WESTERN POWER DISTRIBUTION

Serving the Midlands, South West and Wales

Network Development Report

South Wales

April 2022

Contents

Introduction

The Network Development Reports cover targeted areas of the extra high voltage (EHV) and 132 kV distribution networks where developments are expected on the 0-10 year window. For information on the methodology used to undertake the studies and how stakeholder feedback is taken into account, please refer to the Network Development Plan Methodology Report. Each section follows a consistent format, as outlined below.

Network Overview

A summary of the network area studied. This includes geographic area, load composition and schematic diagrams of the area of network supplied.

Network Operability Modelling

As part of the network analysis, actions undertaken by network automation schemes and manual switching schemes are modelled. This ensures that following any outage combination which could occur, the subsequent topology of the network most closely represents how the distribution network is operated in real time. The network operability actions are written as a series of Python scripts, and triggered as part of the load flow routine either as a pre-emptive action (i.e. prior to load flow calculation) or as a remedial action (i.e. post load flow calculation).

This section summarises the network automation and manual switching schemes that are modelled.

Network constraint summary

Constraints identified on the area of network in focus are summarised in a concise way. Where a Bulk Supply Point or Grid Supply Point group is studied as a whole, each constraint within the group is captured as part of the same network group.

Constraint summary

Table which includes information about the nature of the constraint, including:

- **Constrained assets -** for the area in focus, this encompasses multiple parts of the network which are affected by the same underlying outage conditions. This could be summarised for multiple sections of a circuit or transformers operating as part of a group.
- **Type of constraint -** this could include thermal overloading of assets, voltages outside of statutory limits or demand disconnected for security of supply assessment;
- **Constrained condition** - prevailing load conditions whereby the constraint occurs, relating to the representative study periods which WPD cover in the Network Development Plan;
- **Limiting factor of constrained assets** – the rating of the asset which triggers the constraint; and
- **Outage combination which causes the constraint –** the combination of intact, first or second circuit outages that trigger the constraint. In areas of network with complex running arrangements the most critical outage combination is not evident, which necessitates the analysis methodology as outlined in the NDP Methodology Report.

Scenario identification

A table to outline the trigger years for constraints on the network area studied. This captures the earliest year that a network investment decision needs to be taken.

Solution options

A summary of the solutions which have been considered to alleviate the projected constraint. These are modelled for their technical suitability and are summarised in a table under the following categories:

- Reinforcement, covering new-build solutions to increase the capacity of the network in focus. This could include new assets or the removal of ancillary rating limitations on existing assets. In addition, the Network Development Plan analysis can highlight where additional substations could be established as an alternative solution for load growth as a more coordinated solution.
- Operational mitigation covers actions which WPD can take to mitigate constraints without the requirement for additional network capacity. This could include proposals to change running arrangements or limit access windows where arranged outages can be taken.
- Load Management Schemes cover plant, equipment and software systems that together manage network loading and voltages. This is achieved by either controlling demand and/or generation connected to the network, operating switchgear to change the topology of the network and/or controlling the settings of tap-change controllers, reactive compensation equipment and flexible power links. Load management schemes can be utilised to manage both demand and generation driven constraints, however this is dependent on the technical/contractual ability for customers to accept curtailment.
- Flexibility covers actions by network users (through contracts with the DNO) to reduce network loading for a given condition by increasing, reducing or shifting their net import or export.

Not all solution options are mutually exclusive to one another, a combination of different solutions can be utilised to undertake low regret investment. The appraisal of different solution options allows for a more coordinated assessment of future network developments to accommodate scenario projections.

Further optioneering will be carried out for all schemes, including a full cost benefit analysis using the Common Evaluation Methodology (CEM) tool as part of the Distribution Network Options Assessment (DNOA) process to assess the use of flexibility against conventional reinforcement (where flexibility is deemed a viable option). These decisions will be published in the next iteration of the DNOA.

Haverfordwest to Brawdy 33 kV Circuit

Figure 1: Pembroke North geographic network coverage

Network Overview

Forming part of the Pembroke group, the Haverfordwest 33 kV network operates in parallel with both Golden Hill and Milford Haven BSPs via several 33 kV circuits under intact network conditions. This Pembrokeshire 33 kV parallel group is currently supplied by five 132/33 kV Grid Transformers (GTs):

- Haverfordwest GT1, 132/33 kV 60/90 MVA
- Haverfordwest GT2, 132/33 kV 60/90 MVA
- Golden Hill GT1, 132/33 kV 60/90 MVA
- Golden Hill GT1, 132/33 kV 60/90 MVA
- Milford Haven GT1, 132/33 kV 22.5/45 MVA

In North Pembrokeshire, a 33 kV ring is formed via two 33 kV overhead line circuits from Haverfordwest BSP, supplying the following 33/11 kV Primary substations:

- Brawdy, St Davids, Fishguard and Nevern
- St Davids is supplied by a single 33/11 kV transformer

33 kV circuits are connected directly from Haverfordwest BSP to Brawdy Primary, directly from Haverfordwest to Fishguard Primary and between Brawdy Primary and Fishguard Primary. St Davids Primary and Nevern Primary are fed via single 33 kV circuits from Brawdy and Fishguard respectively.

It is possible to transfer Nevern Primary out of the Pembrokeshire 33 kV group and into the Swansea North group via an alternative 33 kV connection into the Rhos 33 kV network.

There are existing generation connections to both the 33 kV and 11 kV networks in the area and geographically this area has significant renewable energy potential for further growth.

Network Operability Modelling

The following network automation and manual switching schemes have been modelled in the analysis of this area, aligning to how the network is currently operated:

- Under intact network conditions, four 33/11 kV Primary substations operate in a 33 kV ring network supplied via Haverfordwest BSP.
- This North Pembrokeshire 33 kV ring network has one point of interconnection and this is with the Rhos 33 kV network. This is to support the Haverfordwest group by reducing the group demand in line with arranged outage conditions and as such Nevern Primary can be transferred into the Rhos 33 kV network.
- Curtailment of 33 kV connected generators within the group are modelled at a variety of arranged outages, as outlined in customer connection agreements.
- Network automation has been modelled on this basis.

