ABERNETHY 33KV CIRCUIT REINFORCEMENT ENGINEERING JUSTIFICATION PAPER

[redacted]

CONTENTS

1 Executive Summary

1.1 Summary

This Engineering Justification Paper (EJP) outlines the proposal to reinforce the 33kV network between Abernethy GSP, and Milnathort Primary Substation [redacted]

Within this paper, different options are considered to address the raised issues, while Ofgem-provided Cost Benefit Analysis (CBA) and Common Evaluation Methodology (CEM) were used to ensure that the most efficient and cost-effective solution is being progressed. The former determines the reinforcement option with the best NPV through the whole project life cycle, while the latter assesses whether flexibility employment would be viable and more economic compared to the baseline reinforcement.

Our proposed investment at Abernethy GSP will resolve the thermal overload and deliver a compliant network up to at least 2050 [redacted]. The C0(a) and C0(b) costs of the considered options have been derived from the ED2 Ofgem Unit Cost Rates, with price base in 2020/21 and 2023/24, respectively. All costs given are C0(a), unless stated otherwise.

An overview of the considered options, the main drivers for the decision to progress or not to CBA, and the CBA results of the progressed options is provided in **Error! Reference source not found.**.

Table 1.1 Overview of Considered Options

Option	Description	CBA Consideration and Result
1. Do Nothing	No change to existing network topology	[redacted] Not Progressed to CBA
2. Reinforcement of Existing Assets - Upgrade OHL	[redacted]	[redacted] - Not progressed to CBA
3. Adding New Assets – single new feeder	Install a clean 3rd feeder from Abernethy to Milnathort	[redacted] Not progressed to CBA
4. Reinforcement by Adding New Assets – two new feeders	Move Milnathort/Glendevon to clean feeders, loop in the existing 1L5/6L5 feeders to create a new ring.	[redacted] is electrically feasible. - **Progressed to CBA** [redacted]
5. Flexibility and Reinforcement	Flexible service contract to reduce peak demand and defer capital investment. In this case, flexibility is assessed to defer the investment of option 5.	CEM suggests 5 year-deferral of investment.. Although a flex viability assessment was conducted to ensure that there is enough flexibility in the area to accommodate the deferral and it suggests that there is only enough for 3 years. The reinforcement of option 4 can be deferred to 2027 using flexibility services. **-** **Progressed to CBA and considered under CEM.** [redacted] **Preferred Option**

It has been decided to progress option 5 as this is the most cost-effective and efficient solution for this scheme. [redacted]

[redacted]

Table 1.2 Cost Breakdown of Option 5

Asset Description	Volume	C0(a) Cost
33kV UG Cable (Non Pressurised)	[redacted]	
33kV CB (Gas Insulated Busbars) (ID) (GM)		
33kV - TRAFO - 20/40MVA 33/11kV transformer		
2.5 MVAr reactor		
33kV OHL (Pole Line) Conductor		
33kV Pole		
33kV Switch (PM)		
Flexibility costs 2025-2027		
Total Cost		

This investment to carry out the reinforcement works is being assigned to the South Caledonia Region for design refinement and project delivery. It is proposed that the reinforcement works will start in 2025/2026, with flexibility acquirement in 2025/2026/2027, and delivery in 2027/2028.

This scheme delivers the following outputs and benefits:

- The uplift in network capacity of 57.3 MVA firm capacity to meet the needs of our customers.
- Facilitates the efficient, economic, and co-ordinated development of our Distribution Network for Net Zero.

The proposed solution is designed to be strategic, so that there will be enough headroom to operate without congestions in the considered grid area until at least 2050.

2 Investment Summary Table

The table below provides a high level summary of the key information relevant to this EJP and the reinforcement of Abernethy 33kV network.

Table 2.1 Definitions and Abbreviations

Name of Scheme/Programme	Abernethy GSP Network Reinforcement
Primary Investment Driver	Load related – Thermal overload of Abernethy feeders (306) and (307) Project Number: PH004282
Scheme reference/	EJP/SHEPD/IVEE/ABNE/001
Output reference/type	40km 33 kV UG Cable (Non-Pressurised) 8x 33 kV CB (Gas Insulated Busbars) (ID) (GM) 2x 33kV - TRAFO - 20/40MVA 33/11kV transformer 1km 33 kV OHL (Pole Line) Conductor 20 x 33 kV Poles Flexibility Services in 2027

Scottish & Southern Electricity Networks

Cost	[redacted]	
Delivery Year	2026/27	
Reporting Table(s)	CV1: Primary Reinforcement	
Outputs in RIIO ED2 Business Plan?	Partially funded in RIIO ED2 Plan. Funding covers up to £990,000 as per the previous EJP.	
Spend Apportionment	**ED2**	**ED3+**
	[redacted]	N/A
MVA released	57.3 MVA	N/A

3 Appendices Summary

Table 3.1: Appendices Summary

Appendix	Summary of Contents
Appendix A	Definitions and Abbreviations
Appendix B	Network Plans
Appendix C	Sensitivity Analysis

4 Introduction

This paper outlines the need for reinforcement of the 33 kV network between Abernethy GSP (241), and Milnathort (251) / Glendevon (273) Primaries within the RIIO-ED2 period, to address the future thermal issues at Abernethy feeders 306 and 307.

Abernethy GSP is located within the Perthshire area of Scotland and sits within the South Caledonia region of SHEPD's licence area.

This paper presents options to rectify the projected conductor overload using flexible solutions and conventional reinforcement.

Section 5 outlines the existing network arrangements, the load growth forecast based on the Distribution Future Energy Scenarios (DFES) data and network analysis, justifying the requirement of reinforcement. An overview and a comparison of the considered options are given in Section 6, with a detailed option analysis being provided in Section 7, where the reasons for the options that are deemed unviable, and thus not taken forward to the CBA, are presented. Details and the results of the CBA can be found in Section 8. The deliverability and possible risks of the proposed option are addressed in Section 9, while Section 10 presents the strategic planning of investment to operate a congestion-free grid up to at least 2050. Finally, Section 11 concludes this EJP, providing main conclusions and recommendations contained within this document.

5 Background Information

5.1 Existing Network Arrangements

The Abernethy GSP is currently supplied via 2x 120MVA 132kV/33kV transformers split across 2x section 1250A Cu 33kV busbar which was recently installed as part of another investment project - PH004146. The board is currently an outdoor board, but this is proposed to be replaced with an indoor board as part of upgrade works triggered by a new connection job (EXJ802).

Abernethy GSP currently supplies approximately 22,651 customers via 7x 33kV circuits and 8 primary substations. There are three 33kV rings, with interconnections for Braco, Burghmuir and Coupar Angus GSPs.

There are proposed but not yet delieved OHL reinforcement works planned on feeder 6L5 due to the connection of a large generator embedded on this network. This reinforcement has been considered as completed for these studies, taking into account the larger thermal rating.

The primary substations are Abernethy (local), Balbeggie, Bridge of Earn, Errol, Glendevon, Harbour, Milnathort and Scone. The diagram below shows the geographical layout of the Abernethy network.

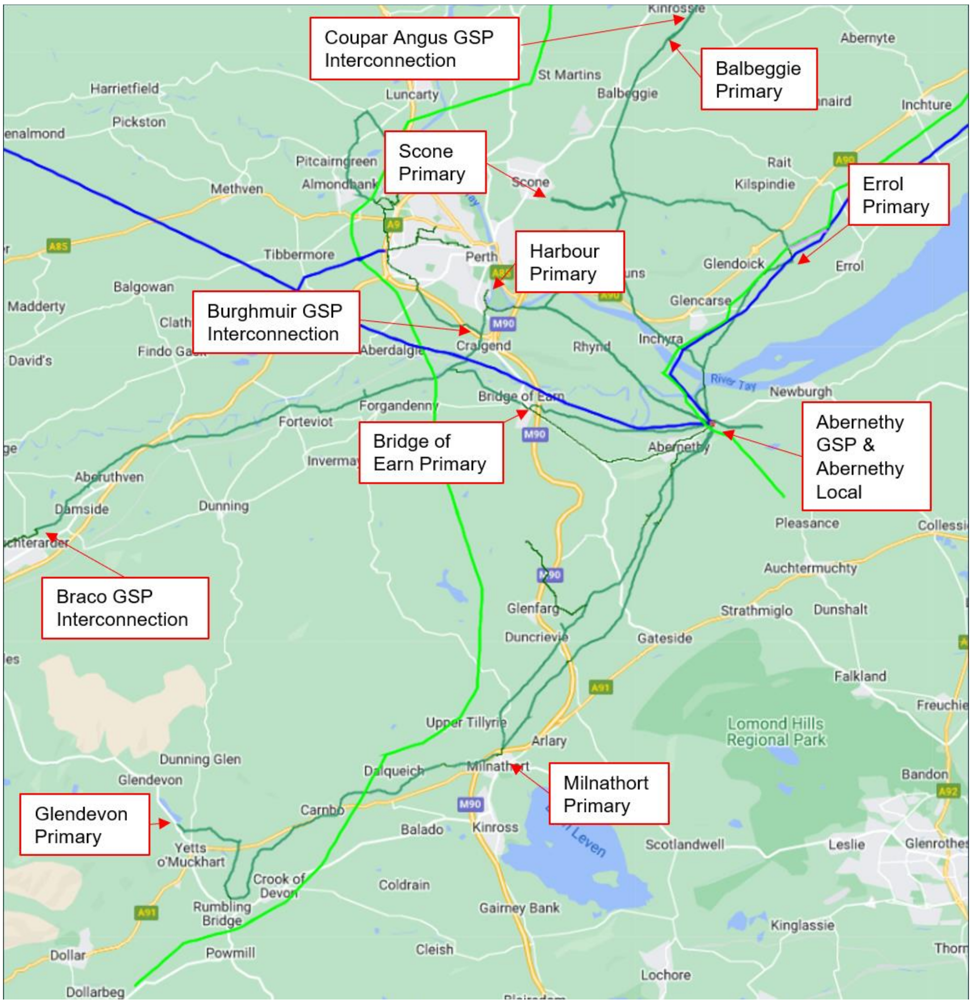

Figure 5.1

This EJP specifically relates to the reinforcement works required on 1L5 & 6L5 which feed south to Milnathort and Glendevon. The diagram below shows the geographical layout of these feeders between Abernethy and Milnathort/Glendevon. This ring has 7,058 customers currently connected.

