EJP/SHEPD/KEITH 1/KEITH 1 33KV CIRCUITS/PH004212

KEITH 1 33KV CIRCUITS ENGINEERING JUSTIFICATION PAPER

Scottish & Southern Electricity Networks

CONTENTS

1 Executive Summary

1.1 Summary

This paper outlines both the requirement for, and scope of intervention on the Keith 1 GSP 303/304 closed ring circuit. The circuits currently supply ~12,800 customers and due to the predicted load growth within the RIIO – ED2 period and beyond, voltages drop below regulatory thresholds under outage conditions.

Within this paper, seven different options are considered depending on location, electrical and physical solutions to address the voltage issues. Through the whole system approach and overarching stakeholder engagement, the area-specific requirements in terms of site requirements and foreseeable local authority plans have been collected to aid the decision making. Additionally, asset health related issues have been identified as well that further support the works. A summary of the options is provided in [redacted]

Option	Description	NPV	Year of Associated Costs	Advantages	Disadvantages	Results
1. Do Nothing	Do nothing to the existing network	N/A	N/A	Low cost and workload	[redacted]	[redacted]
2. Flexibility Solution or Curtailment	Not viable	N/A	N/A	N/A	N/A	[redacted]
3. Load Transfer	Load Transfer & Monitor demand development	N/A	N/A	Low cost and workload.	Not possible without reinforcement	[redacted]
4. Reinforcement of Existing 303/304 Circuits	Reinforce to lower impedance of conductor in ED2.	N/A	N/A	Increase network resilience. Create headroom for new demand.	[redacted] No options for larger capacity conductors [redacted]	[redacted]
5. Network Extension: New Primary at Buckie	Run two new circuits to Buckie and establish a new primary substation to support half of the load from Buckie	N/A	N/A	Increase network resilience. Create headroom for new demand. Provide additional support for the 11kV network in Buckie.	No room for two new circuit breakers at Keith GSP or Switchroom extension	Considered but not progressed.

6. Do Minimum	Establish a new Buckie primary site and install two 2.5MVar Statcoms to either side of the new 33kV switchboard	N/A	N/A	Low cost to achieve compliant volts for 2028. Can be built offline minimising outages for existing customers	Interim solution only - scheduled connections reinforcement on the 303/304 ring [redacted]	[redacted]
7. Combination of Reconfiguration, Network Extension and Reinforcing Existing Assets	Reconfigure network with new circuit to Buckie, shed Cullen from ring and reinforce existing circuits	£9.51m	24/25	Increase network resilience. Create headroom for new demand. Much can be built offline minimising outages for existing customers	High Cost Large scope of works with potential time delays for consents/planning Long lead times for large plant items.	Preferred (only) option

Table 1.1: Summary of Considered Options

[redacted]

The proposed scheme delivers approximately 7.68MVA additional capacity, which although small for the scale of investment, does highlight the constraints of the existing network due to load growth in the preceding years. The solution is designed to be sufficient to support the network through its lifetime, therefore it will facilitate the efficient, economic, and coordinated development of our Distribution Network for Net Zero.

[redacted]

2 Investment Summary Table

The Table below provides a high-level summary of the key information relevant to this Engineering Justification Paper (EJP) and on the proposed option of reinforcing, reconfiguring, and extending the Keith 1 303 & 304 network. [redacted] Due to the single viable option available, no comparative CBA was carried out.

Name of Scheme/Programme	Keith 1 33kV Circuits	
Primary Investment Driver	Load related – voltage issues throughout the Keith 33kV network	
Scheme reference/ mechanism or category	EJP/SHEPD/KEITH1/KEITH 1 33KV CIRCUITS/PH004212	
Output reference/type	[redacted]	
Cost	[redacted]	
Delivery Year	2024/25	
Reporting Table(s)	CV1: Primary Reinforcement	
Outputs in RIIO ED2 Business Plan? (Is this expenditure in the baseline allowances? If not totally in baseline allowance identify how much is.)	Partially funded in RIIO ED2 Plan. Funding covers up to £5.58m as per the previous EJP.	
Spend Apportionment	**ED2**	**ED3+**
	[redacted]	-
MVA Released	7.68	-

3 Appendices Summary

Appendix	Summary of Contents
Appendix A	Definitions & Abbreviations
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4 Introduction

This Engineering Justification Paper (EJP) describes our proposed load related investment plan for the reinforcement of Keith 1 GSP 33kV circuits in RIIO-ED2. The primary driver considered within this paper are voltage issues caused by the application of forecast load growth under our Stakeholder supported Distribution Future Energy Scenario (DFES).

Section 5 & 6 of this Engineering Justification Paper (EJP) describes the rationale behind our proposed load related investment plan for the reinforcement of constrained 33kV circuits fed from Keith 1 GSP in in RIIO-ED2.

This EJP provides high-level background information for this proposed scheme explaining the existing network arrangements, the load growth forecasts through the Distribution Future Energy Scenarios (DFES) and setting out the need for this project. [redacted]

Sections 7 & 8 provide an exhaustive list of the options considered through the optioneering process to establish the most economic and efficient solution. Each option is described in detail, with the EJP setting out the justification for those options which are deemed unviable solutions, and therefore not taken forward to the Cost Benefit Analysis.

Finally, Section 10 of this EJP also sets out the deliverability of the plan for RIIO-ED2 and this proposed investment.

5 Existing Network Arrangements

Keith GSP is located within the Moray area of Scotland and sits within the North Caledonia region of SHEPD's licence area. This substation is supplied via 4 x 90MVA 132kV/33kV transformers split across 2 x 33kV busbars (Keith 1 & Keith 2) and supplies 24,085 customers[1] via 7x 33kV circuits and 10x Primary Substations.

The existing 33kV network configuration is shown in Figure 5.1 & Figure 5.2. This network is situated in rural Northeast Scotland with approximately 79% of the 33kV network made up of OHL. Keith 33kV circuits comprise of three closed rings and one radial feeder. GSP Interconnections are present between MacDuff, Elgin, Boat of Garten, Tarland and Kintore (Rothienorman post 2021/22).

There are currently various large elements of contracted (but not yet delivered) reinforcement on the network attributable to individual connections, which include an effective reconductoring of the entire 303/304 ring. This has been included within the model and assumed as complete for the purposes of this paper and study.

[1] Data from SIMS as of 01/09/2023

Figure 5.1: Geographic Representation of Keith 1 & 2 33kV Circuits

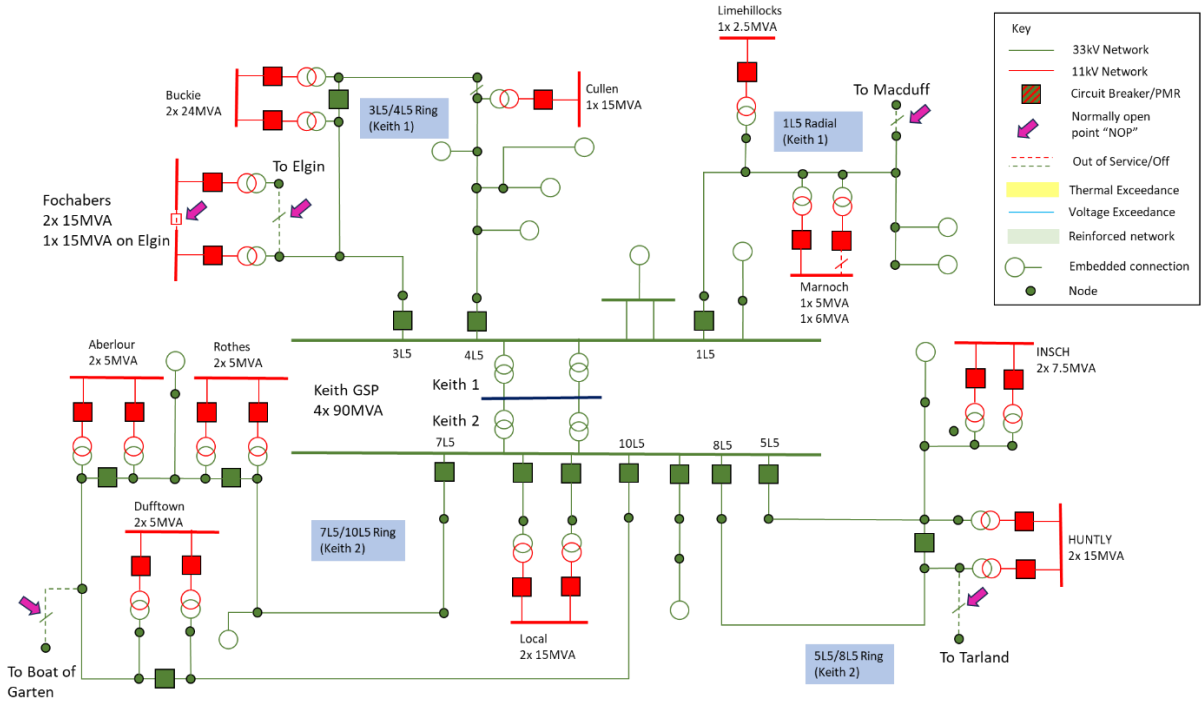


Figure 5.2: Schematic Representation of the Keith 1 & 2 33kV Network

5.1 Load Forecast for Keith 1 GSP

SHEPD have carried out extensive scenario studies through the Distribution Future Energy Scenarios (DFES) which is based on the National Grid's Future Energy Scenarios (FES) 2020 and local stakeholder input. The DFES comprises of four potential pathways for the future of energy, based on how much energy may be needed and where it might come from. The variables for the four scenarios are driven by government policy, economics and consumer attitudes related to the speed of decarbonisation and the level of decentralisation of the energy industry. SHEPD have worked closely with their partner Regen to develop the forecasts between 2020 and 2050 through enhanced engagement with the local authorities, local enterprise partnerships (LEPs), devolved governments, community energy groups and other stakeholders.