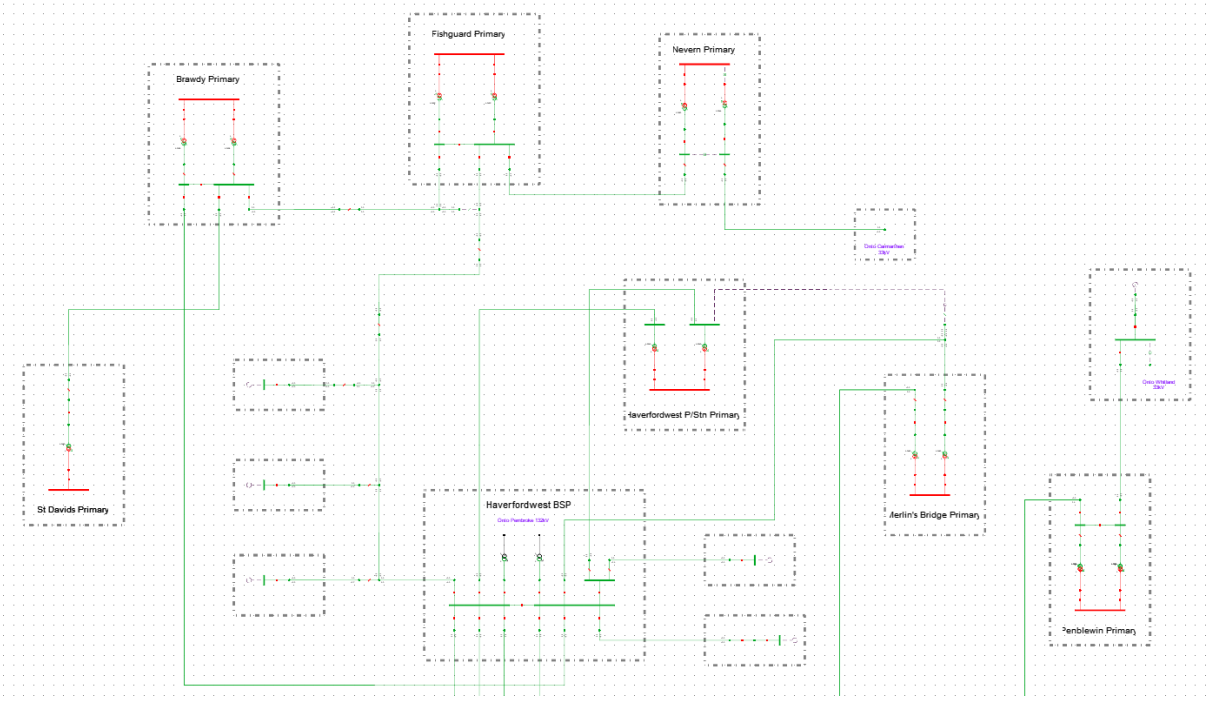

Figure 2: Pembroke North 33 kV network schematic diagram

Future Network Constraints

Haverfordwest - Brawdy/Fishguard/Nevern/St Davids 33 kV Network

For a first circuit outage (FCO) condition which results in the loss of either Haverfordwest to Brawdy or Haverfordwest to Fishguard 33 kV circuit, the remaining circuit in service picks up the group demand. In line with future growth scenarios, these circuits will begin to experience thermal overload. Haverfordwest to Brawdy 33 kV becomes overloaded in 2025 under the Leading the Way scenario, with both circuits experiencing thermal overload in 2028. If the demand at Nevern could be transferred out of the group, the thermal capacity of the existing circuits would be reached in 2028.

FCO conditions would also cause voltages at the remote ends of the circuits to fall below statutory limits. For an outage of the existing Haverfordwest to Brawdy circuit, low voltages would occur at St Davids, whereas for an outage of the Haverfordwest to Fishguard circuit, low voltages would occur at Nevern and Fishguard. This is due to the magnitude of demand and impedance of the long overhead line circuits resulting in excessive volt drop.

Constraint summary

Generation | **Demand**

The table below outlines the nature of the network constraints identified in the network analysis.

Constrained assets	33 kV circuits between Haverfordwest BSP and Brawdy Primary substation and Haverfordwest to Fishguard Primary substation	
Type(s) of constraint	Thermal overload and voltage excursions outside statutory limits	
Constrained condition(s)	Winter Peak Demand Intermediate Warm Peak Demand (from 2028) Summer Peak Demand (from 2028)	
Limiting factor of constrained assets	The Haverfordwest to Brawdy 33 kV Circuit has a winter rating of 17.8 MVA. The Haverfordwest to Fishguard 33 kV Circuit has a winter rating of 19.1 MVA.	
Outage combination which causes the constraint	First Circuit Outage	For the arranged or fault outage of one of the circuits which feeds into this 33 kV group, the remaining circuit in service could overload.

Scenario identification

The table below highlights when the constraint occurs during the 0-10 year period across the different scenarios studied from the 2021 Distribution Future Energy Scenarios.

Scenario	Study year			
	Baseline	**2025**	**2028**	**2032**
Steady Progression				✓
System Transformation				✓
Consumer Transformation			✓	✓
Leading the Way		✓	✓	✓
WPD Best View			✓	✓

Solution options

All of the solutions identified below could alleviate the projected constraints in all scenarios out to 2032 subject to cost benefit analysis.

Solution option	Summary
Reinforcement	Installation of a new 33 kV circuit between Haverfordwest BSP and Brawdy Primary substation to alleviate the projected overloads / limitations across the forecast load growth period under FCO conditions. A circuit length of approximately 16.3 km would be required, assumed predominantly as overhead line construction with underground cable sections. This reinforcement strategy would also improve network security and resilience under SCO conditions. Currently, this North Pembrokeshire ring is vulnerable to SCO conditions. If a fault occurred on the Haverfordwest to Brawdy 33 kV circuit when the Fishguard circuit was out of service for planned maintenance then all supplies to the North Pembrokeshire group would be lost. It may be possible to restore Nevern Primary substation and some demand at Fishguard or Brawdy using the interconnection with the Rhos BSP 33 kV group. However, due to the thermal rating of the circuit and voltage limitations it would not be possible to restore all load until one of the Brawdy or Fishguard circuits from Haverfordwest could be returned to service. To facilitate this new 33 kV connection to Brawdy, it would be necessary to install an indoor Gas-Insulated Switchgear (GIS) 33 kV switchboard to replace the existing outdoor arrangement at Haverfordwest BSP as currently there are no options for additional circuit breaker bays within the existing design. This option is expected to add a further 18 MVA of capacity, with a new firm capacity of 35.8 MVA.
Operational mitigation	It is noted that there are limitations to the existing technique of voltage analysis. The reactive behaviour of load, in particular projected load, modelled at the 11 kV bars of Primary substations does not take detailed account of the reactive behaviour of individual customers nor the effects of secondary network impedance. Development of load survey and analysis techniques will enable the materiality of these effects to be better understood.
Load Management Schemes	Any additional connections into this group may be included in an Active Network Management (ANM) scheme, which could also be utilised to manage constraints on over-committed networks.
Flexibility services	Flexibility services could be procured via a ‘Secure’ product to help alleviate projected overloads, but this will become less effective and economical as the demand grows in the area. Dispatch of services may be required for extended periods of time at peak demand.

Fishguard 33/11 kV Primary Transformer Capacity

For a first circuit outage (arranged or fault) which results in the loss of either Fishguard 33/11 kV Primary Transformer, the remaining transformer in service begins to overload in 2028 under the WPD Best View, Consumer Transformation and Leading the Way scenarios.

Constraint

Generation Demand

The table below outlines the nature of the network constraints identified in the network analysis.

Constrained assets	Fishguard 33/11 kV T1 Fishguard 33/11 kV T2	
Type(s) of constraint	Thermal overload	
Constrained condition(s)	Winter Peak Demand Intermediate Warm Peak Demand (LW 2028) Summer Peak Demand (LW 2028)	
Limiting factor of constrained assets	Fishguard 33/11 kV T1 (10/14 MVA) Fishguard 33/11 kV T2 (10/14 MVA)	
Outage combination which causes the constraint	First Circuit Outage	FCO (arranged or fault) which results in the loss of either Fishguard Primary Transformer

Scenario identification

The table below highlights when the constraint occurs during the 0-10 year period across the different scenarios studied from the 2021 Distribution Future Energy Scenarios.

Scenario	Study year			
	Baseline	**2025**	**2028**	**2032**
Steady Progression				
System Transformation				
Consumer Transformation			✓	✓
Leading the Way			✓	✓
WPD Best View			✓	✓

Solution options

All of the solutions identified below could alleviate the projected constraints in all scenarios out to 2032 subject to cost benefit analysis.