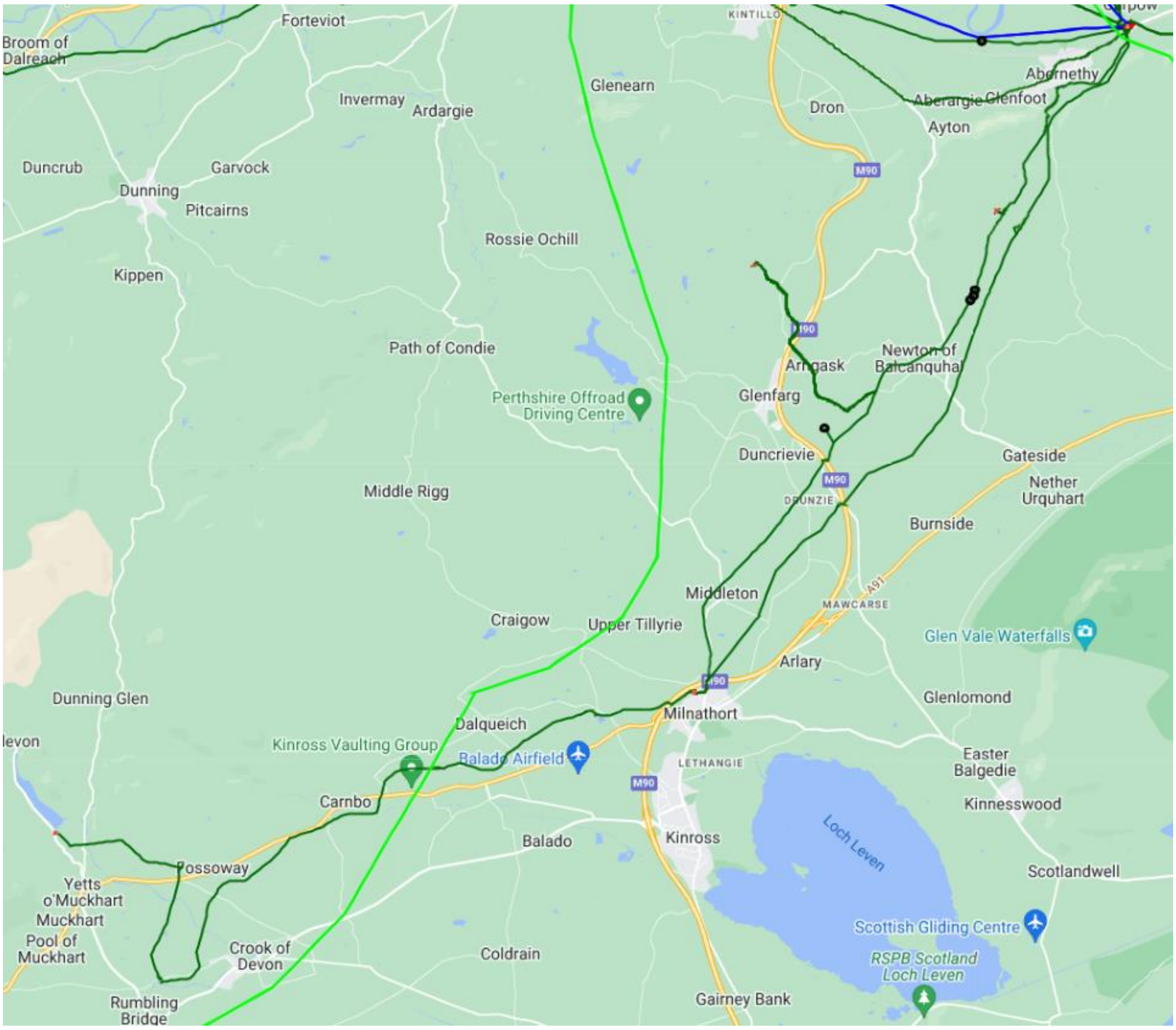

Figure 5.2

Schematic Diagram

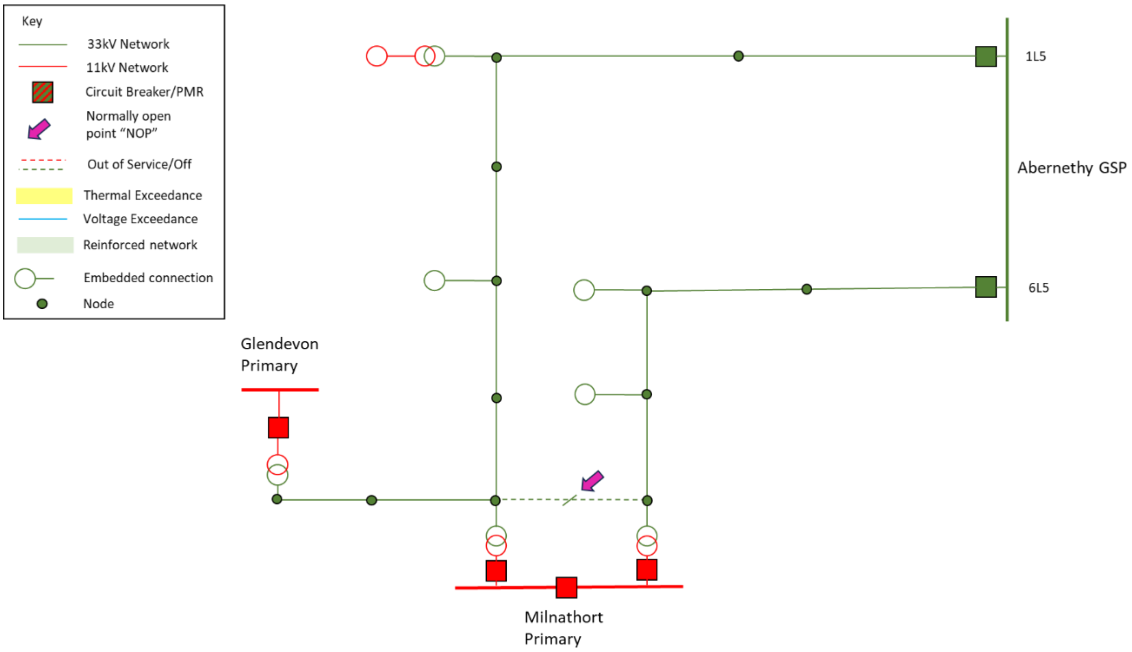

Figure 5.3

[redacted]

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5.2 Load Forecast for (area of network specified)

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-W)** as the baseline scenario for investment.

The DFES load forecast data from 2022 has been used to assess the network under future energy demand scenarios. The table and graph below show the load growth from 2023 to 2050. The general trend remains consistent between Milnathort, Harbour, Bridge of Earn and Scone primary substations – initially the loads are forecast to rise quickly between 2023 and 2035, with the load growth slowing then slowing from 2035 to 2050. For the smaller sites of Balbeggie, Errol, Glendevon and Abernethy Local, the load growth is generally more consistent across the full range dates.

Winter Max Load Forecasts for Abernethy 33kV Circuits EJP - DFES 2022 Data

Abernethy GSP Winter Max CT

	ED2						ED3					Future	
Substation	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2035**	**2050**
ABERNETHY	1.58544	1.65248	1.69881	1.74848	1.83654	1.9331	2.0473	2.16347	2.2457	2.31705	2.39119	2.53884	3.55207
BALBEGGIE	4.01659	4.13995	4.23631	4.38221	4.64518	4.96154	5.32209	5.73113	6.03125	6.32543	6.6579	7.42585	9.46819
BRIDGE OF EARN	3.87438	4.22222	4.63903	5.13169	5.82215	6.63436	7.52446	8.42272	9.16554	9.88074	10.7143	12.291	15.2006
ERROL	2.58221	2.64819	2.73633	2.85909	3.16051	3.50545	3.95638	4.40128	4.71608	4.97876	5.27348	5.86708	7.57723
GLENDEVON	1.81198	1.85765	1.91069	2.01398	2.13907	2.28336	2.48246	2.68128	2.83113	2.94136	3.06908	3.29094	4.26054
HARBOUR	8.74733	8.81108	8.9293	9.35599	10.0424	11.1485	12.1421	13.1504	13.8825	14.5713	15.2953	16.7356	21.0584
MILNATHORT	12.4602	13.2565	13.7217	14.3183	15.4547	16.6442	18.2273	19.9115	21.3401	23.1242	24.7408	27.3691	35.6955
SCONE	4.26572	4.50067	4.62889	4.8026	5.28453	5.8006	6.36034	6.9266	7.43176	8.01418	8.66009	9.97549	13.3509
Total	**39.34**	**41.09**	**42.50**	**44.61**	**48.39**	**52.91**	**58.06**	**63.39**	**67.64**	**72.15**	**76.80**	**85.49**	**110.16**

Figure 5.5

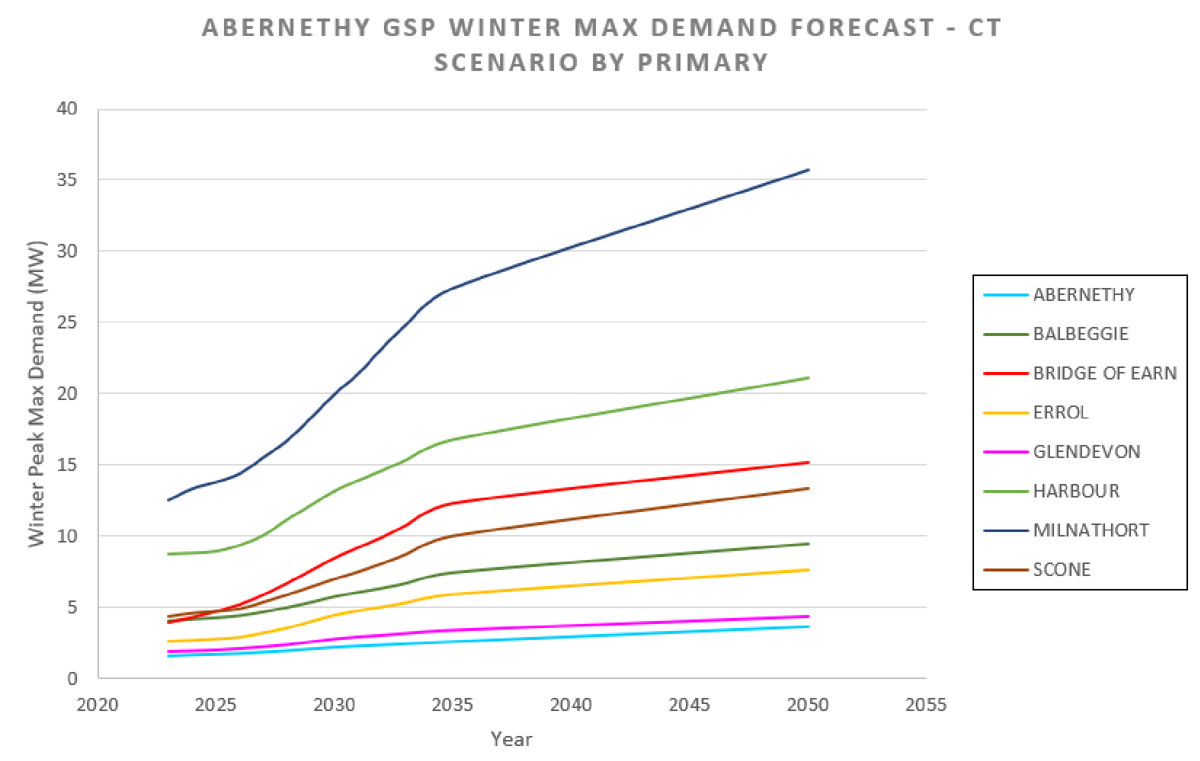


Figure 5.6

Regarding the specifics of this EJP, the main driver behind the required reinforcement works is the relatively large increase in demand at Milnathort Primary substation. With a 2023 loading of 12.46MW, this is forecast to increase significantly to 27.36MW by 2035 which is a 219% increase in 12 years. There is a further increase to 35.69MW by 2050 which is a rise of 286%.