Based on the enhanced stakeholder engagement feedback, SHEPD have chosen **Consumer Transformation (CT)** as the baseline scenario for investment.

Table 5.1 and Figure 5.3 show the demand projections in MW of each primary fed from Keith 1 GSP under the CT Scenario. These forecasts show a significant step change in demand over the historically derived forecasts used within the ED1 price control.

KEITH 1 GSP Winter Max Load Forecast - DFES Consumer Transformation Scenario (MW)

	ED2						ED3					Future	
Substation	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2035**	**2050**
BUCKIE	12.31	14.41	14.77	15.23	16.19	17.28	18.38	19.31	20.29	21.38	22.58	24.59	29.59
CULLEN	2.38	2.51	2.58	2.67	2.92	3.17	3.44	3.73	3.99	4.27	4.58	5.17	7.17
FOCHABERS (T1)	3.57	3.68	3.72	3.80	3.95	4.17	4.94	5.79	6.10	6.47	6.89	7.71	8.44
LIMEHILLOCKS	1.52	1.76	1.81	1.87	1.98	2.11	2.29	2.48	2.61	2.70	2.81	3.01	3.84
MARNOCH	2.31	3.00	3.10	3.21	3.44	3.68	3.93	4.19	4.42	4.59	4.77	5.09	5.89
ACCEPTANCES > 1MVA	148.46	148.46	148.46	148.46	148.46	148.46	148.46	148.46	148.46	148.46	148.46	148.46	148.46
TOTAL KEITH 1 GSP	**170.55**	**173.82**	**174.44**	**175.25**	**176.94**	**178.87**	**181.44**	**183.95**	**185.86**	**187.86**	**190.09**	**194.04**	**203.39**

From analysis 55% of Fochabers Primary is supplied from Keith GSP and 45% on Elgin GSP

2023 data taken from existing Load Estimates – actual measured data for the Keith network in 22/23

Acceptances Data extracted from PROMIS - see NRN Related Excel file in Modelling folder.

Table 5.1: Winter Peak Load Forecast for Keith 1 - From DFES 2022 CT Scenario Data

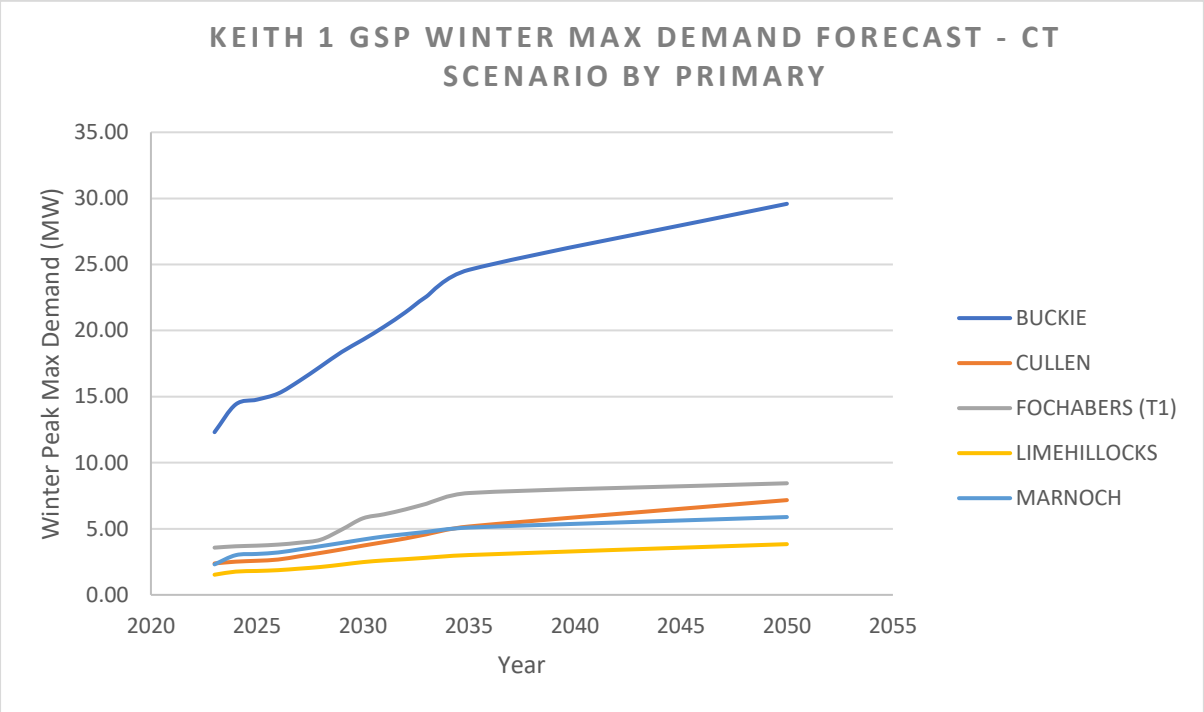


Figure 5.3: Keith 1: Winter Peak Demand Forecast by Primary (CT Scenario)

The baseline 2022/23 peak demand for Keith 1 is 22.09MW. Contracted demand connections that are yet to be commissioned > 1MVA total at 148.46MW, which includes G99 Battery Storage connections.

Diversified peak demand (excluding acceptances) is expected to increase at Keith 1 GSP by approximately 8.32MW to 30.41MW in the period from 2022/23 to the end of ED2 in 2027/28 according to the DFES CT scenario.

Figure 5.4 shows a closer look at the forecast demand against each individual primary and the rating of the existing primary transformers. None of the primary transformers connected to Keith 1 GSP show their capacity being exceeded within the ED2 price control. However, forecasts show that load growth will exceed primary transformer ratings at Buckie in 2035; Limehillocks in 2041; and Fochabers in 2046.

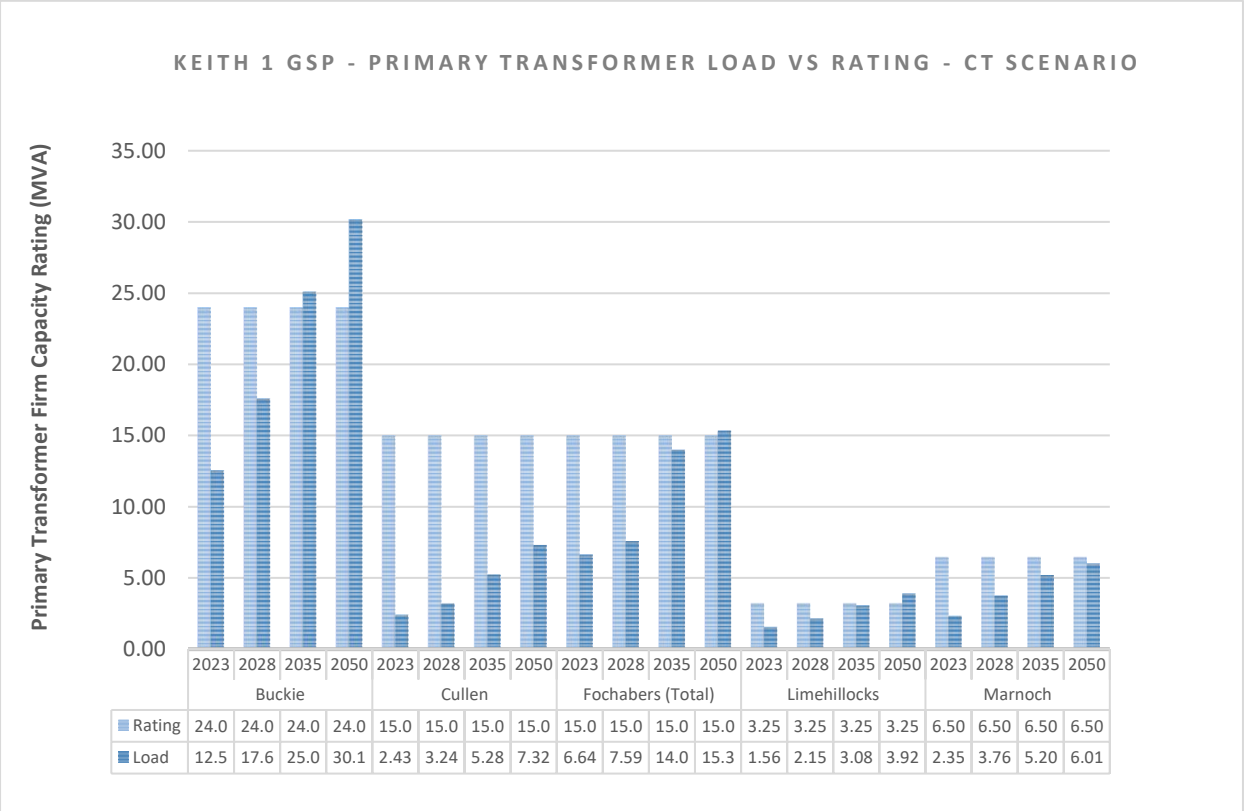


Figure 5.4: Keith 1 Primary Transformer Rating vs Forecast Load (CT Scenario)

5.2 Generation Forecast for Keith 1 GSP

There is currently 90.71MW of generation connected to the Keith 1 33kV network, with a further 195.82MW contracted to connect (see Appendix B). All of this contracted at 33kV with dedicated feeds from the Keith 1 GSP.

