_ngto018

[redacted]

[redacted]