Only one contracted job >1MW has been indayscluded within these studies in addition to the DFES loading. This is EXL145 for Kinross Moto services. This is for 1250kVA and will not form part of the DFES loadings.

It is clear from this load growth data alone that we will breech the thermal limits of multiple different assets on the 1L5 / 6L5 ring, even before studies are run. The Milnathort Primary transformers are currently 7.5/15MVA units and under certain outage conditions, Milnathort is required to pick up Glendevon via the 11kV network. [redacted] This does not take into account the additional load for EXL145 which may be connected by then.

In addition to the transformers, the incoming 33kV feeders have sections of 0.1in Cu OHL which has a relatively low thermal rating of 16.9MVA (winter rating). [redacted]

[redacted]

5.3 Existing Asset Conditions

[redacted]

The criticality and heath indecies and health scores of the existing assets at Milnathort and Glendevon Primaries and of the relevant Abernethy CBs are given in Table 5.1. As shown, the conditions of the assets at Abernethy GSP are in perfect condition. [redacted] There are no plans for non-load investment within the ED2 period for these assets.

[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 were highlighted during this engagement.

5.5 Network Analysis Summary

Winter Max load flow Assessment (thermal & voltage)

The following assumptions have been made:

Assumptions
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
All contracted reinforcement work has been switched in, assumed to have been completed.
All unknown cables assumed to be equal to lowest rated cable in RSN.
DFES - 2028 CT-W, plus all contracted demand =>1MVA. [redacted]

Following completion of network analysis using the DFES 2028 CT-W scenario, the following constraints have been identified as being present before the end of the current ED2 price control period. These will require intervention in order to maintain statutory limits and avoid thermal overloads. The findings of the most onerous outages are outlined in the tables and diagrams below.

[redacted]

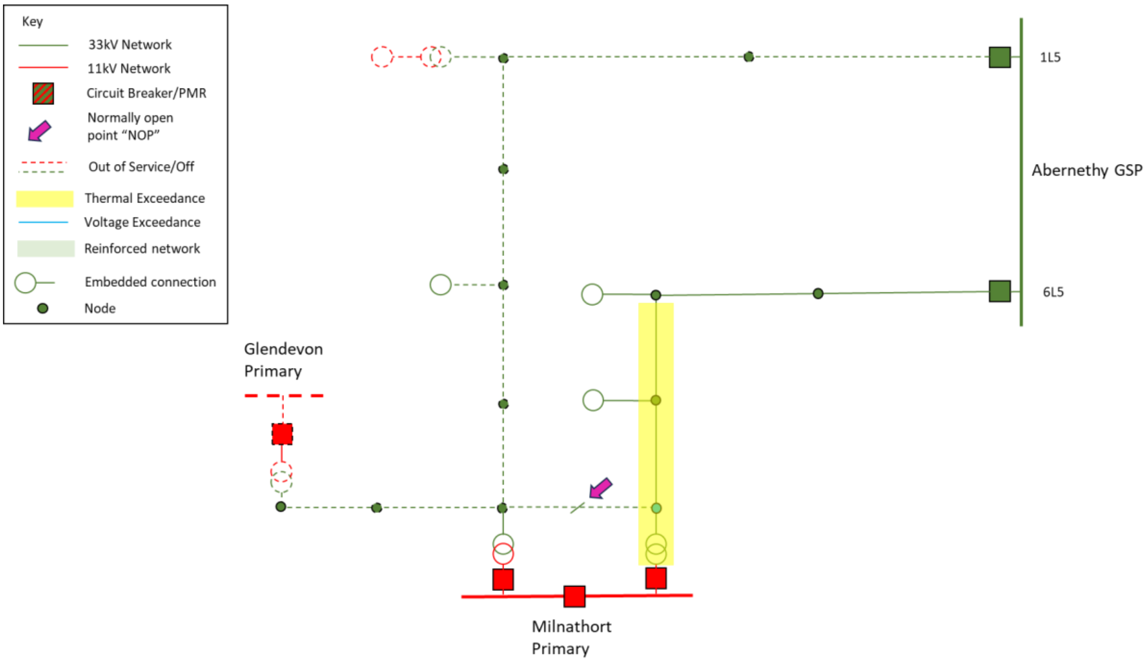


Figure 5.8

[redacted]

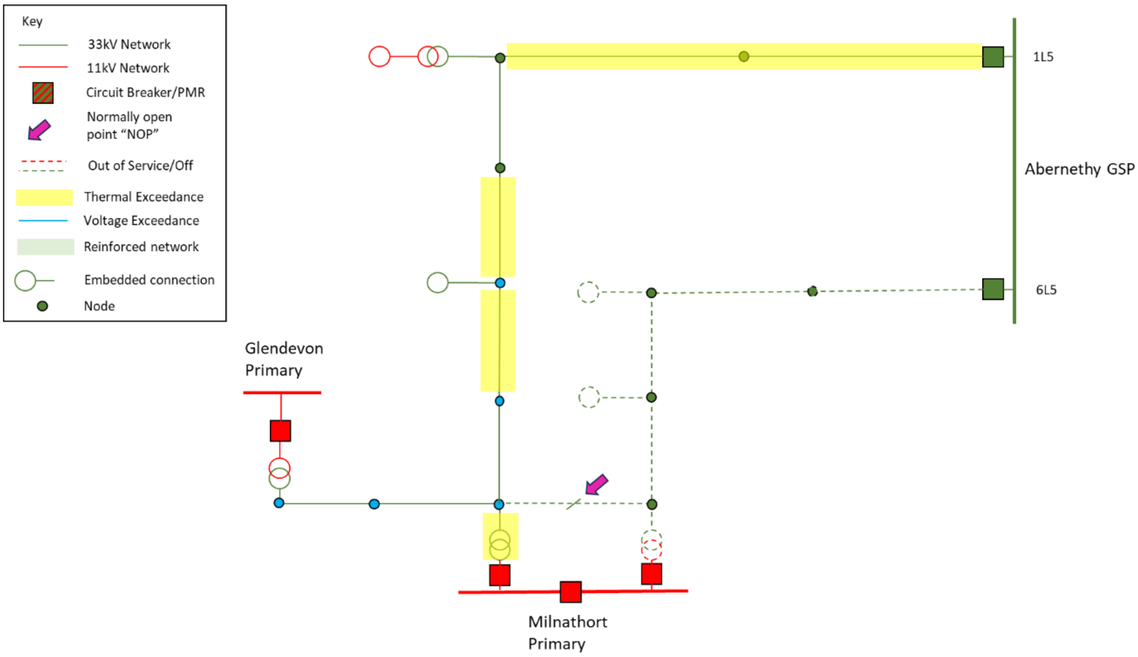


Figure 5.9

5.5.1 Summary

In summary, without intervention the forecasted increase in demand loading on the Abernethy 33kV network within ED2 will cause significant voltage and thermal issues on the Milnathort 33kV network leading to non-compliance. A total of 29.28km of existing OHL will require reinforcement, as well as both primary transformers at Milnathort Primary Substation.

At present the Glendevon 11kV network requires to be fully supported by Milnathort Primary for loss of the Glendevon Primary transformer. As this is a single transformer site, there is no other option for backfeeding. [redacted]

Network studies show that the existing 11kV network can support the additional load growth based on the DFES 2028 CT-W forecasts with no additional reinforcement works. This ensures a compliant network.

Multiple constraints were identified on the 11kV network based on 2035 load projections so this will need to be considered at a future date, however it is beyond the scope of this paper.

5.6 Regional Stakeholder Engagement and Whole systems analysis Summary

There are no particularly notable existing connections on the Milnathort 33kV ring. Both feeders have embedded generation customers as well as on line 33/LV transformers.

There are a couple of notable proposed connections:

[redacted]

[redacted]

[redacted]

The Abernethy GSP, much like the majority of GSPs in South Caledonia has seen a significant increase in the number of very large capacity requests >10MW in recent years. Of the 14 connection requests for demand connections >10MW, 12 of these were from 2022 until now. These were exclusively battery storage requests.

For demand connection requests between 1MW and 10MW the results are much the same – 19 jobs in total with only 7 of these coming in prior to 2022. This shows there is a significant increase in large jobs over the past 12-18 month.

[redacted]

Milnathort and Glendevon Primary Substations supply Perth and Kinross and Clackmannanshire.

SSEN has strong working relationships with local authorities and other key stakeholders in the region. We have met with Perth and Kinross Council to discuss local area energy planning, and the Council was a project partner in SSEN's Project RESOP trialling a software platform to support energy planning endeavours. We have also collaborated with the Council to install electric vehicle charging infrastructure at strategic locations along the A9 trunk road. SSEN engages with Scottish Government's LHEES Forum, Transport Scotland, Community Energy 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.

Perth and Kinross Council aims to achieve net zero by 2045 in alignment with Scottish Government targets and is rolling out a variety of projects and developments in pursuit of this. The Council has secured ECO Grants to support the provision of heat pumps to off gas and rural households across the local authority area through 2026. They also aim to have a fully developed electric vehicle network by 2030.

Clackmannanshire Council published a joint Regional Energy Masterplan with Stirling Council in December 2023. This publication includes details on the Councils' intentions to decarbonise heat and assess opportunities for local renewable energy generation. Clackmannanshire Council also secured funding via Energy Efficiency Scotland: Area Based Scheme to offer grants to residents for home upgrades, including solar PV and accompanying batteries.