The existing 90.71MW of connected generation is predominantly onshore wind and a mixture of other technologies including Gas, CHP and Anaerobic Digestion with very little Hydro or PV connected in the area.

The DFES 2022 data for generation growth under the CT scenario at the primaries connected to Keith 1 show a small amount of growth across ED2 and out to 2050, albeit mostly resulting in net demands on the primary substations for summer peak generation/minimum demand conditions (see Table 5.2). Limehillocks and Marnoch are the exceptions here, however, the scale of generation growth (0.8MW and 0.6MW respectively) is well within the capability of the existing primary transformers and 33kV 301 feeder.

KEITH GSP Generation Growth by Primary – DFES 2022 CT Scenario (MW)
These are net figures, so a negative represents net demand

	ED2						ED3					
Substation	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2035**
BUCKIE	-9.50	-9.50	-9.50	-9.40	-9.30	-9.20	-9.10	-9.10	-9.00	-8.90	-8.80	-8.80
CULLEN	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-1.00	-0.90	-0.90	-0.90
FOCHABERS (T1)	-1.43	-1.43	-1.43	-1.43	-1.43	-1.43	-1.43	-1.43	-1.43	-1.38	-1.38	-1.38
LIMEHILLOCKS	0.30	0.40	0.40	0.50	0.60	0.70	0.80	0.80	0.90	1.00	1.00	1.10
MARNOCH	1.20	1.20	1.20	1.30	1.30	1.40	1.40	1.50	1.50	1.60	1.70	1.80
TOTAL KEITH 1 GSP	**-10.43**	**-10.33**	**-10.33**	**-10.03**	**-9.83**	**-9.53**	**-9.33**	**-9.23**	**-9.03**	**-8.58**	**-8.38**	**-8.18**
ABERLOUR	-1.50	-1.50	-1.50	-1.40	-1.40	-1.40	-1.40	-1.40	-1.40	-1.40	-1.40	-1.40
DUFFTOWN	-3.80	-3.70	-3.70	-3.50	-3.40	-3.30	-3.20	-3.10	-3.00	-2.90	-2.90	-2.80
HUNTLY	-3.00	-2.90	-2.90	-2.80	-2.70	-2.60	-2.60	-2.50	-2.40	-2.40	-2.30	-2.30
KEITH	-4.20	-4.10	-4.10	-4.00	-4.00	-3.90	-3.90	-3.80	-3.70	-3.70	-3.70	-3.70
ROTHES	-1.30	-1.20	-1.20	-1.20	-1.20	-1.20	-1.20	-1.20	-1.20	-1.20	-1.20	-1.20
TOTAL KEITH 2 GSP	**-13.80**	**-13.40**	**-13.40**	**-12.90**	**-12.70**	**-12.40**	**-12.30**	**-12.00**	**-11.70**	**-11.60**	**-11.50**	**-11.40**
TOTAL KEITH GSP	**-24.23**	**-23.73**	**-23.73**	**-22.93**	**-22.53**	**-21.93**	**-21.63**	**-21.23**	**-20.73**	**-20.18**	**-19.88**	**-19.58**

From analysis 55% of Fochabers Primary is supplied from Keith GSP and 45% on Elgin GSP
Insch assumed to be fed from Rothienorman so removed

Table 5.2: Generation Growth by Primary for Keith 1 GSP - DFES 2022 Data CT Scenario

With small growth in generation and mostly net minimum demands showing on the primaries supplied by Keith 1 GSP, it has been determined that no assessment of the impact of DFES generation growth is required. Any individual generator connections have/will include specific attributable reinforcement and the impact of worst-case demand has been studied as part of the forecast load growth assessment.

5.3 Existing Asset Conditions

Keith 33kV circuits 303, 304, 307 and 310 have been checked against proposed interventions for non-load related drivers during RIIO ED2. This includes:

1. All conductors and associated equipment.
2. All switchgear and auxiliary equipment on the circuits and at connected primary substations.
3. Transformers and auxiliary equipment at connected primary substations.

This primarily relates to the condition and criticality of each asset as tracked by SSEN's Condition Based Risk Management INVEST system.

The CBRM models maintained by SSEN provides a Health, Criticality, and Risk score for each individual asset. The risk score (asset health and criticality) is a key metric that will trigger a need for investment into this asset category. This is calculated using a variety of asset-specific data which includes basic parameters in addition to the observed and measured condition of each asset.

From cross checking the INVEST data with the circuits showing voltage constraints, approximately 36 OHL poles are proposed to be replaced during ED2 period on the relevant circuits. Whilst this information may not directly lead to savings in load or non-load investment, it will create efficiencies in outage planning and minimise customer disruption if linked with the reinforcement within this report.

[redacted]

[redacted]

5.4 Existing Operational Issues

Regional stakeholder engagement was carried out, including representatives from regional and large capital design, delivery, consenting, protection, and asset management.

No operational issues regarding existing assets related to Keith 1 have been identified by stakeholders. However, the issue of space within the Keith 1 & 2 33kV switch room was highlighted. There is limited space for new breakers at present, but recent cancellations of contracted large 33kV connected demand and generation projects have meant that there is now existing space for one 33kV breaker on the GT1 side of the Keith 1 board.

6 Network Analysis Summary

6.1 Winter Max Load Flow (Thermal & Voltage) Assessment Results

Using the DFES 2022 CT Scenario winter peak data, a full winter maximum load flow and fault level study of the Keith 1 network has been undertaken in PSSE for the following load forecast years:

- 2023
- 2028 (End of ED2)
- 2035

Please note that 2050 was not studied as constraints were found to be so comprehensive in 2035, modelling would not accurately reflect network conditions with 2050 loads applied.

The study was based on various assumptions as outlined in Table 6.1.

Assumption	Type
Voltage Limits: Normal Running Arrangements: 0.940 – 1.012pu for networks with 33kV/LV connections 0.940 – 1.03pu for clean 33kV networks N-1 Conditions: 0.9 – 1.012pu for networks with 33kV/LV connections 0.9 – 1.03pu for clean 33kV networks	Technical threshold for study
All reinforcement under EKC684 & EXF768 on 3L5/4L5 is complete	Dependency
Existing Auto Change Over schemes at Fochabers and Cullen remain unchanged	Dependency

Table 6.1: Winter Max Power Systems (PSSE) Study Assumptions

Following completion of network analysis, Table 6.2 details the following constraints that have been identified that are forecast to present on the network before the end of the current ED2 price control period in 2028. These constraints will require intervention as the voltage is below statutory limits as outlined in the ESQCR regulations.

Schematic indications of the locations of the constraints can be seen in Figure 6.1 and Figure 6.2, while extracts of the results for the constrained circuits can be viewed in Appendix D.

Circuit/GSP:	Scenario	[redacted]
Keith 1 304/4L5	N-1 Loss of Keith 1 303/3L5 and Buckie T1	[redacted] [redacted] This doesn't directly impact customers as the tap changers at Buckie Primary rectify the issue for voltage on the 11kV bus, and there are no 33kV/LV connected customers at points on the 304/4L5 feeder with low voltages.

Keith 1 303/3L5	N-1 Loss of Keith 1 304/4L5 and Buckie T2	[redacted] [redacted] This doesn't directly impact customers as the tap changers at Buckie Primary rectify the issue for voltage on the 11kV bus, and there are no 33kV/LV connected customers at points on the 303/3L5 feeder with low voltages.