Solution option	Summary
Reinforcement	Replacing both Fishguard Primary Transformers with larger 12/24 MVA units (including removal of any ancillary rating limitations) will alleviate any of the projected overloads in the 0-10 year period for the projected load growth.
Operational mitigation	As constraint could occur during a first circuit fault outage condition, operational mitigation is not possible.
Load Management Schemes	Any additional connections into this group may be included in an ANM scheme, which could also be utilised to manage constraints on over-committed networks.
Flexibility services	Generation turn up or demand turn down services could be procured to alleviate projected circuit overloads but this will become less effective and economical as the demand grows in the area. Dispatch of services may be required for extended periods of time at peak demand. The product recommended for this network condition would be secure to procure demand reduction.

St Davids 33/11 kV Firm Capacity

St Davids is connected via a 33 kV circuit to Brawdy Primary, supplied via Haverfordwest BSP. The substation is supplied by a single 5/6.25 MVA 33/11 kV transformer and is reliant on 11 kV interconnection to Brawdy for the loss of supply to its transformer. The 11 kV interconnection has not been studied in detail, further analysis of the 11 kV network in St Davids / Brawdy would be required to fully analyse the transfer capability.

In the scenario projections, a large amount of marine generation is expected to connect at St Davids. If the expected generation is to connect at 11 kV, additional Primary capacity would be required. However; a 33 kV connection may be more suitable for the expected development. This would alleviate generation driven constraints in the area.

For intact running conditions, the Primary Transformer begins to overload from 2025 under the Consumer Transformation and Leading the Way scenarios.

Constraint summary

Generation Demand

The table below outlines the nature of the network constraints identified in the network analysis.

Constrained assets	St Davids 33/11 kV Primary Transformer 5/6.25 MVA	
Type(s) of constraint	Thermal overload	
Constrained condition(s)	Summer Peak Generation	
Limiting factor of constrained assets	St Davids 33/11 kV Primary Transformer 5/6.25 MVA	
Outage combination which causes the constraint	Intact	Generation overloads driven on intact network due to the large amount of marine embedded generation connected.

Scenario identification

The table below highlights when the constraint occurs during the 0-10 year period across the different scenarios studied from the 2021 Distribution Future Energy Scenarios.

Scenario	Study year			
	Baseline	**2025**	**2028**	**2032**
Steady Progression				
System Transformation				
Consumer Transformation		✓	✓	✓
Leading the Way		✓	✓	✓
WPD Best View				

Solution options

All of the solutions identified below could alleviate the projected constraints in all scenarios out to 2032 subject to cost benefit analysis.

Solution option	Summary
Reinforcement	Installation of a second 33/11 kV transformer at St Davids Primary will alleviate any of the projected overloads in the 0-10 year period for the projected load growth. This improves network resilience and reduces the dependency on 11 kV interconnectivity under FCO conditions. This proposal will also require the installation of a new approximate 12.5 km 33 kV circuit to Brawdy Primary including a new 33 kV circuit breaker and associated equipment to facilitate connection at Brawdy. To facilitate this new 33 kV connection to Brawdy, it would be necessary to install an indoor Gas-Insulated Switchgear (GIS) 33 kV switchboard to replace the existing outdoor arrangement at Brawdy Primary as currently there are no options for additional circuit breaker bays within the existing design.
Operational mitigation	As constraint could occur during a first circuit fault outage condition, operational mitigation is not possible.
Load Management Schemes	Any additional connections into this group may be included in an ANM scheme, which could also be utilised to manage constraints on over-committed networks.
Flexibility services	Flexibility services could be procured to help alleviate projected overloads. Dispatch of services may be required for an extended period of time given the first circuit outage constraint.

Llanfyrnach Primary

Figure 3: Llanfyrnach Primary geographic network coverage

Network Overview

Llanfyrnach Primary is fed from Carmarthen BSP and supplies an area of 11 kV network in South Wales, North West of Carmarthen. Llanfyrnach is supplied by a single 33 kV circuit via the St Clears - Whitland 33 kV circuit. There is a single 5 MVA transformer at the site.

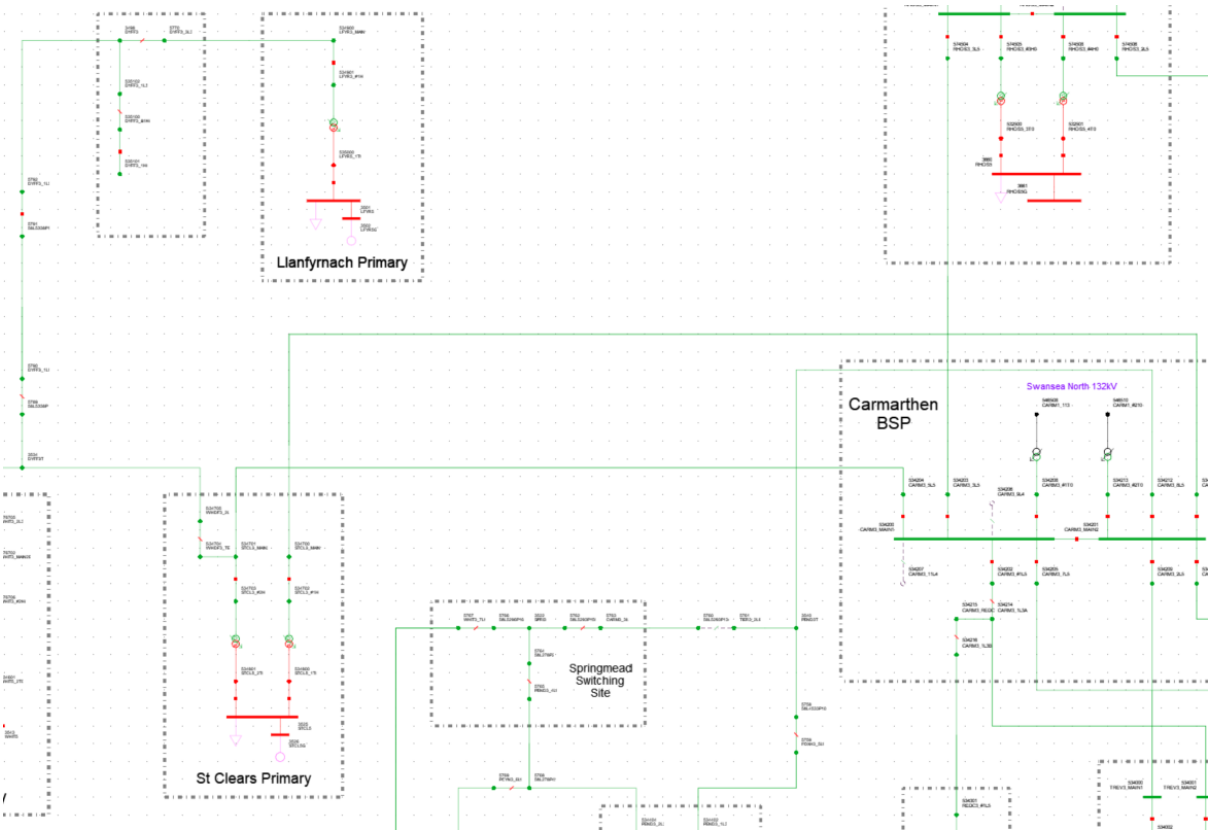

Figure 4: Llanfyrnach Primary 33 kV network schematic

Llanfyrnach Primary Transfer Capacity

Constraint summary

Generation Demand

The table below outlines the nature of the network constraint identified in the network analysis. For an outage (arranged of fault) of the circuit feeding a 33 kV generation customer and Llanfyrnach Primary, the alternative feed is through an 11 kV back feed arrangement. When the group demand minus 1 MVA exceeds the capacity currently restorable via 11 kV interconnection, the group is not compliant with demand security of supply requirements. This constraint occurs in 2028 under the WPD Best View, Leading the Way and Consumer Transformation, and 2032 under Steady Progression and System Transformation.