5.7 Flexible Market Viability

To provide a cost-effective integration of new customers into the grid and to account for the expected load growth in the future, flexibility is used to defer or even avoid grid reinforcements.

Necessary for a postponement of the investment in assets is that the appropriate flexibility is available on the market. Therefore, the availability of flexibility to cover the expected demand that would otherwise exceed the network capacity was assessed for both Milnathort and Glendevon Primaries.

The key assumptions used in the flex viability assessment are the following:

1. 90% of non-MD customers are domestic, giving a current estimate of 7631 domestic households in Milnathort and Glendevon in 2023. The number of households in the future is scaled according to government projections (increasing with time in Perth and Kinross).
2. 5.7% household participation rates in flexibility in 2023, up to 10.5% in 2029.

3. Milnathort is an existing CMZ however no flexibility has been procured within this CMZ as yet.
4. Average power reduction potential per household is 0.61 kW (based on results from ESO DFS). Growth of EVs and heat pumps has been identified using the DFES data for the CT scenario in each primary, and an assumption is made that 50% of future EV and heat pump connections participate in flexibility services.
5. Assumed 20% of all the MD customer's capacity would be available to be turned down for flexibility (this includes shops, hospitals, schools, etc.) Growth in commercial demand according to the DFES CT scenario has been accounted for in this figure.
6. 0.688 MW of reservoir hydro power were identified in Milnathort and Glendevon primaries and was included as generation appropriate for generation turn-up in this assessment.

The outcome of the flexibility study shows that flexibility is feasible at this site until 2027. However, thereafter it will become infeasible, as shown in the table below.

[redacted]

5.8 Confidence Table

Table 5.2 Confidence Table

Confidence Factor	Certainty (High, Medium, Low)	Comments
Load Forecast	High	Load forecast is in keeping with historical trend and accounts for contracted commercial background. All four DFES scenarios are within expectations and should accurately project the area's demand forecast.
Existing Asset Condition	High	The current asset conditions were provided by the Asset management database.
Existing Operational Issues	High	No current operational issues are known
Connections Activity	High	Load forecast is in keeping with historical trend and accounts for contracted commercial background.
Regional Stakeholder engagement	High	The local authorities have recently updated their commitment to achieve the zero net goals. They have set out goals and funding to reach these goals in the next years, which is incorporated in the forecast of the local DFES.
Flexible Market Viability	Medium	The flexibility availability has been assessed for Milnathort and Glendevon Primaries. Results indicate that there is enough flexibility to cover the exceedance up to 2027. This would require us contracting with 94% of the identified potential flexibility and therefore the is a volume risk about being able to procure

		this flexibility. This calculation is conservative and focused work in this area may allow us to successfully procure more flexibility. Early procurement may be needed to minimise network risk.
Funding Position	High	[redacted] Scheme partially funded as per the previous EJP.

6 Summary of options considered

6.1 Summary of Options

Table 6.1

Option	Description	Est. Cost C0(a)	Year of costs	Advantages	Disadvantages	CBA
1. Do Nothing	Leave the existing network as it currently stands	[redacted]	[redacted]	Low cost and easy to deliver/no works	[redacted]	NO
2. Upgrade OHL	Upgrade only [redacted] 150mm Cu at 75 degrees	[redacted]	[redacted]	[redacted]	[redacted]	NO
3. 3rd feeder	Install a clean 3rd feeder from Abernethy to Milnathort	[redacted]	[redacted]	[redacted] Clean route means minimal impact on customers.	[redacted] Cost. 7 panel 33kv board required at Milnathort - space requirements. New breaker at Abernethy. Cable route may be 20km. [redacted]	NO

					[redacted]	
4. Clean feeders	Move Milnathort/Glendevon to clean feeders, loop 1L5/6L5	[redacted]	[redacted]	[redacted] Minimal impact on existing customers. [redacted] Creates capacity on OHL due to load shedding.	Cost. 6 panel 33kv board required at Milnathort - space requirements. New breakers at Abernethy. Cable route may be 40km.	YES
5. Flexibility & reinforcement **Preferred option**	Flexible service contractor to reduce peak demand and defer capital investment. In this case, flexibility is assessed to defer the investment of option 5.	[redacted]	[redacted]	Defers the investment and leads to a reduced NPV, thus providing a benefit to the costs.	Flexibility does not increase network capacity permanently, so additional costs need to be covered for flexibility.	YES

6.2 Options comparison table

Option		CBA total Results (Whole life NPV)	C0 (a) costs (£)					
			2024	2025	2026	2027	2028	2029
1	Do nothing	[redacted]						
2	Reinforcement of existing assets	[redacted]						
3	Reinforcement by Adding New Assets and Network Reconfiguration – 3rd feeder	[redacted]						
4	Reinforcement by Adding New Assets and Network Reconfiguration – two new feeders	[redacted]						
5	Flexibility and Reinforcement	[redacted]						

The C0(a) costs of the recommended option as per ED2 submission are listed below.

Table 6.2 C0(a) costs of preferred option

Recommended Option		Investment Driver	CBA total Results – Whole Life NPV	C0 (a) costs (£)						
				2024	2025	2026	2027	2028	2029	2030
5	Option 5- Flexibility and Reinforcement	CV1	[redacted]							

The C0(b) costs of the recommended as per ED2 submission adjusted for RPI to 23/24 Price Base

Table 6.3 C0(b) costs of preferred option

Recommended Option		Investment Driver	CBA total results	C0 (b) costs (£)						
				2024	2025	2026	2027	2028	2029	2030
5	Option 5- Flexibility and Reinforcement	CV1	[redacted]							

7 Detailed option analysis

7.1 Option 1: Do Nothing

[redacted]

- [redacted]

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

7.2 Option 2: Reinforcement of overloaded Overhead line assets only

[redacted] Option 3 would be to only reinforce these overloaded sections with larger 33kV conductor. The advantage of this solution is that it would be the minimal amount of work required to alleviate the thermal overloads.

[redacted]

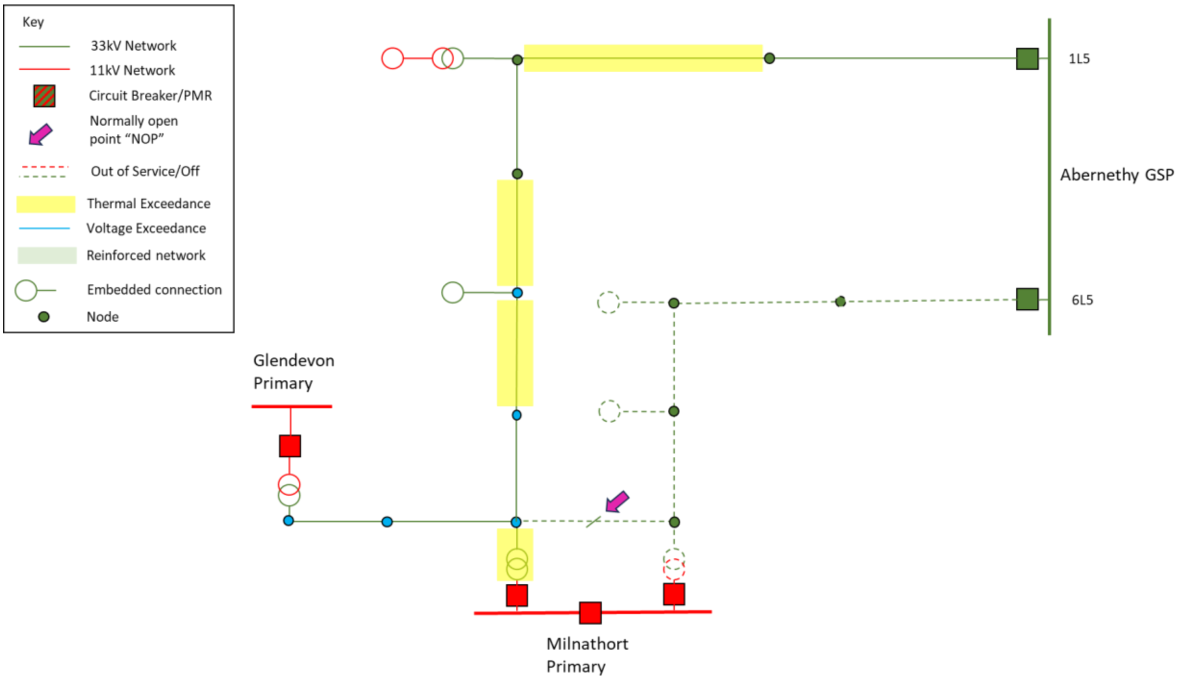


Figure 7.1

[redacted] This will require the upgrade/installation of 2.21km of 100mm Cu OHL. 710m of this will be a clean build, installed between p139-p132. This effectively removes 4.2km of unnecessary conductor – previously used to supply Rumbling Bridge Primary which has been removed from the network.

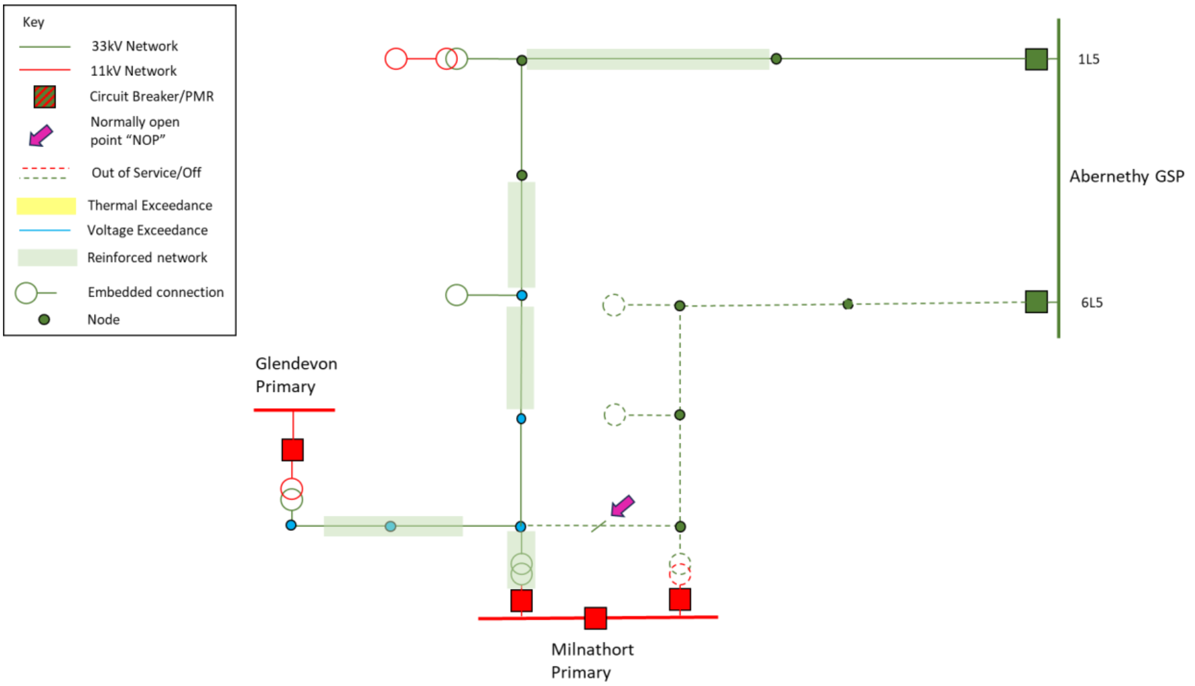


Figure 7.2

For Loss of feeder 1L5, the backfeed is provided by 6L5. Glendevon primary substation is directly affected by this outage and is off under this scenario. Backfeeding of all existing customers is via the Milnathort 11kV network and so the load appears on the Milnathort 11kV busbar. [redacted]