Table 6.2: Identified Constraints from Winter Max Load Flow Analysis - Keith 1 DFES 2028 CT

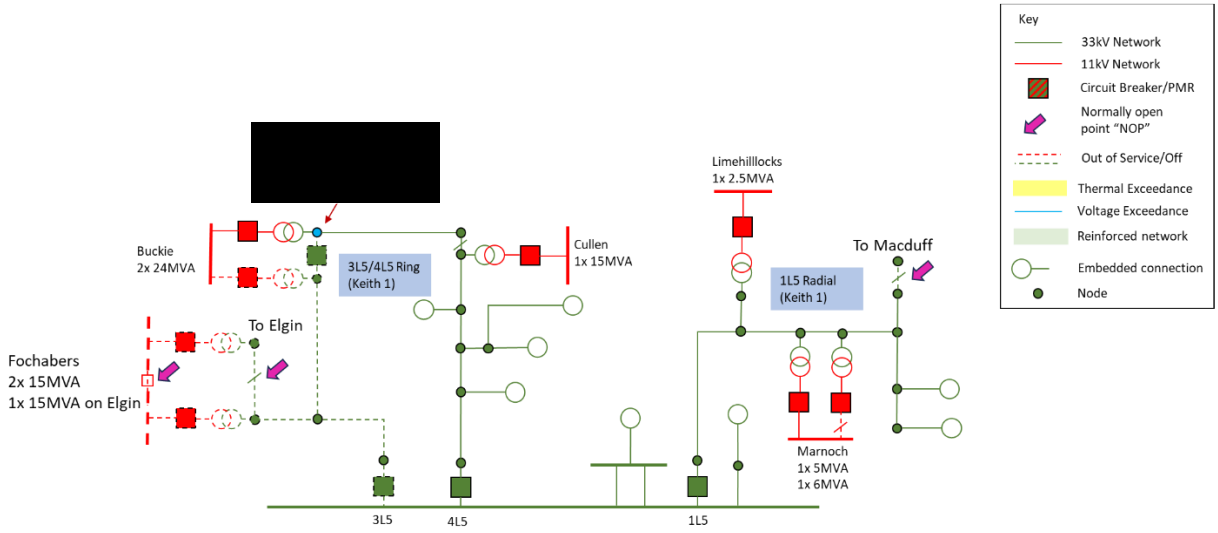


Figure 6.1: PSSE Winter Max 2028 DFES CT Load Flow Results - Scenario: Loss of Keith 1 303/3L5

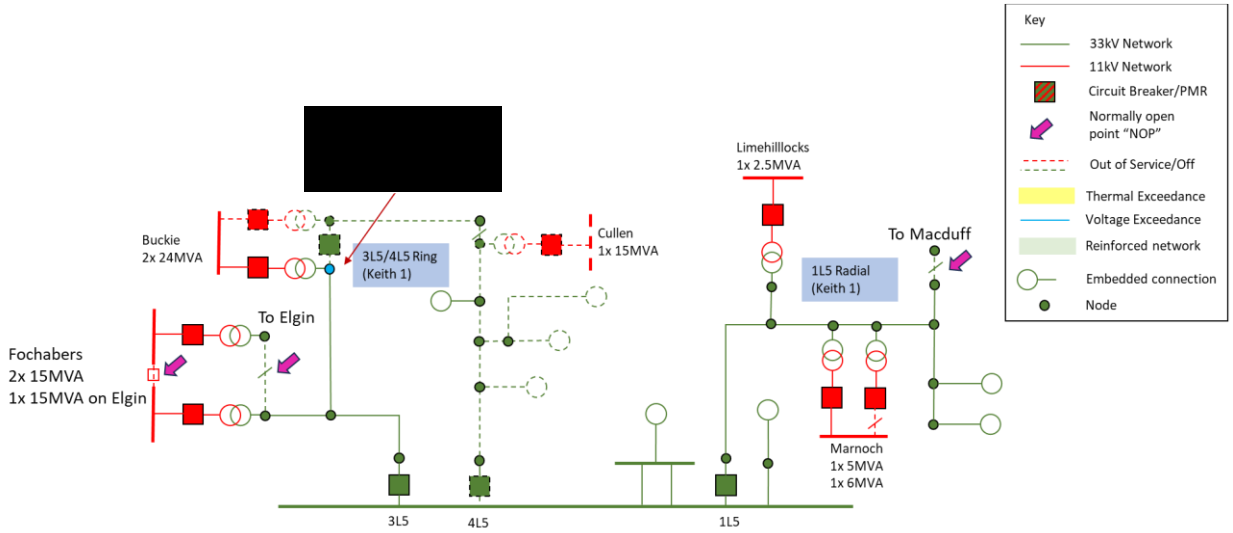


Figure 6.2: PSSE Winter Max 2028 DFES CT Load Flow Results - Scenario: Loss of Keith 1 304/4L5

6.1.1 Fault Level Analysis

There are no fault level issues on the Keith GSP network when considering 2027/28 maximum demand and maximum generation conditions. Fault Level results are detailed in Table 6.3.

Max 3 Phase/Earth Fault Level (All gen & demand operating @ rated output)		**Voltage**	**Make Rating (kA)**	**Current I_p (kA)**	**CB Break Rating (kA)**	**I_b(sym) @ 60ms (kA)**	**% Make**	**% Break**	**Comments**
15430	KEIT3- 33.000	33	63.0	43.82	25.0	13.010	69.55%	52.04%	Marnoch 33kV outdoor bus and MAINS OF CRANNA B086_L and FORGLEN B085_L Air Brakes to be designated Orange Triangle as part of existing connection works. Rest of network within asset ratings. Maximo ratings used where possible, but many make ratings not available. Where make ratings not available an assumption of 2.5 x the break rating has been used.
83640	CULLEN3A 33.000	33	63.0	10.28	25.0	4.385	16.32%	17.54%	
83646	BUCKIE3B 33.000	33	63.0	9.12	25.0	4.014	14.47%	16.05%	
83652	MARNOC3A 33.000	33	63.0	5.16	10.0	2.138	20.64%	21.38%	
83641	CULLEN1A 11.000	11	50.0	9.89	20.0	3.762	19.78%	18.81%	
83645	BUCKIE1A 11.000	11	33.4	16.82	13.1	7.142	50.36%	54.52%	
83661	FOCHAB1A 11.000	11	22.2	7.26	8.7	3.273	32.74%	37.62%	
83651	LIMEHI1A 11.000	11	31.3	4.26	12.5	1.723	13.62%	13.79%	
83653	MARNOC1A 11.000	11	33.4	7.34	13.1	2.920	21.97%	22.29%	

Table 6.3: Max Fault Level Results for Keith 1 GSP - 2022 DFES 2028 CT Scenario

6.1.2 Summary

In summary, the forecast increased level of demand on the Keith 1 33kV network will cause non-compliance voltage issues in ED2 with the existing network arrangement/assets and capacity.

The need for the network reinforcement works is apparent in ED2 to ensure the network voltage remains compliant.

6.2 Regional Stakeholder Engagement

6.2.1 Contracted Background

Keith 1 GSP has received a high number of applications for large generation & storage projects with various battery sites now contracted to connect at 33kV via direct feeds from dedicated circuit breakers on the existing 33kV switchboard. This includes ~99MW of battery storage and 17MW of onshore wind.

There are currently various large elements of contracted (but not yet delivered) reinforcement on the Keith 1 network attributable to individual connections, which include an effective reconductoring of the entire 303/304 ring. This has been included within the model and assumed as complete for the purposes of this paper and study.

It is likely that work to be carried out under the preferred option of this paper will supersede and/or enhance the programmed work for connections reinforcement. Should this be the case, any apportioned customer payments towards this reinforcement will contribute toward the full cost of the preferred option. The details of the connections and reinforcement already specified are below.

[redacted]

6.2.2 Large Connection Impacts

A prospective development that will impact both Keith 1 and Keith 2 33kV networks is the electrification of distilleries in the area. [redacted]

[redacted]

[redacted]

At this stage the proposal is to be assessed under a feasibility study, with only pre-application meetings having been carried out. Without contracted applications SHEPD cannot be 100% certain that this requirement will materialise, and thus cannot include them in any assessment to rectify the voltage issues identified on the 303/304 ring. However, should they contract, the increase in loading will have a large impact on the development of the 33kV circuits in the area.

The likelihood of these connections proceeding remains high as the electrification is driven through regulatory requirements to decarbonise.

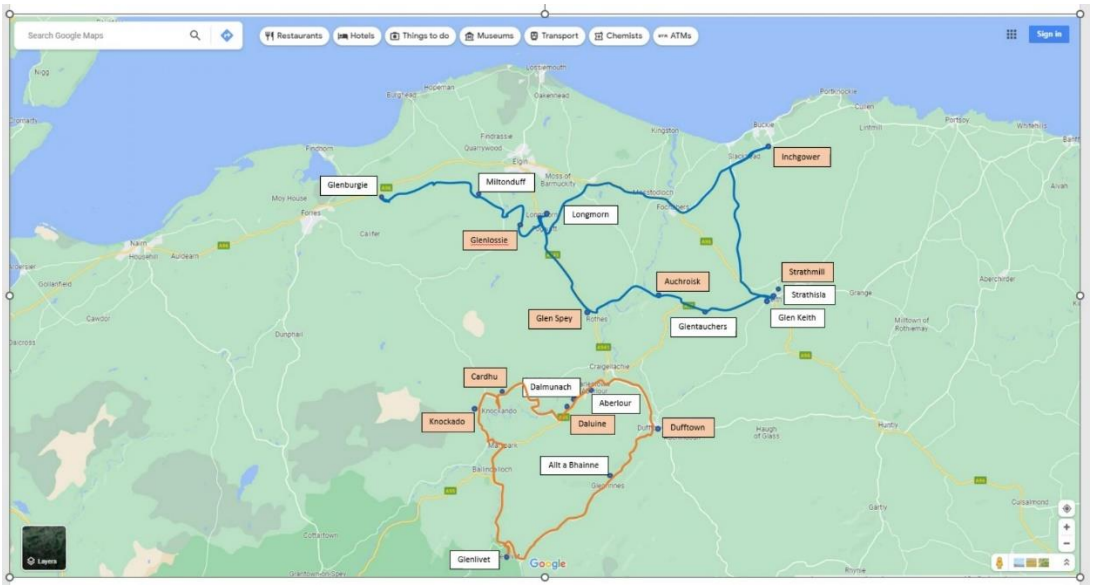


Figure 6.3: Geographic Location of Distilleries to be Electrified with 33kV Supplies.