Constrained assets	Group Demand and transfer capacity	
Type(s) of constraint	Demand Security of Supply	
Constrained condition(s)	Demand security assessment made using annual group demand peak.	
Limiting factor of constrained assets	1.8 MVA back feed capacity of 11 kV back feed arrangement	
Outage combination which causes the constraint	First Circuit Outage	For the arranged or fault outage of the 33 kV circuit that feeds into this group, the 11 kV back feed capacity would be exceeded.

Scenario identification

The table below highlights when the constraint occurs during the 0-10 year period across the different scenarios studied from the 2021 Distribution Future Energy Scenarios.

	Study year			
Scenario	**Baseline**	**2025**	**2028**	**2032**
Steady Progression				✓
System Transformation				✓
Consumer Transformation			✓	✓
Leading the Way			✓	✓
WPD Best View			✓	✓

Solution options

The following solution options could resolve the constraint described above. Any final solution will be subject to a cost benefit analysis.

Solution option	**Summary**
Reinforcement	Installation of a second 33 kV circuit and a new 5 MVA transformer at Llanfyrnach Primary. The shortest circuit route would be from St Clears Primary. Alternative reinforcement options could include increasing the 11 kV back feed capacity which would be possible until the group demand exceeds 12 MW, where the demand security restoration requirements would change.
Operational mitigation	Operational mitigation is exhausted as the 11 kV back feed capacity has been exceeded.
Load Management Schemes	Not applicable.
Flexibility services	Demand turn down and/or generation turn up services via a ‘Secure’ product could be procured to support 11 kV transfer capacity. However, the amount of flexibility services required is highly dependent on the location as this impacts the 11 kV transfer capacity.

Swansea North GSP

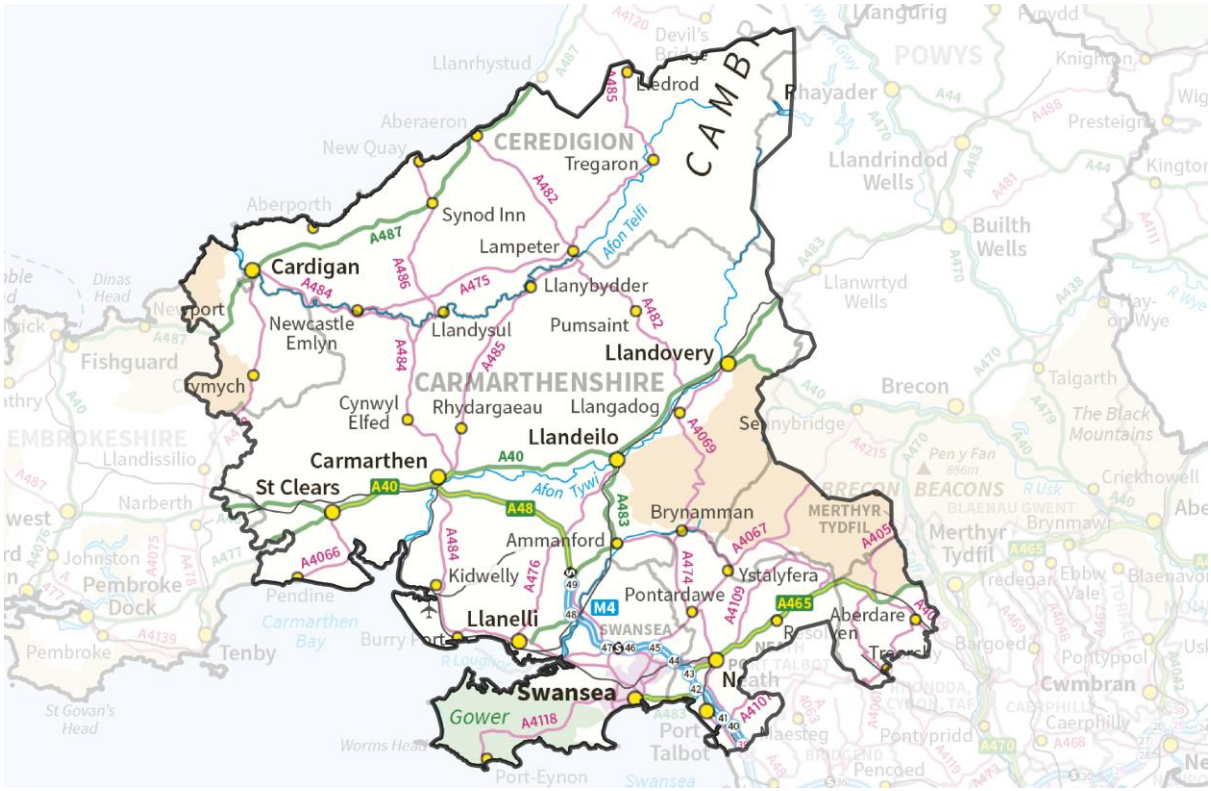

Figure 5: Swansea North 132 kV network coverage

Network Overview

Swansea North Grid Supply Point (GSP) is the largest of nine GSPs in South Wales and is supplied from the interconnected 275 kV and 400 kV National Grid network. The group supplies a total of 345,000 customers and a further 23,000 customers in the SPEN (Manweb) Aberystwyth and Rhydlydan areas. The existing connected demand and generation at Aberystwyth and Rhydlydan is modelled; however the analysis does not account for projected demand growth on other Distribution Network Operator (DNO) areas.

This network is normally run standalone and has ten outgoing 132 kV circuits supplying numerous Bulk Supply Points (BSPs), whilst also benefiting from points of interconnection to Pembroke GSP, Pyle GSP and Upper Boat GSP. Swansea North GSP comprises three 240 MVA 400/132 kV SGTs, two 180 MVA 275/132 kV SGTs and an interconnecting 400/275 kV SGT.

Swansea North GSP also has three local 132/33 kV Grid Transformers supplying a 33 kV network.

Under intact network conditions, Swansea North GSP normally operates with three 240 MVA SGTs and one 180 MVA SGT in service which results in a total transformer capacity of 900 MVA.

Swansea North GSP feeds a large geographic area which has significant renewable energy potential, however, recent network activity has meant that the site has reached both physical and technical limits. The existing design elements now needing management at Swansea North include the following:

- Physical space restrictions for creation of any further 132 kV bays.
- Thermal and voltage limitations on 132 kV circuits.
- Complexity of 132 kV circuits.

- Reverse Power flow restrictions for Super Grid Transformers under the Swansea North Transmission Active Network Management (TANM) system.
- Design of maximum amount of load to be lost (300 MW) for system integrity checks at 132 kV busbar.