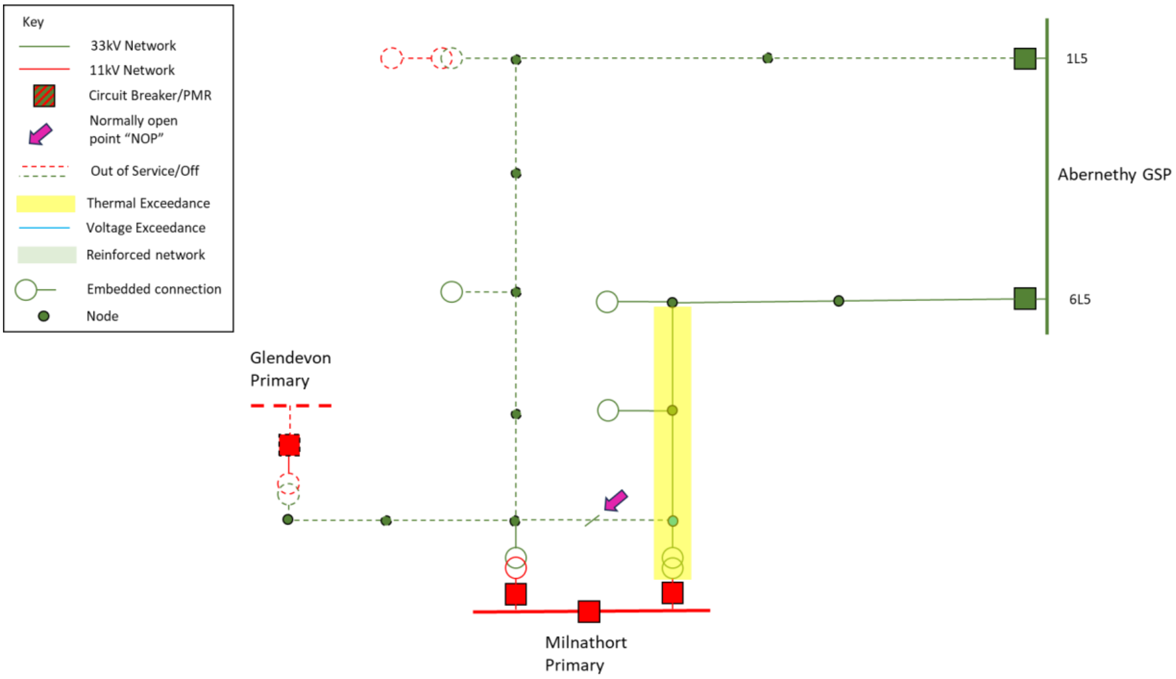


Figure 7.3

[redacted]

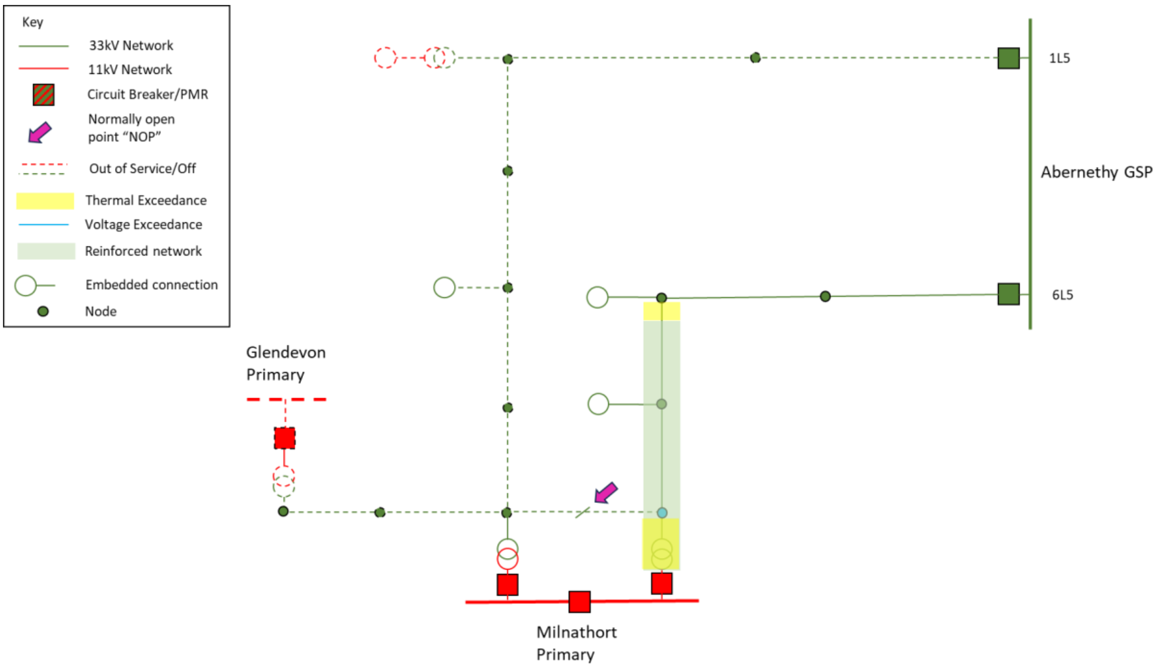


Figure 7.4

[redacted]

Due to this solution not providing adequate asset life it has been dismissed as an acceptable solution and will not progress to CBA stage. This solution is only included to show that an overhead line reinforcement only solution was considered.

7.3 Option 3: Install a new cable circuit from Abernethy to Milnathort (3rd feeder)

[redacted] Doing nothing and only reinforcing the overloaded overhead lines are not practical solutions and have been discounted as viable options.

Option 3 considers the installation of new assets to rectify these issues. Specifically, the installation of a new cable circuit from Abernethy GSP 33kV board to a new 7 panel 33kV board installed at Milnathort Primary substation.

By installing a new 33kV feeder between the GSP and primary substation, the existing feeders are not loaded as highly, as the below diagrams confirm. For this solution to be practical, the existing feeders 1L5 and 6L5 must be moved to the same side of the 33kV board at both Abernethy and Milnathort. The new feeder will be connected to the opposite side. This means that under the most onerous outage – a half board outage – we avoid a scenario where the network is only supported by 1L5 or 6L5 in isolation. It is under this scenario where we see the large thermal overloads and voltage issues on the existing network.

The new 33kV feeder will likely be 20km in length which will require the installation of a suitably sized shunt reactor – most likely a 2.5MVAr unit. The feeder will likely comprise of 3x1c 800mm XLPE cable.

At Milnathort, a new 7 panel 33kV board must be installed. This includes a bus section breaker, 2x transformer breakers and 4 feeder breakers for 1L5, 6L5, the new cable feeder and finally a dedicated breaker for the Glendevon radial.

In order to meet the projected loading at Milnathort in 2050, the primary transformers must be upgraded to 20/40MVA units.

Protection have highlighted issues with this design which triggered additional studies.

In order to effectively to effectively protect three parallel circuits as in this suggested solution we have the option of installing either a differential or distance protection scheme. The limitations of each for the suggested scenario is outlined below.

Differential protection:

- The level of the generation connected on 1L6 and 6L5 means a simple 2 ended scheme is not possible.
- In order to establish a 4 ended differential scheme protection grade communication channels would need to be established to each of the generation sites. This means installing fibre between each end of the circuit, including each of the online generators. Protection relays and additional CTs would also need to be installed. The installation of fibre itself would mean a huge amount of excavation with associated costs, but by itself does not improve the network capacity in any way. This solution would be prohibitively expensive considering the very long distances required.

Distance protection

- It is desirable to set a Zone 1 reach of 80% of the circuit length in order to ensure instantaneous fault clearance for as much of the circuit as possible. This would result in a fault on the generators side being cleared by the feeder circuit breakers which is obviously undesirable.

- In order to combat this, the Zone 1 reach would need to be lowered to 80% of the distance to the first generators resulting in a reach of 32% and 24% for 1L5 and 6L5 respectively. This means that the vast majority of the feeder circuit would only be covered by Zone 2, resulting in delayed fault clearance of 400ms.
- Given the level of generation connected mid circuit on both 1L5 and 6L5 there is also a substantial risk of underreach due to the fault contribution of the generators. Calculations indicate an underreach of 21% and 11% respectively for 1L5 and 6L5 in the event of a remote end busbar fault. This would potentially result in the fault only being cleared by the Zone 3 protection and remaining on the system to in excess of 800ms. This is deemed to be unacceptable.

This solution will not be progressed to CBA. This solution is only included to show that a 3rd feeder reinforcement solution was considered, but it is not viable due to protection issues.