6.2.3 Local Authority Plans

SSEN has strong working relationships with local authorities and other key stakeholders in the region. We have met with Aberdeenshire and Moray Councils to discuss local area energy planning and have engaged with Scottish Government's LHEES Forum, Community Energy Scotland, Transport Scotland, and the Scottish Futures Trust. This engagement has helped SSEN to stay informed about planning and development that will impact local communities' use of the network.

Aberdeenshire Council aims to reach net zero by 2045 in alignment with national targets. The Council continues expanding the electric vehicle charging network across the region and assessing feasibility for heat pumps, solar PV, and battery storage installations on council-owned buildings. Grants for air source heat pumps are available through March 2026 to residents across rural Aberdeenshire whose properties are oil- or LPG-heated. Their 2023 Local Development Plan states that there should be one electric vehicle charge point per 25 employees in workplace parking sites.

Moray Council plans for council operations to reach net zero by 2030. In February 2023, the Council announced plans to expand the charge point network across the area. Moray Council is also looking into opportunities to decarbonise heating, including applying for funding through the Public Sector Heat Decarbonisation Fund.

6.3 Flexible Market Viability

The constraints on the 303/304 Keith 1 ring are all due to low voltages on the 33kV network and are located at the extremity of the ring nearly 30km from Keith 1 GSP. There are batteries connecting directly at 33kV to Keith 1 that theoretically could provide reactive power support, however, these are not embedded, have their own sole use circuits, and are all located far away from the identified constraints. As reactive power needs to be closely located to the low voltage area to be effective these have been discounted from being able to be used to support the low voltage issues in this case.

The closed ring configuration of the circuits means there are numerous outage scenarios which would need to be covered by any flexibility service procured for voltage support. As direct reactive power support has been excluded due to lack of available assets, voltage support would have to be achieved through reduction in active power. The users of this network are primarily residential and combining these with the closed ring configuration and giving clearly requirements to individual households is expected to be challenging. The complexities involved with contracting, monitoring and dispatching services for these scenarios, along with the limited capacity of viable non-intermittent generation within close proximity to on the circuits mean that flexibility is not a viable option for the identified constraint.

6.4 Confidence Table

Confidence Factor	Certainty (High, Medium, Low)	Comments
Load Forecast	Medium	Load forecast is in keeping with historical trends and is assumed to account for contracted commercial background. However, there is some doubt as to the scale of inclusion for distilleries in the area.
Existing Asset Condition	High	Thorough engagement carried out with asset health teams.
Existing Operational Issues	High	Thorough engagement carried out with operational teams.
Connections Activity	High	Load forecast is in keeping with historical trends and accounts for contracted commercial background.
Regional Stakeholder engagement	Medium	Unsure if distilleries in area have been included in forecasting, however, recent engagement has been undertaken through connections work.
Flexible market Viability	High	The constraints on the 303/304 Keith 1 ring are all due to low voltages on the 33kV network. As such no flexibility market options are available/viable for this particular circuit configuration.
Funding Position	High	The upgrade was proposed to be delivered through ED2 and covered through the previous ED2 submission EJP.

7 Summary of Options Considered

7.1 Summary of Options

This section of the report sets out the investment options that are considered to resolve the forecast voltage issues on the Keith 1 303/304 33kV network. The table below provides a high-level summary of the seven investment options under consideration along with the advantages and disadvantages associated with each one. A more detailed description of each option is then provided within the proceeding sub-sections.

Option	Description	NPV	Year of Associated Costs	Advantages	Disadvantages	Results
1. Do Nothing	Do nothing to the existing network	N/A	N/A	Low cost and workload	303/304 33kV circuits remain non-compliant	Not viable – [redacted]
2. Flexibility Solution or Curtailment	Not viable	N/A	N/A	N/A	N/A	[redacted] Flexibility is not viable due to lack of reactive power providers and network configuration
3. Load Transfer	Load Transfer & Monitor demand development	N/A	N/A	Low cost and workload.	Not possible without reinforcement	Not viable – [redacted] ant network
4. Reinforcement of Existing 303/304 Circuits	Reinforce to lower impedance of conductor in ED2.	N/A	N/A	Increase network resilience. Create headroom for new demand.	[redacted] No options for larger capacity conductors [redacted]	Not viable – [redacted]
5. Network Extension: New Primary at Buckie	Run two new circuits to Buckie and establish a new primary substation to support half of the load from Buckie	N/A	N/A	Increase network resilience. Create headroom for new demand. Provide additional support for the 11kV network in Buckie.	[redacted]	Considered but not progressed.

6. Do Minimum	Establish a new Buckie primary site and install two 2.5MVar Statcoms to either side of the new 33kV switchboard	N/A	N/A	Low cost to achieve compliant volts for 2028. Can be built offline minimising outages for existing customers	Interim solution only [redacted]	Not viable – [redacted]
7. Combination of Reconfiguration, Network Extension and Reinforcing Existing Assets	Reconfigure network with new circuit to Buckie, shed Cullen from ring and reinforce existing circuits	£9.51m	24/25	Increase network resilience. Create headroom for new demand. Much can be built offline minimising outages for existing customers	High Cost Large scope of works with potential time delays for consents/planning Long lead times for large plant items.	Preferred (only) option

7.2 Options comparison tables

C0(a) Costs of recommended option as per ED2 submission.

Recommended Option		Investment Driver	Total Cost (£m)	C0(a) costs (£)					
				2023	2024	2025	2026	2027	2028
6	Combination of Reconfiguration, Network Extension and Reinforcing Existing Assets	CV1							
		Load Triggered Capital Reinforcement	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

C0(b) Costs for recommended as per ED2 submission adjusted for RPI to 23/24 Price Base

Recommended Option		Investment Driver	Total Cost (£m)	C0(b) costs (£)					
				2023	2024	2025	2026	2027	2028
6	Combination of Reconfiguration, Network Extension and Reinforcing Existing Assets	CV1							
		Load Triggered Capital Reinforcement	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

8 Detailed Option Analysis

The voltage issues on the 303 and 304 circuits are triggered by the increase in demands at all the primary substations on the ring under winter maximum demand conditions. [redacted] The below provides a high-level summary of options considered to rectify the voltage issues.

8.1 Option 1: Do Nothing

If no changes, flexibility, or other interventions are introduced to the Keith 1 303/304 ring, studies have shown that SHEPD will be in breach of ESQCR for compliant voltage requirements. Under peak winter loads in 2028 projected under the 2022 DFES, this will have multiple implications including:

- Quality of supply to customers will be impacted for any outages on 303/304.
- Mandatory security of supply obligations breached.
- Potential for voltage complaints from existing customers due to a deterioration in the quality of supply.
- Limited capacity available for new connections endangering customer relations and the ability to support economic growth and net zero targets.

Due to the regulatory implications and potential impact on customers, this option is deemed unacceptable and will not be carried forward.

8.2 Option 2: Flexible Solution or Curtailment

This option requires securing flexibility services to reduce peak demand to defer or remove the need for reinforcement of existing assets. The constraints on the 303/304 Keith 1 ring are all due to low voltages on the 33kV network and are located at the extremity of the ring nearly 30km from Keith 1 GSP. There are batteries connecting directly at 33kV to Keith 1 that theoretically could provide reactive power support, however, these are not embedded, have their own sole use circuits, and are all located far away from the identified constraints. As reactive power needs to be closely located to the low voltage area to be effective these have been discounted from being able to be used to support the low voltage issues in this case.

The closed ring configuration of the circuits means there are numerous outage scenarios which would need to be covered by any flexibility service procured for voltage support. The complexities involved with contracting, monitoring and dispatching services for these scenarios, along with the limited capacity of viable non-intermittent generation within close proximity to on the circuits mean that flexibility is not a viable option. This option is therefore excluded an not taken through to CBA.

8.3 Option 3: Load Transfer

The network was assessed to see if voltage issues could be mitigated by transferring some load under the following N-1 conditions:

8.3.1 Loss of 303 (trip at 3L5)

[redacted]

Normally, in this scenario Cullen Primary remains connected to the 304 circuit. [redacted]

[redacted]

The load transfer option investigated requires the identical switching and back feed from Portsoy on the 11kV carried out for a loss of 303 as well as 304. [redacted]

8.3.2 Loss of 304 (trip at 4L5)

[redacted]

8.4 Option 4: Reinforcement of Existing Assets

For this option the network was studied with requirement for new conductors that are suitable for 2050 DFES CT loading.

8.4.1 Keith 1 303

- Replace existing (and supersede contracted reinforcement from connections) 15km of overhead conductors with 3 x 630sqm Cu singles from the 3L5 breaker to pole 55 (largest length of cable before reactor required to compensate for charging currents).
- Replace 10.5km of overhead conductor with 400sqmm Al from pole 242 to Fochabers Primary.