Network Operability Modelling

The following network automation and manual switching schemes have been modelled in the analysis of this area, aligning to how the network is currently operated:

- At Swansea North GSP, there is a 400 kV double busbar that supplies three 240 MVA 400/132 kV Super Grid Transformers (SGTs), SGT5, 6 and 7. On a separate 400 kV circuit, there is a 400/275 kV SGT4A which feeds a further two 275/132 kV SGTs (SGT3 and 4B). The five 132 kV connected SGTs supply a 132 kV double busbar arrangement. This 132 kV board runs with a vertical split with SGT5 and SGT6 connected to the Main 1 and Reserve 1 bars and SGT3 and SGT7 connected to the Main 2 and Reserve 2 bars. SGT4B is run on hot standby with an auto-close scheme in place.
- Pyle GSP and Swansea North GSP are run independently at 132 kV, with the VE-route circuit offering interconnection between the two GSPs, which is held normally open on line breaker 405 at Pyle GSP. This is to support the Pyle group for a Pyle SGT outage.
- Upper Boat GSP and Swansea North GSP are run independently at 132 kV, with the D-route offering interconnection between the two GSPs, which is held normally open on line breakers 305 and 405 at Hirwaun BSP. Interconnection is primarily used to improve supply security.
- Pembroke GSP and Swansea North GSP are run independently at 132 kV, with the A-route circuit offering interconnection between the two GSPs, which is held normally open on line breaker 405 at Haverfordwest BSP.
- For an arranged outage of an SGT at Pembroke, this interconnecting circuit (between Haverfordwest 405 and Carmarthen 805) is switched in to parallel Swansea North and Pembroke at 132 kV. The circuit breaker at Haverfordwest is fitted with overload protection, which is intended to operate when the circuit loading is above 500 A (Definite Time (DT), 3 seconds), a condition which could happen for a double SGT outage SCO condition.
- For an arranged outage of the circuit between Swansea North-Carmarthen-Rhos (which is carried on numerous 132 kV circuits), the normally open A-route circuit between Carmarthen and Haverfordwest is switched in to provide support to the Carmarthenshire network from Pembroke. When this arranged outage is followed by a circuit fault between Carmarthen and Llanelli, both of the 132 kV circuits from Swansea North to Carmarthen are lost and the group is entirely fed via Pembroke at 132 kV.
- Curtailment of connected generators within the group are modelled at a variety of arranged outages, as outlined in customer connection agreements.

Network automation has been modelled on this basis.

Swansea North 132 kV network schematic diagram can be viewed in Appendix 1.

Future Network Constraints

Swansea North 132 kV Group

The most onerous FCO would be the loss of the 400/275 kV SGT4A on the basis that it supplies two 275/132 kV 180 MVA SGTs. As a result, the substation firm capacity under FCO conditions is 720 MVA (SGT5, 6 and 7 in service). This firm capacity is met under the Consumer Transformation and Leading the Way 2028 scenarios.

The most onerous Second Circuit Outage (SCO) would be an FCO of SGT4A followed by the fault of one of the remaining 240 MVA SGTs. As a result the substation firm capacity under SCO conditions is 480 MVA. The GSP will only be supplied by the remaining two 400/132 kV 240 MVA SGTs. Under such scenario, the only demand transfer that could be made while still maintaining firm security of supply would be to transfer Hirwaun and Travellers Rest Bulk Supply Points (BSPs) onto Upper Boat GSP.

Constraint summary

The table below outlines the nature of the network constraints identified in the network analysis.

Constrained assets	Swansea North Firm Capacity (SGT ratings)	
Type(s) of constraint	Thermal overload	
Constrained condition(s)	Winter Peak Demand	
Limiting factor of constrained assets	The group is limited by SGT ratings in service for the outage combination. Under First Circuit Outage conditions, the capacity of the group is 720 MVA, for a Second Circuit Outage the capacity of the group is 480 MVA.	
Outage combination which causes the constraint	First Circuit Outage	For the outage of SGT4A at Swansea North GSP.
	Second Circuit Outage	For the arranged outage of SGT4A followed by a subsequent fault to one of the remaining 240 MVA SGTs also at Swansea North GSP.

Scenario identification

The table below highlights when the constraint occurs during the 0-10 year period across the different scenarios studied from the 2021 Distribution Future Energy Scenarios.

First Circuit Outage Constraints

Scenario	Study year			
	Baseline	2025	2028	2032
Steady Progression				
System Transformation				✓
Consumer Transformation			✓	✓
Leading the Way			✓	✓
WPD Best View				✓

Second Circuit Outage Constraints

The Second Circuit Outage constraint is modelled with Hirwaun and Travellers Rest BSPs transferred out of the group.

Scenario	Study year			
	Baseline	2025	2028	2032
Steady Progression			✓	✓
System Transformation		✓	✓	✓
Consumer Transformation		✓	✓	✓
Leading the Way		✓	✓	✓
WPD Best View			✓	✓

Solution options

All of the solutions identified below could alleviate the projected constraints in all scenarios out to 2032 subject to cost benefit analysis.

Solution option	Summary
Reinforcement	To alleviate the projected overloads at Swansea North GSP, a reinforcement strategy is proposed that considers the complex nature of the Carmarthenshire and West Wales 132 kV network. Swansea North is already a large GSP with five 132 kV connected SGTs, ten outgoing circuits and three local GTs. Given the large geographic area supplied and the distribution of future demand growth, it may be more appropriate to establish a new GSP to transfer load away instead of expanding Swansea North further. Ferryside GSP, where National Grid's 400 kV circuit from Pembroke to Walham crosses the 132 kV B-route approximately 6km south of Carmarthen BSP was modelled as a potential location for a new GSP. Supplies to Carmarthenshire and West Wales are transferred onto the new GSP via the existing B-route and EE-route circuits. The establishment of a new GSP in the Ferryside area is believed to be the best solution for the longer-term needs for this part of the South Wales network. • The new GSP would feature two 400/132 kV, 240 MVA SGTs which would provide 240 MVA of capacity for both demand and generation connections and for de-loading Swansea North GSP. • A new GSP will allow better management of power flows between Pembroke and Swansea North and the interconnection into the Aberystwyth and Rhydlydan area. • This would result in less curtailment for generator connections currently participating within the Swansea North TANM system. • The new GSP substation would have multiple spare 132 kV bays which would facilitate the connection of large scale demand or generator connections. • A new GSP between Swansea North and Pembroke would reduce the complexity of several 132 kV circuits and alleviate the existing issues with circuit complexity. Both WPD 132 kV and transmission 400 kV circuit assets are in close physical proximity in the Ferryside area and so this is deemed a natural starting point to consider a new GSP substation. Alternative conventional reinforcement solutions are possible, however, these require detailed whole system studies in collaboration with NGET and SPEN. This could be progressed through a Regional Development Plan (RDP).
Operational mitigation	Swansea North GSP currently benefits from 132 kV interconnection with adjacent GSPs at Pembroke, Pyle and Upper Boat. The only demand transfer that could be made currently while still maintaining firm security of supply would be to transfer Hirwaun and Travellers Rest on to Upper Boat GSP. However this load transfer is exhausted from 2025 in some scenarios.
Load Management Schemes	Very limited due to any future development of significant demand or generation growth now requires that Swansea North GSP and the 132 kV network that it serves is considered for expansion and reorganisation.
Flexibility services	Flexibility services could be procured to help alleviate projected overloads, but this will become less effective and economical as the demand grows in the area. Dispatch of services may be required for extended periods of time at peak demand. The product recommended for this network condition would be Secure to procure demand turn down and/or generation turn up services.

Ravenhill Primary

Figure 6: Ravenhill Primary geographic network coverage

Network Overview

Ravenhill Primary substation is fed from Swansea West Bulk Supply Point (BSP) via two 33 kV underground cables and supplies over 13,500 customers in the Swansea area. Ravenhill Primary has two transformers, both of which are fed from Swansea West BSP.