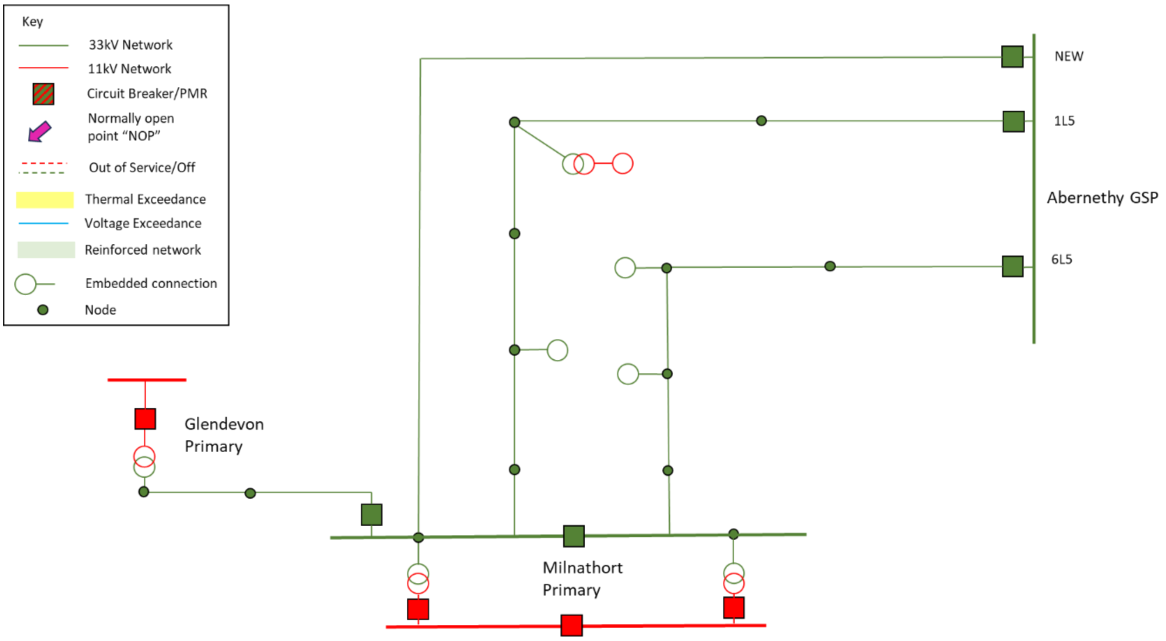


Figure 7.5

Installation of a 3rd cable circuit corrects all voltage and thermal issues under network intact, however this solution creates significant protection issues which are deemed unacceptable. See above diagram.

7.4 Option 4: Install two new cable circuits to Milnathort

[redacted] Doing nothing and only reinforcing the overloaded overhead lines are not practical solutions and have been discounted as viable options.

Option 4 considers the installation of new assets to rectify these issues. Specifically, the installation of two new cable circuits from Abernethy GSP 33kV board to a new 6 panel 33kV board installed at Milnathort Primary substation.

By installing a pair of new 33kV feeders between the GSP and primary substation, the existing feeders 1L5 and 6L5 are no longer required to supply Milnathort and Glendevon. This releases significant capacity (12.57MVA – based on load estimate data from 22-23) onto the existing overhead lines and removes all voltage and thermal constraints.

The solution releases 57.3MVA firm capacity onto the Milnathort/Glendevon network.

To allow for back-feeding under faults, the two existing lines would be looped in between p112 on 1L5 and p44 on 6L5. This would involve the installation of approx. 1km of 33kV 100mm Cu OHL and a suitable NOP would be created with a pole mounted circuit breaker (PMCB) and air break switch disconnector (ABSD).

The new feeders would be connected to opposite sides of the 33kV boards at both Abernethy GSP and Milnathort Primary.

The new 33kV feeders will likely be 20km in length which will require the installation of a suitably sized shunt reactors (one for each cable) – most likely 2.5MVAr in size. Due to space requirements its likely that this would need to be installed at Abernethy GSP. The feeders will likely comprise of 3x1c 1000mm XLPE cable. As this cable size cannot be terminated at the circuit breaker due to size, short sections of 630mm Cu cable will likely be required at each end.

A suitable route will need to be established for these cables and given the distances involved, the route may be challenging to establish. There will be multiple different excavation types, including road crossings, agriculture and a rail crossing at Abernethy GSP.

At Milnathort, a new 6 panel 33kV board must be installed. This includes a bus section breaker, 2x transformer breakers and three feeder breakers – one for each of the new cable feeders and finally a dedicated breaker for the Glendevon radial. Space for a seventh breaker should be considered for future network improvements on the Glendevon network.

In order to meet the projected loading at Milnathort in 2050, the primary transformers must be upgraded to 20/40MVA units.

[redacted]

This solution [redacted] vastly improves the network conditions based upon the 2050 load projections. This solution will be carried forwards to the CBA.