These reinforcements fix voltage issues (0.919pu @ Buckie 33kV bus), but still result in thermal overloads (112% of 40.4MVA) for sections of the 630sqm Cu cable that is derated for proximity. This is the largest cable available to us for thermal rating and practically terminating cables into circuit breakers.

8.4.2 Keith 1 304

- 10.5km of 630sqmm Cu derated for proximity from the 4L5 breaker to pole 95. This section is currently overhead line and is due to be reinforced to 400sqmm Al XLPE as part of proposed works for a new generator connection. This proposal would supersede these works. 630Cu is the largest cable available to us for thermal rating and practically terminating cables into circuit breaker terminations.
- 15.5km of 150sqmm HDCu built from pole 95 to Cullen TR1, and then from Cullen to Buckie TR2. This is the largest copper conductor available before underground cable is required.

For the scenario of a Loss of 303, no conductor can support 2050 loads without voltages dipping to critical levels (0.6pu at Buckie) and conductors thermally overloaded with the 10.5km run of the largest conductor available 165% overloaded (see 0).

With the largest conductors available being unable to support 2050 loads and fix the voltage issues in the current network configuration, reinforcement of existing assets alone is deemed not viable, and this solution will not be progressed to the CBA.

8.5 Option 5: Establish a New Second Primary in Buckie

Given that the main issue causing the voltage constraint is the load growth at Buckie Primary substation, consideration was given to establishing a second Primary substation in or around Buckie. The scope of works for this would include running two new circuits for approximately 20km from two new circuit breakers on the Keith 1 33kV board and terminating them at a newly established primary compound, with suitably rated switchgear and transformers. It would then also require assessment and interconnection of the Buckie 11kV circuits with new feeders from the new Primary in order to shed load from the existing 11kV network and thus Keith 1 303/304. This would mean at least two new 11kV circuits to be built out around the Buckie area.

At present, Keith 1 GSP is limited for space with only one spare circuit breaker available after current large connections contracted with both Distribution and Transmission are considered. Furthermore, following recent detailed design work carried out for large generator connections, including site visits, it is understood that space on the SHET owned Keith super grid compound is limited and surrounding land has been secured by the large generation projects. This has made an extension/relocation of the switch room unfeasible for existing projects, but furthermore would mean that the entire 33kV Keith 1 & 2 Switchroom and board would need to be replaced and relocated to reconnect all feeders and existing directly connected generators.

Given that this option would require a new Primary, two new 20km 33kV circuits from Keith to Buckie, new 11kV circuits built out from the new Primary, and the complete relocation and replacement of the Keith 1 & 2 GSP Switchgear, this option would much more expensive than other options. Additionally, with no space for two new circuit breakers available, and extension/relocation of the switch room at Keith GSP not possible, this option has been deemed not viable a will not be progressed to CBA.

8.6 Option 6: Do Minimum – Relocate Buckie Primary & Install 2 Statcoms

This option involves reactive compensation and voltage control by installing two 2.5MVar Statcoms onto the 33kV board at Buckie Primary. Two are needed as non-compliant volts are seen on either side of the 33kV bus at Buckie, for a loss of either 303/T1 or 304/T2. As such each one would be installed via a dedicated circuit breaker at each end of the busbar.

Due to space and access restrictions at the Buckie Primary substation compound, a new site would be needed to accommodate the two Statcoms and new 33kV switchgear. If this is the case, given the age and condition of the existing primary transformers and 11kV switchgear [redacted] and to save outages, an offline build would be undertaken which would replace all the primary plant.

From initial modelling this option does indeed fix the voltage compliance issues out to 2028 loading. [redacted]

However, with 2035 loads applied, for all outage scenarios the entire mainline of the ring is thermally overloaded, making the network non P2/8 compliant - See Figure 8.1. As such, scheduled reinforcement works on the entire 303/304 ring as part of contracted connections will leave stranded assets by 2035 and will require further intervention in the future.

Given it will only fix voltage issues on the network out until 2028, and the fact that Option 4 has shown that there are no options for reinforcement that can support loads out to 2050, this option would mean that existing contracted connections reinforcement under [redacted] will end up leaving stranded assets and would ultimately be superseded by further work and spend in the following price controls. For this reason this option has been eliminated from further progression.

8.7 Option 7: Combination of Reconfiguration, Network Extension and Reinforcing Existing Assets

For this option the network was studied with an intervention combining reinforcement of existing conductors on 303/304, the relocation of Buckie Primary to allow for space/access requirements, and a new second circuit built from Keith Grid to the new Primary site. The proposed configuration can be seen in Figure 8.2 and the following sections describe the scope of works in more detail.

[redacted]

8.7.1 Dismantlement

- Dismantle/abandon all (approx. 6.2km) 33kV OHL and cable between Pole 242 and Keith 1 3L5 (see Figure 8.3 below).

[redacted]

8.7.2 Reinforcing Existing Assets: 303 Conductors

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

8.7.3 Network Extension/Reconfiguration

[redacted]

Furthermore, the access to the site is via a small lane between residential housing, or a residential street with very tight turning, which could provide issues in delivering large plant to the compound. A bird's eye view of Buckie Primary showing the existing site is provided in Figure 8.7.

[redacted]

These issues were confirmed via consultation with the regional and Large Capital Delivery engineering design teams, who also raised other issues including:

- [redacted]
- Outages and how the build is undertaken while minimising planned customer interruptions – a phased approach would be required with an offline build of the 33kV Switchroom, [redacted]
- With a phased approach to the outages, issues concerning the use of cranes with live outdoor 33kV bars.

With these issues in mind, it is likely that Buckie Primary [redacted]. This requirement has been included in the design works and costing under this option, [redacted]

[redacted] given the age and condition of the existing primary transformers and 11kV switchgear [redacted] and to save outages, an offline build would be undertaken which would replace all the primary plant. This would also ensure that the primary transformers at Buckie are suitably sized at 20/40MVA to handle the projected 2050 loading, with their upgrade required in 2035 as per current DFES CT projections. The works involved [redacted] would include:

- Survey & design works
- [redacted]
- Civils to establish [redacted] primary compound/fencing
- Building for 33kV and 11kV switch room [redacted]
- 2 x new 20/40MVA CER 33/11kV transformers
- 2 x NERs

- 12 x 630A AIS 11kV Circuit Breakers
- RTU & Site Comms
- Furniture, padlocks, site signage, labelling
- Post construction surveys and final records
- Commissioning (internal protection)
- [redacted]

[redacted]

[redacted]

8.7.3.5 Protection & Commissioning – Update ACO Scheme at Fochabers

Carry out protection commissioning and review for the new Primary at Buckie and new/reconfigured breakers at Keith 1.

8.7.4 Updates to Contracted Connections Work

The following scope changes to the reinforcement contracted under [redacted] would be required:

[redacted]

[redacted] [redacted]

[redacted]

Using the PROMIS cost summary (Appendix H), the existing costs towards the elements of the contracted reinforcement that will be superseded or abandoned were derived. These are provided in Table 8.2 and will be deducted from the final costs for this option.

[redacted]

8.7.5 Modelling Results

Network modelling has been carried out to ensure that this proposed solution is compliant and fit for purpose out to 2028, and that assets installed will be suitable for projected 2050 loading. The results of these studies can be found in supporting information, however, examples of compliant 'worst case' outage scenarios have been provided in Appendix IAppendix H. Table 8.3 provides a summary of the MVA released by the intervention of works in Option 7.

Year of Study	Worst Case Outage	Network Capacity (MVA)
2023 (Baseline)	Loss of 304 & Buckie T2	24.59
2028 (Option 7)	Loss of New Circuit & Buckie T2	32.27
	MVA Released	7.68

Table 8.3: MVA Released for Option 7

The scale of the capacity released reflects the nature of the current constraints on the network with load growth in the preceding years and high impedances due to the distance of both Fochabers and Buckie from Keith and Elgin GSPs.

8.7.6 Costs

Costs for the work have been provided below using available unit cost rates only.

9 Cost Benefit Analysis (CBA)

Only one viable option for progression so a CBA was carried out, albeit with no comparison. This has been conducted with a pre-specified discount rate of 3% as per the latest HMRC Green Book parameters, and a pre-tax WACC of 3.9%. The results on NPV are given in [redacted]

Options	CBA Results (NPV) in £m				
	10 years	20 years	30 years	45 years	Whole Life NPV
Option 7 - Network extension, reinforcement and reconfiguration	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

10 Deliverability and Risk

Based on the assessments and studies above on Keith 1 33kV Circuits load-related reinforcement, at this stage of design the preferred solution has been prepared and engineered to ensure it is deliverable, meets the customer needs.

Investment Planning	2023/24	2024/25	2025/26	2026/27	2027/28
33kV Reinforcement		X	X	X	X
Assets	Consents, Design and Surveys	Buildings, Procurement and Construction	Buildings and Construction	Building and Construction	Finalization and Energization

In terms of project-specific risks and deliverability considerations:

- Tight project delivery timelines as consenting, design and procurement may take longer than expected.
- Complications and delays to be considered for the proposed new site at Buckie Primary
- Adequate planning for space and assets at the detailed design phase
- Interactivity should be checked with nearby works to ensure minimal disruption and maximum efficiency.
- Finances are to be cross-checked as per differences between C0 and C1 costs due to inflation and RPE and this should be captured at later stages when C2 cost will be derived.