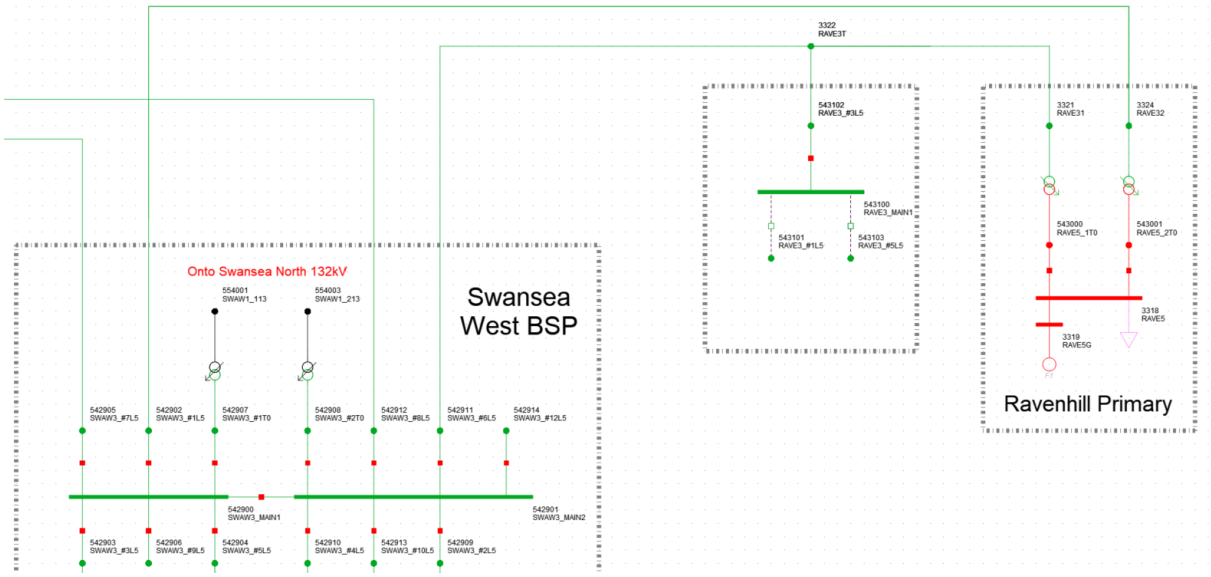

Figure 7: Ravenhill Primary 33 kV network schematic

Ravenhill Transformer Capacity

Constraint summary

Generation Demand

The table below outlines the nature of the network constraint identified at Ravenhill Primary identified in the network analysis. For an outage (arranged or fault) of the T1 Ravenhill circuit, the alternative feed is through the remaining transformer T2 in service. Network constraints occur in 2028 (Leading the Way and WPD Best View) and 2032 (all scenarios) during Winter Peak Demand and Intermediate Warm Peak Demand. The constraint also occurs for Summer Peak Demand in Leading the Way in 2032 onwards. In addition, thermal overloads on transformer T1 also occur in 2032 under the Leading the Way and WPD Best View scenarios.

Constrained assets	Ravenhill 33/11 kV Primary Transformers	
Type(s) of constraint	Thermal overload	
Constrained condition(s)	Winter Peak Demand Intermediate Warm Peak Demand Summer Peak Demand	
Limiting factor of constrained assets	10/14 MVA T2 transformer capacity at Ravenhill 12/24 MVA T1 transformer capacity at Ravenhill	
Outage combination which causes the constraint	First Circuit Outage	As the demand grows to exceed the seasonal rating of T2, the outage (arranged or fault) of T1 results in overloads on the T2 transformer. In 2032 as demand grows to exceed the seasonal rating of T1, an outage of either circuit feeding a transformer at Ravenhill will result in an overload on the opposite transformer.

Scenario identification

The table below highlights when the constraint occurs during the 0-10 year period across the different scenarios studied from the 2021 Distribution Future Energy Scenarios.

Scenario	Study year			
	Baseline	**2025**	**2028**	**2032**
Steady Progression				✓
System Transformation				✓
Consumer Transformation				✓
Leading the Way			✓	✓
WPD Best View			✓	✓

Solution options

The following solution options could resolve the constraint described above. Any final solution will be subject to a cost benefit analysis.

Solution option	Summary
Reinforcement	Undertake remedial works to allow transformer T2 at Ravenhill to operate to the full cyclic rating capabilities. Upon completion of the ancillary rating works, the capacity of the transformer T2 will be increased to 14.5 MVA. The existing transformer T2 requires replacement in 2028 with a unit of equal capacity to T1 (12/24 MVA) to prevent thermal overloads under a first circuit outage. With both transformers being 12/24 MVA, further load growth in the area shows under the Leading the Way scenario the transformer capacity will be exceeded in 2032. This should be considered when deciding on the rating for any replacement of transformer T2. The T1 transformer currently has ancillary rating limits which once checks and remedial works are carried out will be removed allowing it to operate to its full cyclic rating capability. As opposed to increasing the capacity of both transformers further past 12/24 MVA once they become overloaded in 2032, an additional Primary could be established to deload Ravenhill and alleviate further thermal overloads.
Operational mitigation	To reduce the group demand, an 11 kV interconnection could be constructed to allow permanent transfers out of the group. Further studies into the feasibility of this would need to be conducted to determine whether other Primary substations have capacity.
Load Management Schemes	Any additional connections into this group may be included in an ANM scheme, which could also be utilised to manage constraints on over-committed networks.
Flexibility services	Flexibility services would be needed for extended periods at times of peak demand. The product recommended for this network condition is Secure to procure demand reduction or generation turn up.

Ravenhill Circuit Capacity

Constraint summary

Generation Demand

The table below outlines the nature of the network constraint identified at Ravenhill Primary identified in the network analysis. The FCO constraint where the circuits feeding Ravenhill Primary are overloaded occurs in 2032 during Winter Peak Demand and Intermediate Warm Peak Demand for Leading the Way and WPD Best View.

Constrained assets	Swansea West to Ravenhill 33 kV circuits	
Type(s) of constraint	Thermal overload	
Constrained condition(s)	Winter Peak Demand Intermediate Warm Peak Demand	
Limiting factor of constrained assets	Circuit capacity of both circuits feeding Ravenhill Primary	
Outage combination which causes the constraint	First Circuit Outage	FCO along either of the Swansea West – Ravenhill circuits causes the alternative circuit to be overloaded

Scenario identification

The table below highlights when the constraint occurs during the 0-10 year period across the different scenarios studied from the 2021 Distribution Future Energy Scenarios.

Scenario	Study year			
	Baseline	**2025**	**2028**	**2032**
Steady Progression				
System Transformation				
Consumer Transformation				
Leading the Way				✓
WPD Best View				✓

Solution options

The following solution options could resolve the constraint described above. Any final solution will be subject to a cost benefit analysis.

Solution option	Summary
Reinforcement	Uprating a 43 m limiting stretch of each of the circuits feeding Ravenhill Primary to increase the line rating from 20.46 MVA to 27.2 MVA. This will ensure the full capacity of the Ravenhill Primary Transformers can be utilised. Despite uprating the limiting stretch of the circuits, the circuits will still be overloaded; however, reconductoring the circuit further would have a high economic cost due to the length of the circuit. Another reinforcement option is to build a new Primary to feed some of the demand within the Ravenhill area, which will remove the 2032 thermal overload conditions for the transformers at Ravenhill Primary as discussed in the previous section.
Operational mitigation	To reduce the group demand, an 11 kV interconnection could be constructed to allow permanent demand transfer out of the group. Further studies into the feasibility of this would need to be conducted to determine whether other Primary substations have capacity.
Load Management Schemes	Any additional connections (demand or generation) into this group could be included in an ANM scheme, which can be utilised to manage constraints on over-committed networks.
Flexibility services	Flexibility services would be needed for extended periods at times of peak demand. The product recommended for this network condition is Secure to procure demand reduction or generation turn up.