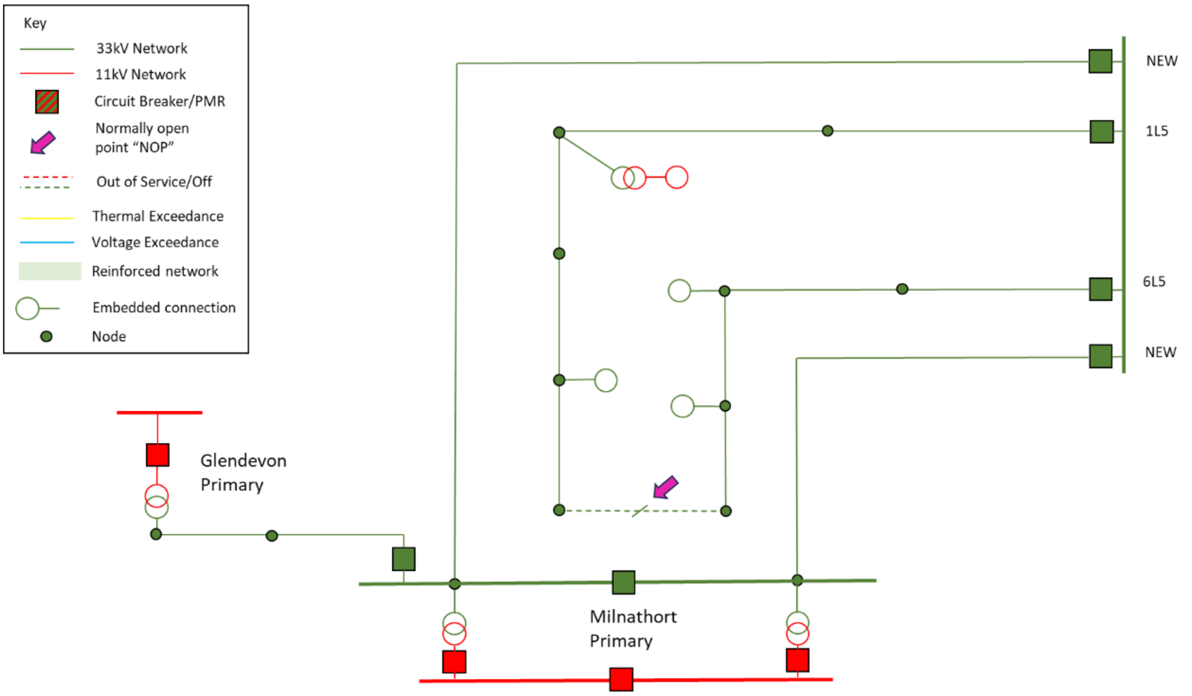


Figure 7.6 - Network intact

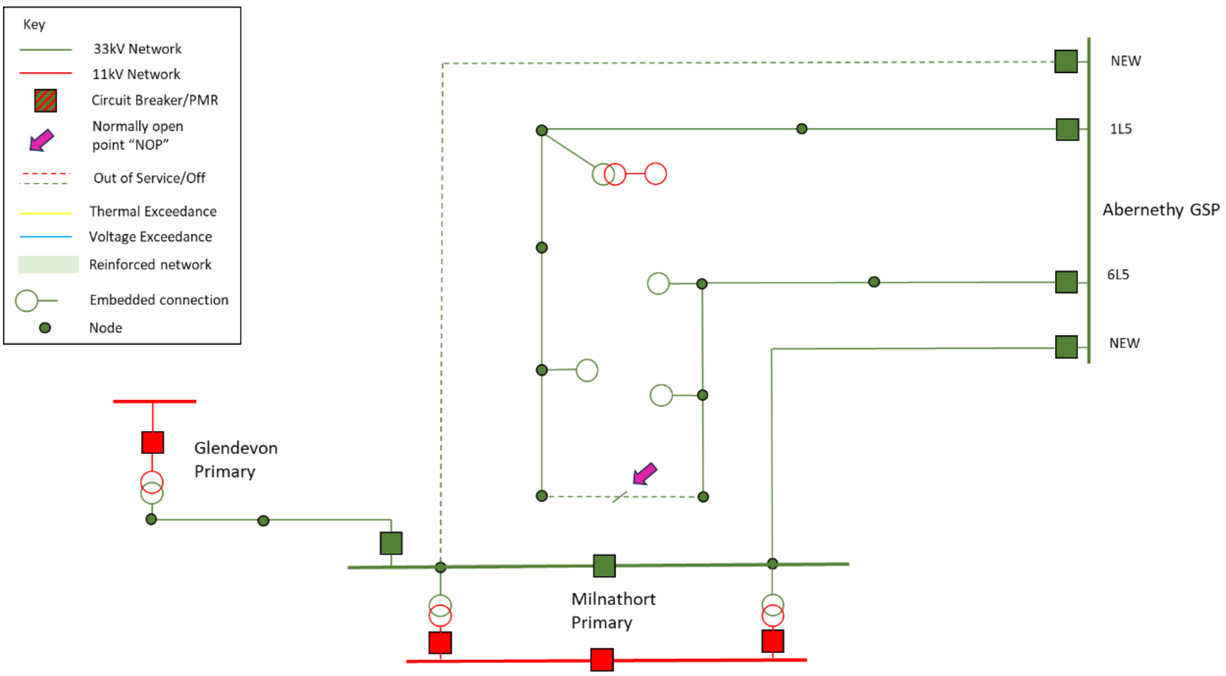


Figure 7.7 - N-1 Feeder 1

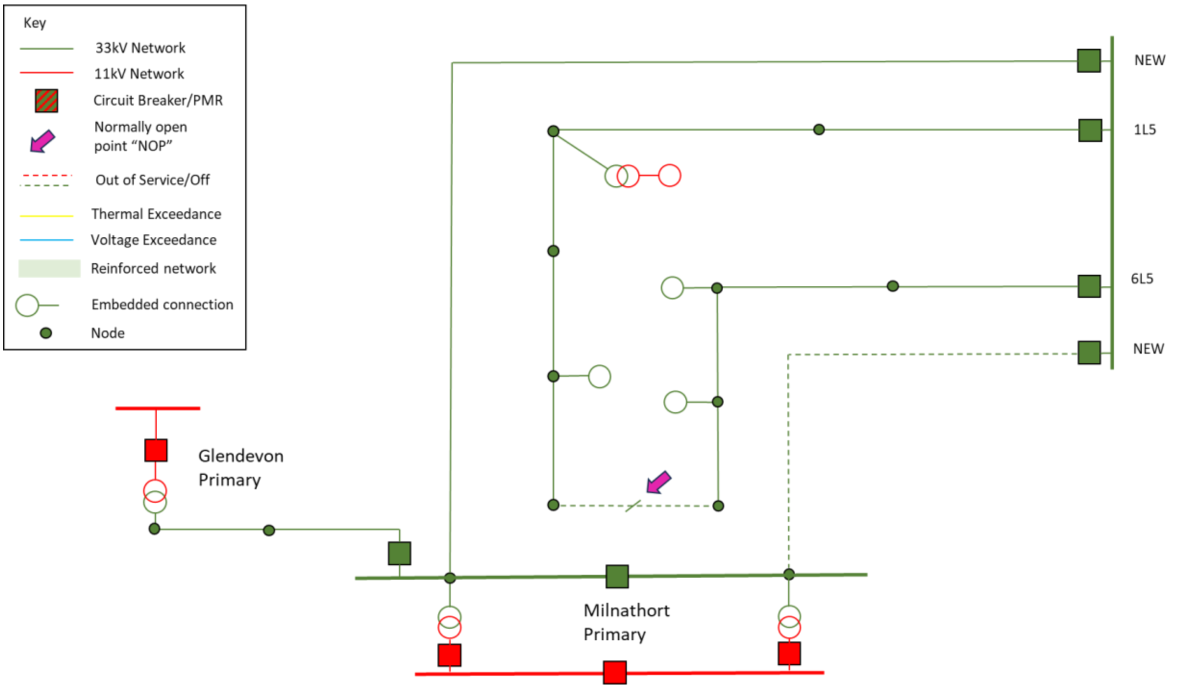


Figure 7.8 - N-1 Feeder 2

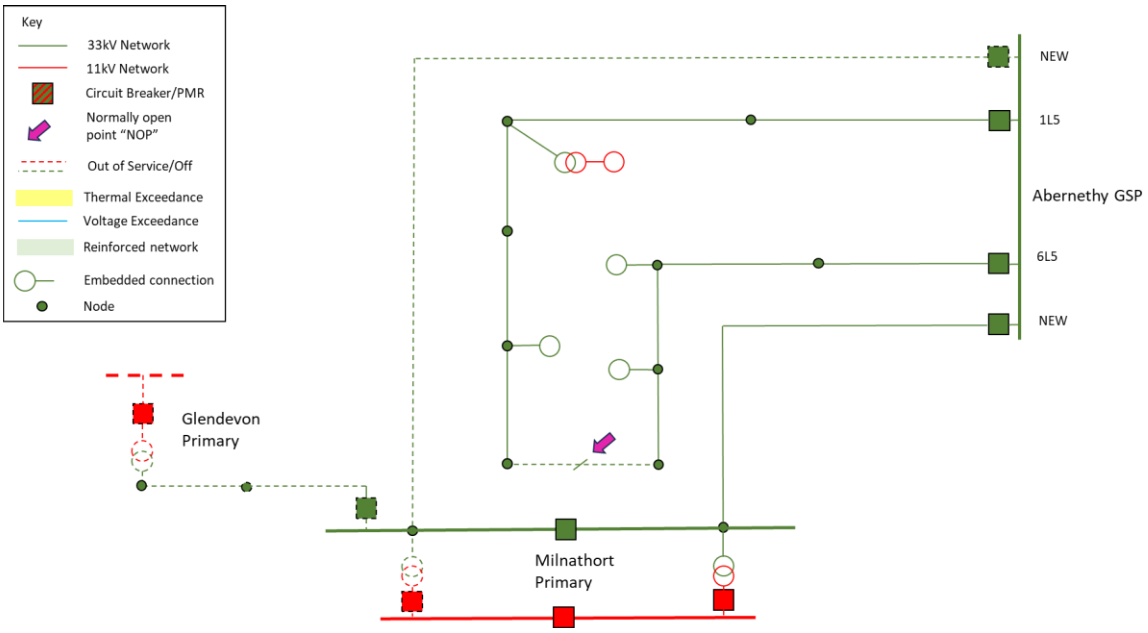


Figure 7.9 - Half Board outage LHS Milnathort

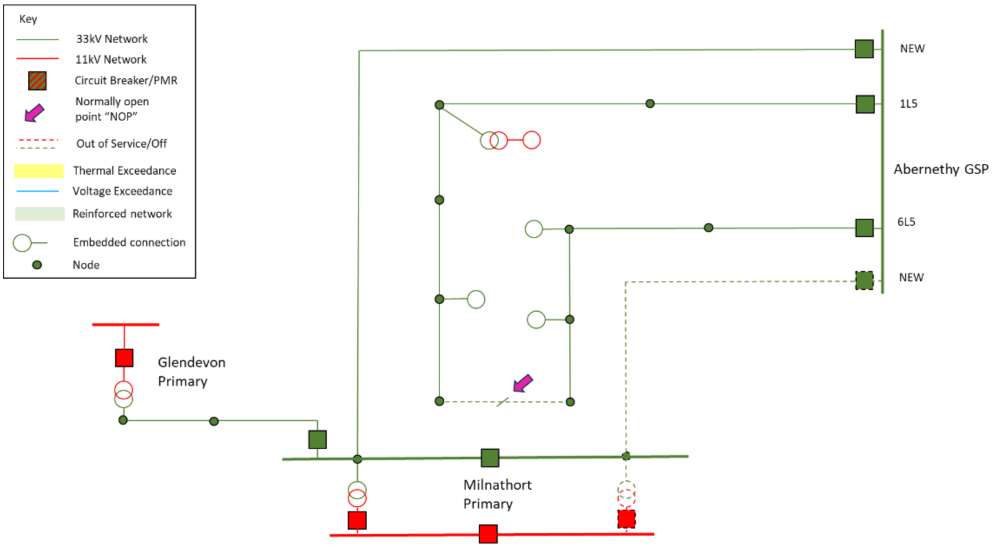


Figure 7.10 - Half Board outage RHS Milnathort

The table below is a summary of estimated costs based on Ofgem ED2 Unit Rates.

Table 7.1 Option 4 Asset Unit Rates

Asset Description	Volume	C0(a) Cost	C0(b) Cost
33kV UG Cable (Non Pressurised)	[redacted]		
33kV CB (Gas Insulated Busbars) (ID) (GM)			
33kV - TRAFO - 20/40MVA 33/11kV transformer			
2.5 MVAr reactor			
33kV OHL (Pole Line) Conductor			
33kV Pole			
33kV Switch (PM)			
Flex cost 2025			
Total Cost			

7.5 Option 5: Flexible Solution with reinforcement

Option 4 offers the most efficient traditional reinforcement solution and thus, it was used as a baseline reinforcement scenario to assess whether the use of flexibility to defer intervention to the network is more economic. This option was progressed to CBA and considered under CEM.

The technical solution for option 5 is identical to option 4 – the same reinforcement works are proposed, but the introduction of flexibility allows a deferment and therefore increase in value.

Based on the assumptions in section 5.7, the flexibility and related services were studied for the CT scenario over a 6 year period, to determine whether flexibility would be an option to solve the thermal issues.

[redacted] **The annual utilisation volumes provided by the internal DFES analysis tool are presented in**

[redacted]

Figure 7.11. Results correlate with the load data given in Section 5.2.

[redacted]

[redacted]

Flexibility is necessary to eliminate the exceedance and to ensure safe network operation. The calculated necessary flexibility in scope and time for the CT scenario is shown in table 7.5.

[redacted]

The results from the CEM tool to determine the use of flexibility to defer the investment are shown in [redacted]

As shown, the tool recommends a five year deferral in the CT scenario. [redacted] The tool suggests a further deferral to 2031. **According to the results above, any further deferral beyond 2031 will not add any benefits and will result in a worse NPV. However, the flex study suggests that there will not be suitable flex availability beyond 2027 and therefore the recommendation is to defer the reinforcement to 2027 only. This still results in a better NPV that option 4, although the advantage is much smaller.**

The table below is a summary of estimated costs based on the Ofgem ED2 Unit Rates. The costs are identical to those of option 4 [redacted]

Table 7.6 Option 5 Asset Unit Rates

Asset Description	Volume	C0(a) Cost	C0(b) Cost
33kV UG Cable (Non Pressurised)	[redacted]		
33kV CB (Gas Insulated Busbars) (ID) (GM)			
33kV - TRAFO - 20/40MVA 33/11kV transformer			
2.5 MVAr reactor			
33kV OHL (Pole Line) Conductor			
33kV Pole			
33kV Switch (PM)			
Flexibility 25-27			
Total Cost			

8 Cost Benefit Analysis (CBA)

8.1 CBA of investment options

Ofgem's RIIO-ED2 standard CBA template was used to assess costs and benefits. An overview of the options that are considered in the CBA are given in Table 8.1.

[redacted]

[redacted]

8.2 CBA Results

A CBA 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 Table 8.2Table 8.1.

Table 8.2 NPV of Options

Options	CBA Results (NPV) in £m				
	10 years	20 years	30 years	45 years	Whole Life NPV
Option 4 - Reinforcement of Existing assets and Network Reconfiguration	[redacted]				
Option 5 – Flexibility and Reinforcement					

[redacted] Given the cost activation years between 2025 and 2027 for the investments, and discount and pre-tax WACC rates specified above, this results in a lower NPV than the baseline reinforcement - option 4. This is because the two options are identical but option 4 requires an earlier investment into assets. Specifically, Option 5 recommends a three year deferral of reinforcement. This may not be viable as per the flex availability analysis presented [redacted] but any deferral leads to a reduction in NPV. As such, Option 5 is the preferred option.

9 Deliverability and Risk

The specific considerations for deliverability based on the scope of this EJP are detailed below:

- Low risk on the new 7-panel 33 kV switchboard – The proposed option involves the installation of a new 7-panel switching station at Milnathort Primary substation. Its has been confirmed that the 11kV board was recently replaced and as it was an offline build, the old switchroom is currently available and is believed to be suitable for this 33kV board. As such, no further land acquirement is required, avoiding the risk of land unavailability.
- Medium risk on cable installation - The proposed new 33kV cable routes from Abernethy GPS to Milnathort are very long (approx. 20km in total), but as this is an end to end installation there is greater flexibility in the route choice. The terrain between the two points is varied and there will be challenges establishing the best route.
- Low risk on Overhead line works. The installation of the new 1km OHL and NOP should be low risk – this is a standard installation on arable land.
- Medium risk on flex availability – The availability of flexibility at both Milnathort and Glendevon was assessed, with results indicating that there should be enough flexibility to cover the exceedance up to 2027. However, flexible services do not increase the network capacity permanently and there is the risk that they might not be in place to provide the flex required.

10 Outlook to 2050

Abernethy 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. 5.2% 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 preferred solution provides suitable thermal capacity for 2050 load projections on all replaced assets both network intact and N-1 scenarios. The Milnathort primary transformer cannot support the entire Glendevon network load for loss of one side of the board, but this issue will not present itself in 2050 as the Glendevon network will require significant intervention prior to 2050 in order to remain P2 compliant. For this reason, Milnathort will not be required to pick up the entire 2050 loading of Glendevon. Without Glendevon, the Milnathort primary transformers will be loaded to 92% by 2050. The incoming 33kV cables will be loaded to 77% under N-1 in 2050.