Further risk and deliverability will be assessed during Design refinement and detailed Design.

11 Outlook to 2050

Keith1 is subject to mandated load scheduling under the DCUSA Schedule 8, Load Managed Areas (LMAs), regulations is currently delivered by the legacy Radio Tele Switching (RTS) system and its Smart meter-based successor.
The move to a Smart meter-based solution for providing LMA based diversity does not, on its own, provide a solution that is compatible with the development of domestic flexibility markets. Consequently, and in the spirit of a Smart and Fair transition, SSEN have committed to removing LMAs during ED2 and ED3.
Three methods used to remove LMAs include:

- Ensuring that any reinforcements driven by LCT growth are sized to ensure that they are not a driver for the continuation of an LMA.
- Improving network monitoring to allow the reduction of the scale of existing LMAs.
- Introducing a new market-based replacement for LMAs, this is expected to take the form of a diversity service.

The geographical area covered by this project is an LMA and as a result we have undertaken checks to ensure that the reinforcement will result in us being able to remove relevant LMA constraints.

Load managed domestic properties in the area account for approx. 5.9% of all customers.
The reinforcement is sufficiently large to allow the immediate removal of relevant LMAs and will remain unrestricted until we are able to offer a future market-based Diversity service or equivalent.

At this stage, the effect of RTS signal discontinuation on LMA areas is only a prediction and at each location may differ from what is stated in this report. Regardless, the options proposed in this paper should provide adequate solutions to any reasonable LMA-related increased demand.
It should be noted that the impact of LMA on the LV network has not been considered here and would require to be assessed separately.

The recommended option provides a solution with the load growth predicted for 2050 in mind, ensuring that any assets installed can support projected DFES loads.

Modelling out to 2050 has identified the following issues:

- Voltage non-compliance at Fochabers
- P2/8 non-compliance with 11kV back feeds not able to support the load growth at Cullen Primary.

Rectifying these constraints will be subject to a future EJP for a future price control business plan that can build on the network designed within this paper.

12 Conclusion and Recommendation

This Engineering Justification Paper provides relevant information on Keith 1 33kV Circuits in terms of necessary load-related investment within the RIIO - ED2 price control period.

[redacted] This paper provides options engineering with the help of stakeholder engagement and a whole system approach. As the constraints are voltage related on the 33kV network, an assessment of the potential ability of flexibility to delay intervention using the CEM tool was not possible.

Due to the nature of the existing contracted background at Keith 1, scheduled reinforcement, and constraints on the 303/304 feeders, there exists no traditional reinforcement that can support loads out to 2028 without stranded assets by 2050. Additionally, due to physical limitations driven by the large volume of contracted connections, space for new switchgear on the Keith 1 33kV switchboard is

limited. As such, through careful consideration of options, this paper has established that there is only one efficient and deliverable solution to fix constraints forecast for 2028 and ensure that assets are not stranded by 2050. With only one option available, no Cost Benefit Analysis has been carried out.

The load-related investment for Keith 1 33kV Circuits has been triggered by load growth projected by DFES Consumer Transformation scenario. To counter the voltage non-compliance for outage network scenarios, out of the proposed options, Option 7 has been selected as preferred which involves:

Option	Advantage	Disadvantage	MVA release	Costs (C0(b)) - £m)/NPV	Risks
Option 7: Combination of Reconfiguration, Network Extension and Reinforcing Existing Assets	Increase network resilience. Create headroom for new demand. Much can be built offline minimising outages for existing customers	High Cost Large scope of works with potential time delays for consents/planning. Long lead times for large plant items.	7.68	[redacted]	Large scope of works with potential time delays for consents/planning. Long lead times for large plant items.

The recommendation of this option is to proceed with planning and corresponding design work as per the forecasted workload of design and delivery teams.

13 References

The documents detailed in Table 13.1 - Scottish and Southern Electricity Networks Documents, Table 13.2 – External Documents, and Table 13.3 – Miscellaneous Documents, should be used in conjunction with this document.

Table 13.1 - Scottish and Southern Electricity Networks Documents

Reference	Title
Previous EJP on Keith 33kV Circuits	Engineering Justification Paper - 72/SHEPD/LRE/KEITH
PR-NET-NPL-007	Planning Standards for 33kV and 22kV Distribution Network
TG-NET-SST-026	Ratings of Oil-Filled Power Transformers
TG-NET-SST-200	Primary Substation Plant Catalogue
TG-NET-CAB-009	Load Ratings of LV to 33 kV Underground Cables - Design Data

Table 13.2 – External Documents

Reference	Title
ENA EREC P2	Security of Supply
Ofgem CEM tool	ON22-WS1A-P1 CEM Tool V 2.2 SSEN
Ofgem CBA tool	RIIO-ED2_Cost Benefit Analysis_Template_0

Table 13.3 – Miscellaneous Documents

Appendix A Definitions and Abbreviations

Table 13.4 – Definitions and Abbreviations

Acronym	Definition
AIS	Air-insulated Switchgear
ASCR	Aluminium Conductor Steel Reinforced
BSP	Bulk Supply Point
CBA	Cost Benefit Analysis
CBRM	Condition Based Risk Management
CEM	Common Evaluation Methodology
CI	Customer Interruptions
CML	Customer Minutes Lost
CT	Consumer Transformation
DFES	Distribution Future Energy Scenarios
DNO	Distribution Network Operator
EJP	Engineering Justification Paper
ESA	Electricity Supply Area
EV	Electric Vehicle
FCO	First Circuit Outage
FES	Future Energy Scenarios
GIS	Geographic Information System
GM	Ground Mounted
GSP	Grid Supply Point
HI	Health Index
IDP	Investment Decision Pack
LCT	Low Carbon Technology
LEP	Local Enterprise Partnership
LI	Load Index
LRE	Load Related Expenditure
LW	Leading the Way
NPV	Net Present Value
OHL	Overhead Line
PM	Pole Mounted
PV	Photovoltaics
RSN	Relevant Section of Network
SCO	Second Circuit Outage
SSEN	Scottish and Southern Electricity Network
SP	Steady Progression

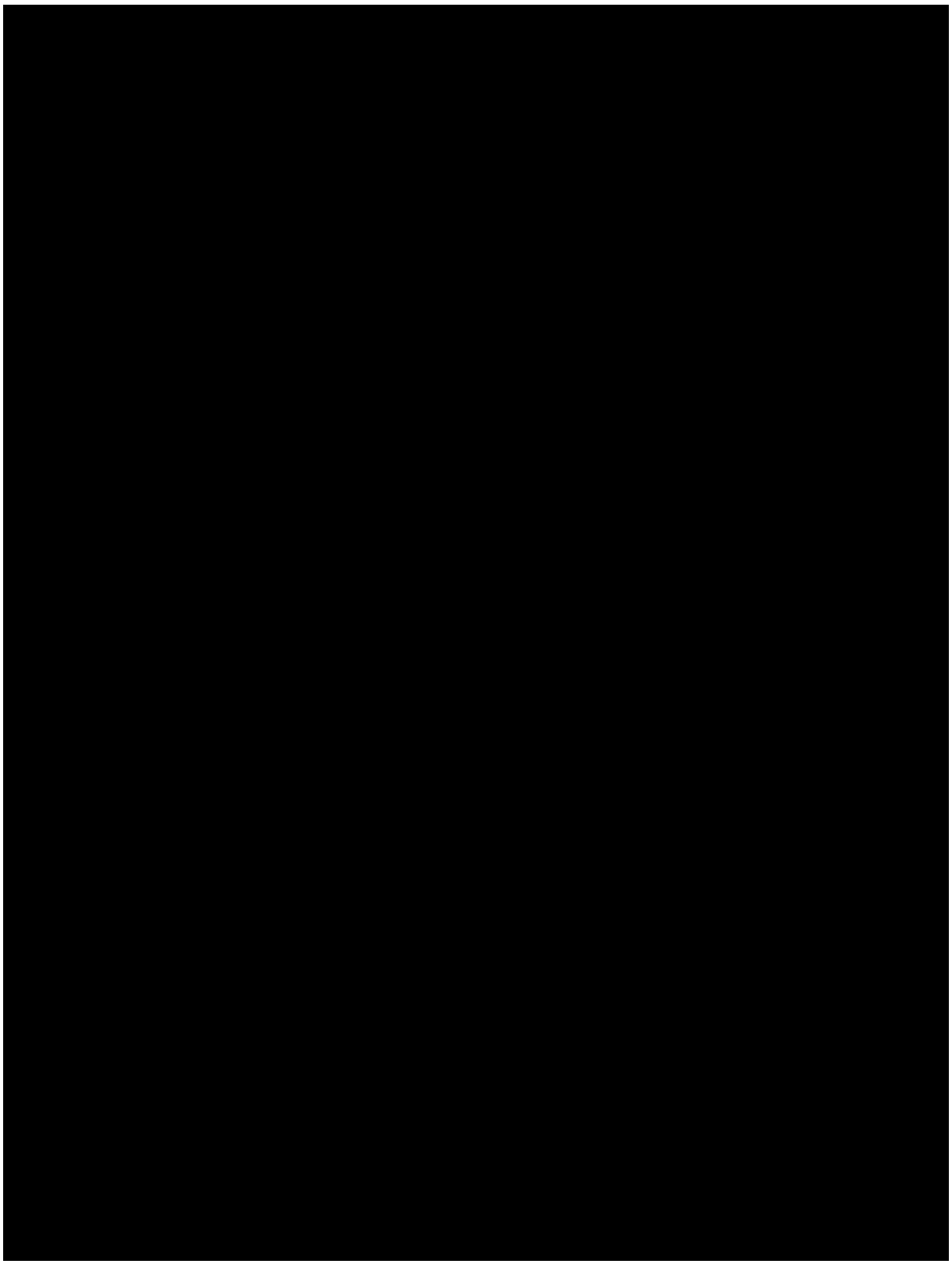
ST	System Transformation
XLPE	Cross-linked Polyethylene