Aberdare Primary

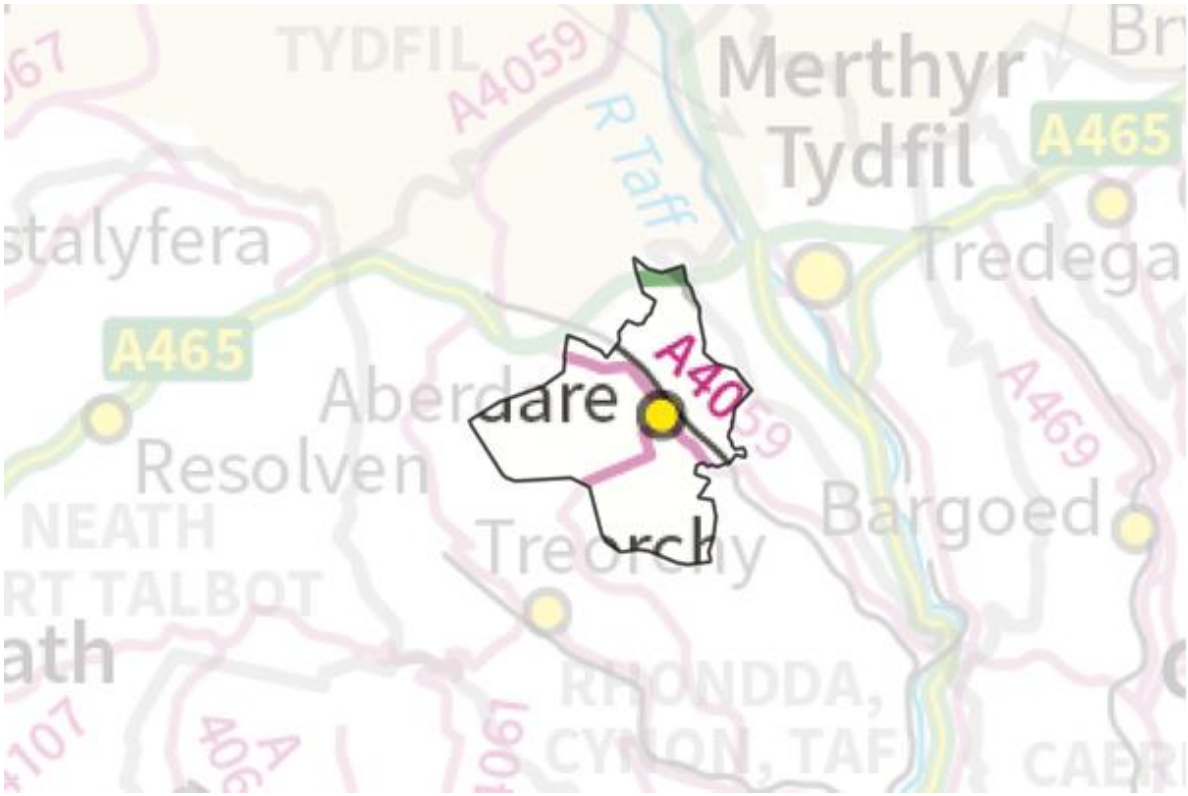

Figure 8: Aberdare Primary geographic network coverage

Network Overview

Aberdare Primary is a dual transformer Primary substation supplied from Hirwaun 33 kV via two 33 kV circuits and supplies over 14,500 customers in Aberdare Town and the surrounding area. The Hirwaun 6L5 circuit has a rating of 22.75 MVA and the 1L5 circuit has a rating of 17.6 MVA. Transformers T1 and T2 at Aberdare both have a continuous maximum rating of 23 MVA, which will be increased during RIIO-ED2 as the 12/24 MVA transformers are replaced with 20/40 MVA transformers through a condition-based asset replacement scheme.

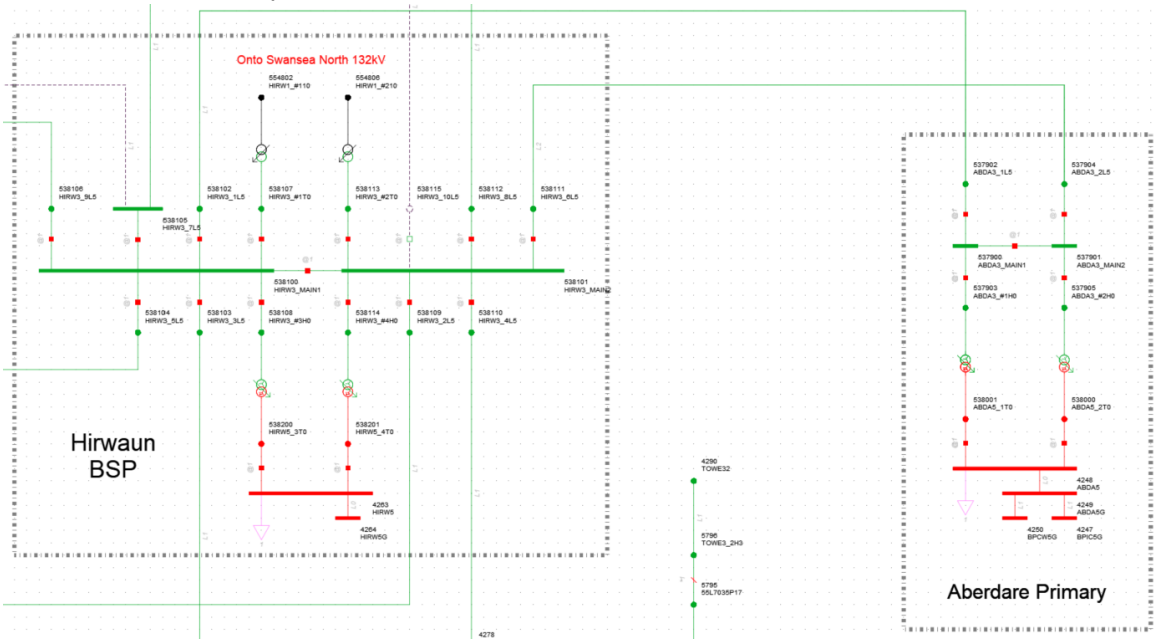

Figure 9: Aberdare Primary 33 kV network schematic

Aberdare Primary Capacity

Constraint summary

Generation Demand

The table below outlines the nature of the network constraint identified in the network analysis. The constraint occurs in 2025 (Leading the Way and WPD Best View) during Winter and Intermediate Warm Peak Demand. As demand continues to increase, the capacity of the entire Aberdare Primary network will also need increasing.

Constrained assets	Aberdare 33/11 kV Primary Transformers & 33 kV circuits between Hirwaun BSP and Aberdare	
Type(s) of constraint	Thermal overload	
Constrained condition(s)	Winter Peak Demand Intermediate Warm Peak Demand	
Limiting factor of constrained assets	Hirwaun – Aberdare T1 33 kV circuit limited to 17.6 MVA	
Outage combination which causes the constraint	First Circuit Outage	Post-2025: A fault condition which results in the loss of the Hirwaun 6L5 – Aberdare T2 circuit, as group demand is being fed through the remaining 33 kV circuit in service. Post-2028: A fault condition that results in either of the circuits feeding Aberdare Primary being disconnected.

Scenario identification

The table below highlights when the constraints occur during the 0-10 year period across the different scenarios studied from the 2021 Distribution Future Energy Scenarios.