Under Network intact the network remains compliant to 2034. By 2035 there is a minor volage issue at Glendevon. There is a solution to correct this with minor intervention, but this is beyond the scope of this paper.

In order to remain fully compliant in 2050, the Glendevon network will likely require a 2nd transformer and dual 33kV circuits. Whilst this is beyond the scope of this paper, the solution does facilitate this change as we will be installing a suitable 33kV switchboard at Milnathort and 33kV cables which can deliver the required power. Adding an additional breaker at Milnathort will be the easiest solution to this issue and this is not something that is possible at present.

11 Conclusion and Recommendation

This Engineering Justification Paper outlines the proposal to reinforce and reconfigure part of the 33kV network at Abernethy GSP within the RIIO - ED2 price control period to address the projected thermal and voltage issues. [redacted] Option 5 is the best, most efficient, and cost-effective solution as per the Common Evaluation Methodology and Cost Benefit Analysis, and with the help of stakeholder engagement, whole system approach, and flexibility market analysis.

The load-related investment has been triggered by load growth projected by DFES, for the CT-W scenario. To correct the thermal overload for abnormal network scenarios, Option 5 has been selected as the preferred solution which utilises the available local flexibility and helps to delay the proposed reinforcement start date by three years. The summary of the proposed option can be found in Table 11.1.

Table 11.1 Summary of Recommended Option

Option	Advantage	Disadvantage	MVA release	Costs (C0(a) - £m)	Risks
Option 5 – Flexibility and Reinforcement	Most cost-effective And efficient option	Flexibility does not increase network capacity permanently, so additional costs need to be covered for flexibility.	57.3	[redacted]	Although the flex availability assessment, there is a risk that the required amount of flexibility might not be available.

Table 11.2: Option 5 Asset Unit Rates

Asset Description	Volume	C0(a) Cost	C0(b) Cost
33kV UG Cable (Non Pressurised)	[redacted]		
33kV CB (Gas Insulated Busbars) (ID) (GM)			
33kV - TRAFO - 20/40MVA 33/11kV transformer			
2.5 MVAr reactor			
33kV OHL (Pole Line) Conductor			
33kV Pole			
33kV Switch (PM)			
Flexibility 25-27			
Total Cost			

This investment to carry out the reinforcement works is being assigned to the South Caledonia Region for design refinement and project delivery. It is proposed that the works will start in 2023/2024 with estimated delivery in 2025/26.

12 References

The documents detailed in Table 12.1 - Scottish and Southern Electricity Networks Documents, Table 12.2 – External Documents, and

, should be used in conjunction with this document.

Table 12.1 - Scottish and Southern Electricity Networks Documents

Reference	Title
TG-NET-NPL-007	Planning Standard for 33kV and 22kV Distribution Networks
TG-NET-NPL-010	Planning Standard for 11kV and 6.6kV Distribution Networks
TG-NET-SST-026	Ratings of Oil-Filled Power Transformers
Ofgem/SSEN CEM tool	ON22-WS1A-P1 CEM Tool V 2.2 SSEN

Table 12.2 – External Documents

Reference	Title
ENA EREC P2	Security of Supply
Ofgem CBA tool	RIIO-ED2_Cost Benefit Analysis_Template_0

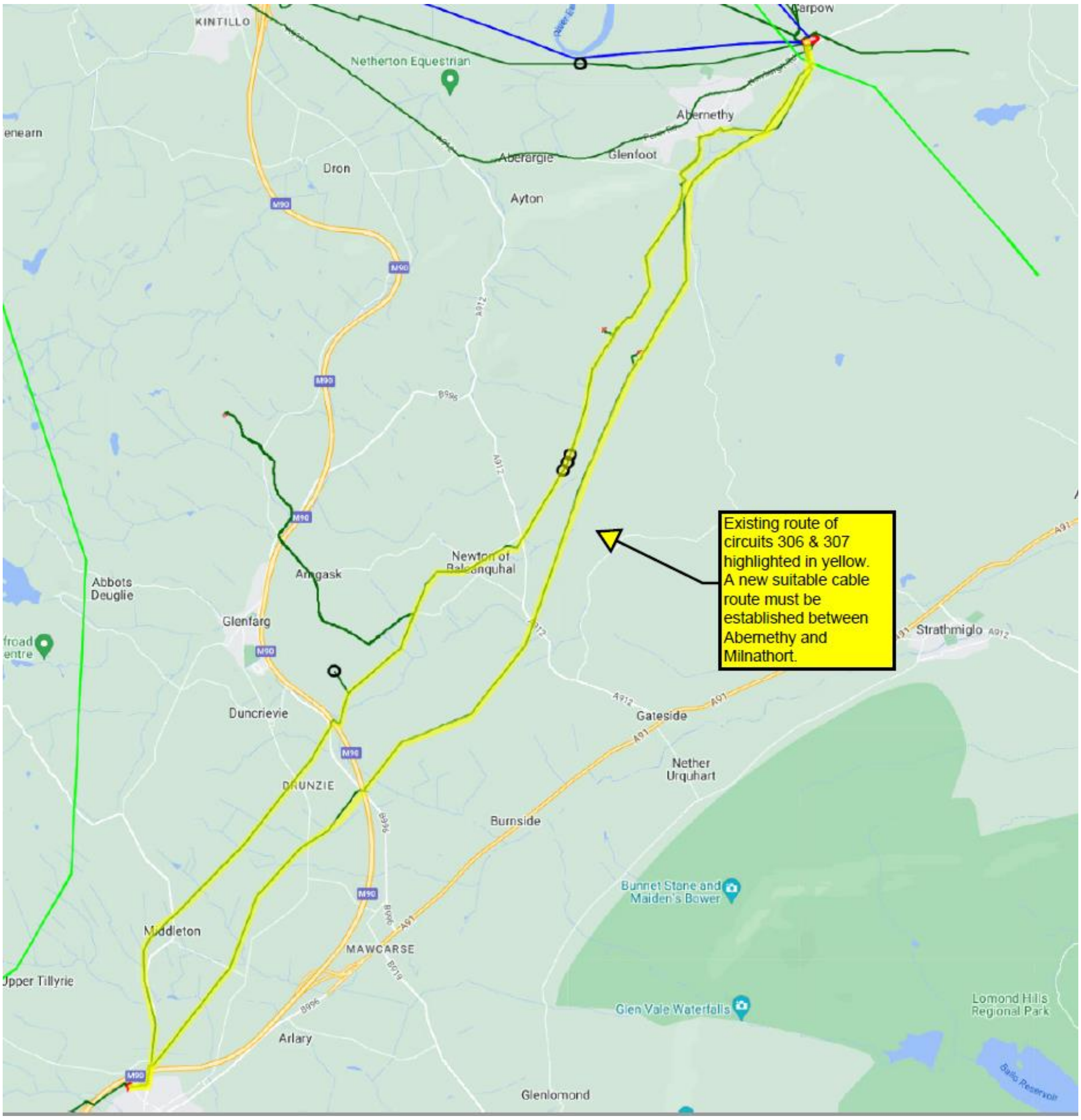
Appendix A Definitions and Abbreviations

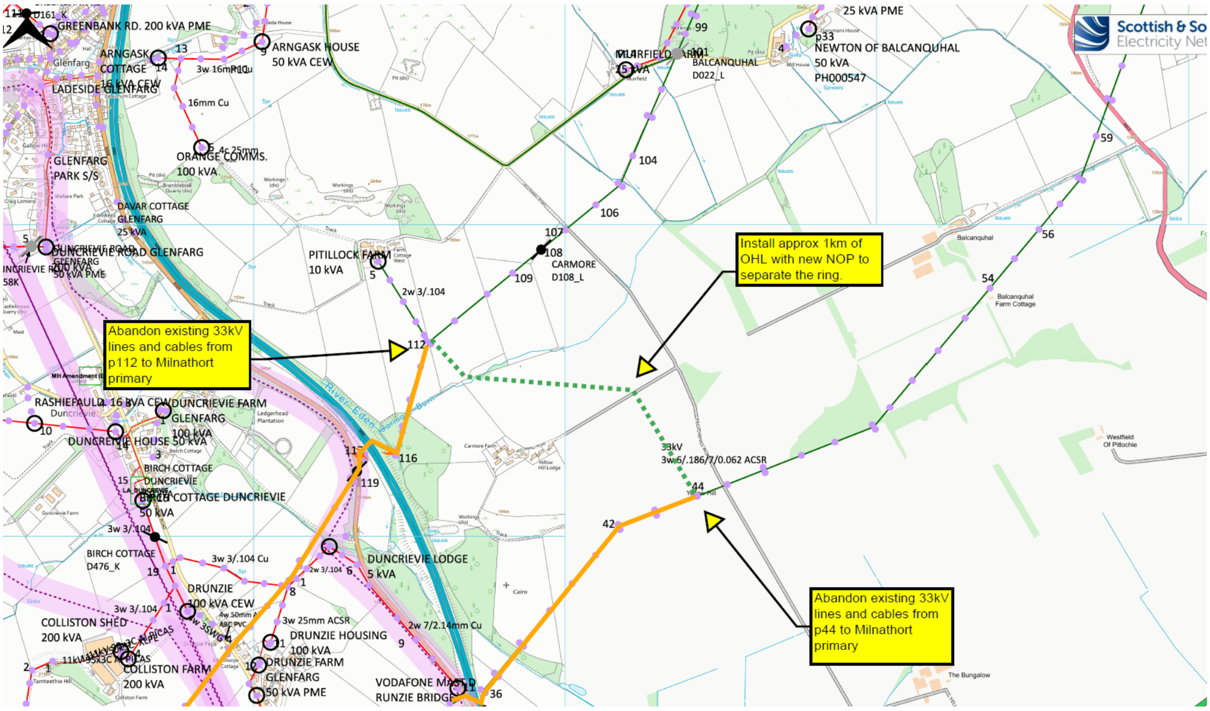
Table 12.3 – Definitions and Abbreviations

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 Network plans





Appendix C 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 12.4.

Table 12.4

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 deployment of flexibility and the reconfiguration of the 33kV network at Abernethy by 2028.

Figure 12.1 shows that by the time the reinforcement will be in completed the network will be constrained regardless of the distributed future energy scenario considered.

Once the reinforcement is complete in 2028, the investment will be large enough to meet the projected peak demand under all net-zero scenarios up to at least 2050.