Appendix B Connected/Contracted Generation Data

[redacted]

Appendix C Keith 1 Contracted Demand Data

Appendix D Winter Max DFES CT 2028 Network Assessment Results (Constrained Circuits)



Appendix E Results of P2/8 Load Growth Assessment for Cullen Primary

Appendix F Load Transfer Results – Loss of Keith 1 304

Appendix G Reinforcement Only Results

Appendix H [redacted]

[redacted]

Appendix I Option 7 Modelling Results

3.1 Winter Maximum Keith 1 Proposed Network Intact — **Appendix A**

VOLTAGE LEVELS Circuit & Location:	Voltage Min (pu)	Limit	Pass / Fail	Comments
Keith 1 33kV Bus	0.999	0.94	PASS	
Fochabers 11kV Bus	0.995	0.94	PASS	
Buckie 11kV Bus	0.984	0.94	PASS	
Cullen 11kV Bus	0.984	0.94	PASS	
Limehillocks 11kV Bus	0.994	0.94	PASS	
Marnoch 11kV Bus	0.995	0.94	PASS	
Buckie 33kV Bus	0.979	0.94	PASS	
1L5 Pole 262 (NOP with Macduff)	0.980	0.94	PASS	

POWER FLOWS Circuit & Location:	Thermal Max (%)	Limit	Pass / Fail	Comments
Keith GT1	19%	100%	PASS	100% = 90MVA.
Keith GT3	19%	100%	PASS	100% = 90MVA.
Fochabers T1	61%	100%	PASS	100% = 7.5MVA ONAN rating for CER
Buckie T1	91%	100%	PASS	100% = 12MVA ONAN rating for CER
Buckie T2	71%	100%	PASS	100% = 12MVA ONAN rating for CER
Cullen T1	44%	100%	PASS	100% = 7.5MVA ONAN rating for CER
Limehillocks T1	69%	100%	PASS	100% = 3.25MVA. ONAN only rating - for winter cyclic can be rated to 1.3 x Nameplate
Marnoch T1	50%	100%	PASS	100% = 7.8MVA. ONAN only rating - for winter cyclic can be rated to 1.3 x Nameplate

Keith 3L5	33%	100%	PASS	100% = 40.4MVA. Highest thermal rating on circuit
Keith 4L5	10%	100%	PASS	100% = 35.4MVA. Highest thermal rating on circuit
Keith New Circuit	33%	100%	PASS	100% = 40.4MVA. Highest thermal rating on circuit
Keith 1L5	23%	100%	PASS	100% = 26.9MVA. Highest thermal rating on circuit

3.3 Network Outages (N-1)

LOSS OF 303/3L5 and Buckie Primary TR1 — **Appendix B**

Portgordon Maltings Switched Out (DSR). Fochabers Fed from Elgin.

VOLTAGE LEVELS Circuit & Location:	Voltage Min (pu)	Limit	Pass / Fail	Comments
Keith 33kV Bus	1.002	0.9	PASS	
Buckie 33kV Bus	0.973	0.9	PASS	
Buckie 11kV Bus	0.992	0.9	PASS	

POWER FLOWS Circuit & Location:	Thermal Max (%)	Limit	Pass / Fail	Comments
Buckie T2	80%	100%	PASS	100% = 24MVA. ONAF rating for CER
Keith New Circuit	48%	100%	PASS	100% = 35.4MVA. Highest thermal rating on circuit

LOSS OF ELGIN 303/3L5 — **Appendix C**

ACO Scheme at Fochabers Operates. Portgordon Maltings Switched Out (DSR)

VOLTAGE LEVELS Circuit & Location:	Voltage Min (pu)	Limit	Pass / Fail	Comments
Keith 33kV Bus	1.002	0.9	PASS	
Fochabers 33kV Bus	0.913	0.9	PASS	
Fochabers 11kV Bus	0.997	0.9	PASS	

POWER FLOWS Circuit & Location:	Thermal Max (%)	Limit	Pass / Fail	Comments
Fochabers T1	81%	100%	PASS	100% = 15MVA. ONAF rating for CER
Keith 3L5/NEW	39%	100%	PASS	100% = 40.4MVA

LOSS OF KEITH NEW CIRCUIT **Appendix D**

VOLTAGE LEVELS Circuit & Location:	Voltage Min (pu)	Limit	Pass / Fail	Comments
Keith 33kV Bus	1.006	0.9	PASS	
Buckie 33kV Bus	0.964	0.9	PASS	
Buckie 11kV Bus	0.981	0.9	PASS	
Fochabers 33kV Bus	0.934	0.9	PASS	
Fochabers 11kV Bus	0.994	0.9	PASS	

POWER FLOWS Circuit & Location:	Thermal Max (%)	Limit	Pass / Fail	Comments
Buckie T2	81%	100%	PASS	100% = 24MVA. ONAF rating for CER
Keith 3L5	67%	100%	PASS	100% = 40.4MVA

3.4 Fault Level Study (For 33kV Connections)

Max 3 Phase/Earth Fault Level SHEPD Contribution (All gen operating @ rated output)	**Make Rating (kA)**	**Current I_p (kA)**	**CB Break Rating (kA)**	**I_b(sym) @ 60ms (kA)**	**R (pu on 100MVA Base)**	**X (pu on 100MVA Base)**	**X/R Ratio**	**Comments**
KEIT3- 33.000	63.0	39.88	25.0	9.84	0.00773	0.10681	13.81759	Marnoch 33kV outdoor bus and MAINS OF CRANNA B086_L and FORGLEN B085_L Air Brakes to be designated Orange Triangle
CULLEN3A 33.000	63.0	7.57	25.0	2.77	0.14142	0.39995	2.82810	
CULLEN1A 11.000	50.0	8.54	20.0	2.51	0.20102	1.39995	6.96423	

BUCKIE3A 33.000	63.0	12.22	25.0	4.06	0.07008	0.27954	3.98887	as part of existing connection works. Rest of network within asset ratings. Maximo ratings used where possible, but many make ratings not available. Where make ratings not available an assumption of 2.5 x the break rating has been used.
BUCKIE3B 33.000	63.0	12.55	25.0	4.15	0.06867	0.27578	4.01602	
BUCKIE1A 11.000	33.4	19.01	13.1	5.28	0.06213	0.67433	10.85353	
LIMEHI3B 33.000	63.0	8.91	25.0	3.21	0.11583	0.33325	2.87706	
LIMEHI1A 11.000	31.3	4.30	12.5	1.51	0.60074	2.60867	4.34243	
MARNOC3A 33.000	63.0	5.94	25.0	1.96	0.16413	0.52958	3.22659	
MARNOC1A 11.000	33.4	7.77	13.1	2.55	0.32598	1.43165	4.39183	
FOCHAB3B 33.000	63.0	3.16	25.0	1.14	0.31477	0.97041	3.08292	
FOCHAB1A 11.000	22.2	5.47	8.7	1.72	0.37437	1.97041	5.26327	
BEYSIDE33 33.000	63.0	5.1	25.0	2.13	0.26178	0.47471	1.81339	

Appendix J Sensitivity Analysis

For each investment proposed in this EJP, we have reviewed the annual max demand figures under all DFES scenarios out to 2050. Based on this assessment, we will place this investment into one of the categories from Table 13.5.

Table 13.5

Category	Description	Applies to this EJP?
A	Schemes where the chosen investment size is large enough to meet peak demand/generation under all net zero compliant scenarios to 2050 or Schemes where the chosen investment size is large enough to meet peak demand/generation in ED2 and plans for further reinforcement are in place.	✓
B	Schemes where we would require further future reinforcement of the particular asset(s) being proposed under a more aggressive scenario to 2050	
C	Schemes where the proposed investment is not required under any scenario to 2050 (if any)	

D	Schemes where investment can be deferred until a later date under some scenarios i.e. ST scenario indicates no investment needed until 2030	

Justification for Categorisation:

[redacted]

The project falls into **category A**.

The proposed strategy includes the reinforcement of existing conductors on 303/304, the relocation of Buckie Primary to allow for space/access requirements, and a new second circuit built from Keith Grid to the new Primary site.

Figure 13.1 shows that the network is already constrained regardless of the distributed future energy scenario considered.

The proposed investment mitigates the constraints within ED2. The new assets are not expected to experience any thermal overload up to at least 2050. Further reinforcement will be required within ED3 for a compliant network up to at least 2050.