Scenario	Study year			
	Baseline	**2025**	**2028**	**2032**
Steady Progression				✓
System Transformation			✓	✓
Consumer Transformation				✓
Leading the Way		✓	✓	✓
WPD Best View		✓	✓	✓

Solution options

The following solution options could resolve the constraint described above. Any final solution will be subject to a cost benefit analysis.

Solution option	Summary
Reinforcement	To alleviate the projected overloads on the circuit, the limiting 4 km section of 33 kV overhead circuit can be reconductored in 2025. However, when selecting the rating of the new section of conductor, consideration should be given to the additional growth forecast in Aberdare and conductor ratings selected accordingly to support the group demand served by the future 20/40 MVA transformers. The second circuit and reconductored first circuit will become overloaded by 2032 in the Leading the Way and WPD Best View scenario, at which point new circuits would need to be built to support Aberdare Primary and the 11 kV board changed to 2000 A. This would be lower cost than uprating the underground sections of the existing circuits. The increased transformer capacity will meet demand until 2034 where the WPD Best View and Leading the Way scenarios project demand to exceed the capacity. Due to space limitations on site, the most suitable solution would be to build a new Primary in the Aberdare region.
Operational mitigation	To reduce the group demand, additional 11 kV interconnection could be constructed to allow permanent transfers out of the group. Further studies into the feasibility of this would need to be conducted to determine whether other Primary substations have sufficient capacity to support this.
Load Management Schemes	Any additional connections (demand or generation) into this group could be included in an ANM scheme, which can be utilised to manage constraints on over-committed networks.
Flexibility services	Flexibility services would be needed for extended periods at times of peak demand. The product recommended for this network condition is Secure to procure demand reduction or generation turn up.

Cardiff East & Cardiff North 33 kV Group

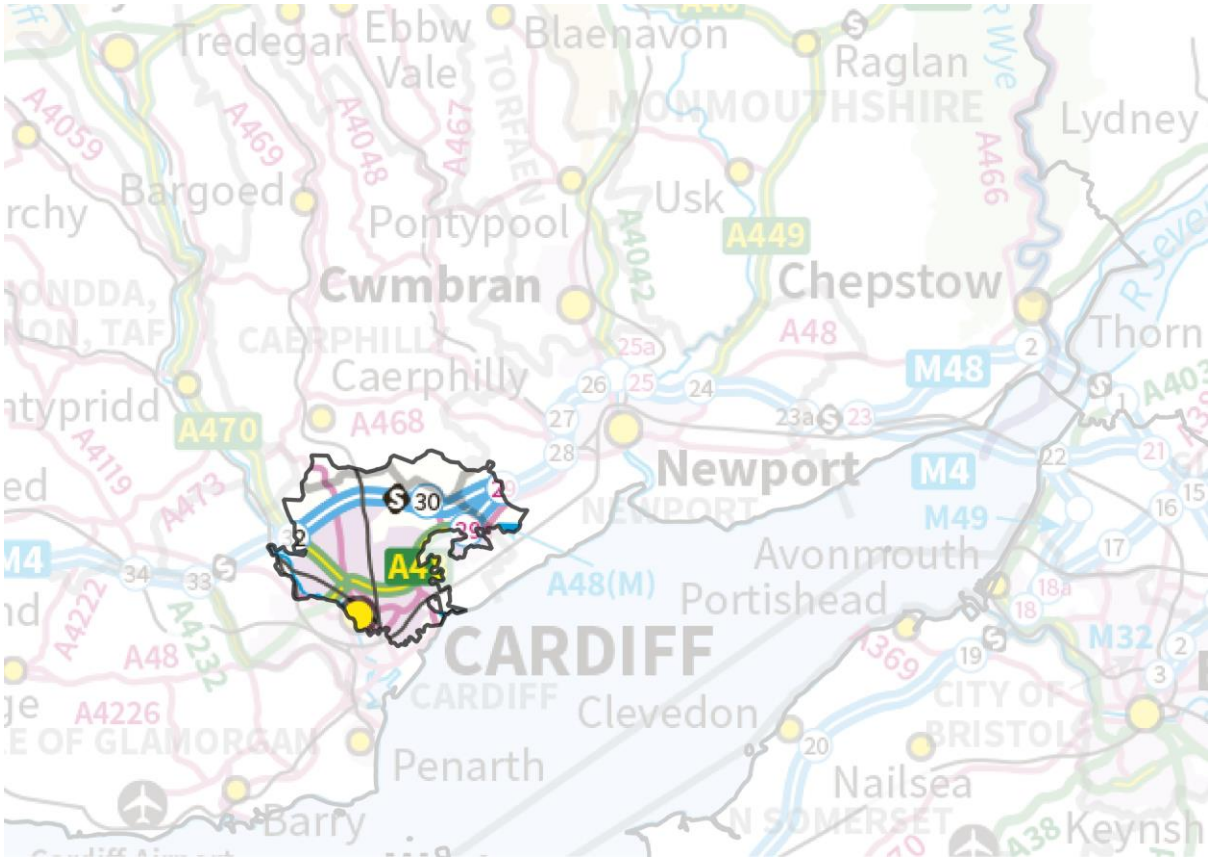

Figure 10: Cardiff East & Cardiff North geographic network coverage

Network Overview

Forming part of the Aberthaw / Cardiff East group, the Cardiff East & Cardiff North 33 kV network operates in parallel via several 33 kV circuits under intact network conditions and is currently supplied by three 132/33 kV Grid Transformers (GTs):

- Cardiff East GT2, 132/33 kV 60/90 MVA
- Cardiff East GT4, 132/33 kV 60/90 MVA
- Cardiff North GT2, 132/33 kV 45/90 MVA

Cardiff East also has two 132/11 kV GTs supplying a separate 11 kV network.

The Cardiff East & Cardiff North 33 kV network feeds a large densely populated urban area, supplying over 75,000 customers, one 33 kV metered demand connection and the following 33/11 kV Primary substations:

- Ashgrove, Cyncoed, Crwys Road, Llanishen, Birchgrove, Heath, Heath Hospital, St Mellons, Park Lane and Northcote Street
- Llanishen is supplied by a single 33/11 kV transformer.

Given the close proximity between Primary substations and urban area supplied by this network there is only a very modest level of connected distributed generation under 10 MW. The nature and demographic area also indicates that the group is likely to be subjected to a large amount of both electric vehicle charge points and heat pump systems in the future.

Network Operability Modelling

The following network automation and manual switching schemes have been modelled in the analysis of this area, aligning to how the network is currently operated:

- Under intact network conditions, the Cardiff East & Cardiff North 33 kV group operates in parallel via several 33 kV circuits.
- The Cardiff East and Cardiff North 33 kV network has one point of interconnection and this is with the Cardiff Central and Cardiff West 33 kV network. This is to support the Cardiff East and Cardiff North 33 kV group by reducing the group demand in line with arranged outage conditions and as such Park Lane can be transferred into the Cardiff Central and Cardiff West 33 kV group. However due to fault level restrictions, it is not possible to operate the two groups in parallel except for switching time.
- A RIIO-ED1 load-related reinforcement scheme is currently under construction to establish a second 132/33 kV, 60/90 MVA GT at Cardiff North BSP substation. Since there is no practical way of splitting the group without carrying out 33 kV circuit works it is currently intended for the new GT to be placed on hot-standby in order to maintain the network fault level within the rating of existing switchgear. As an interim arrangement, the unit shall only be brought into service when one of the GTs at either Cardiff East or Cardiff North is out of service for maintenance or a fault.

Network automation has been modelled on this basis.

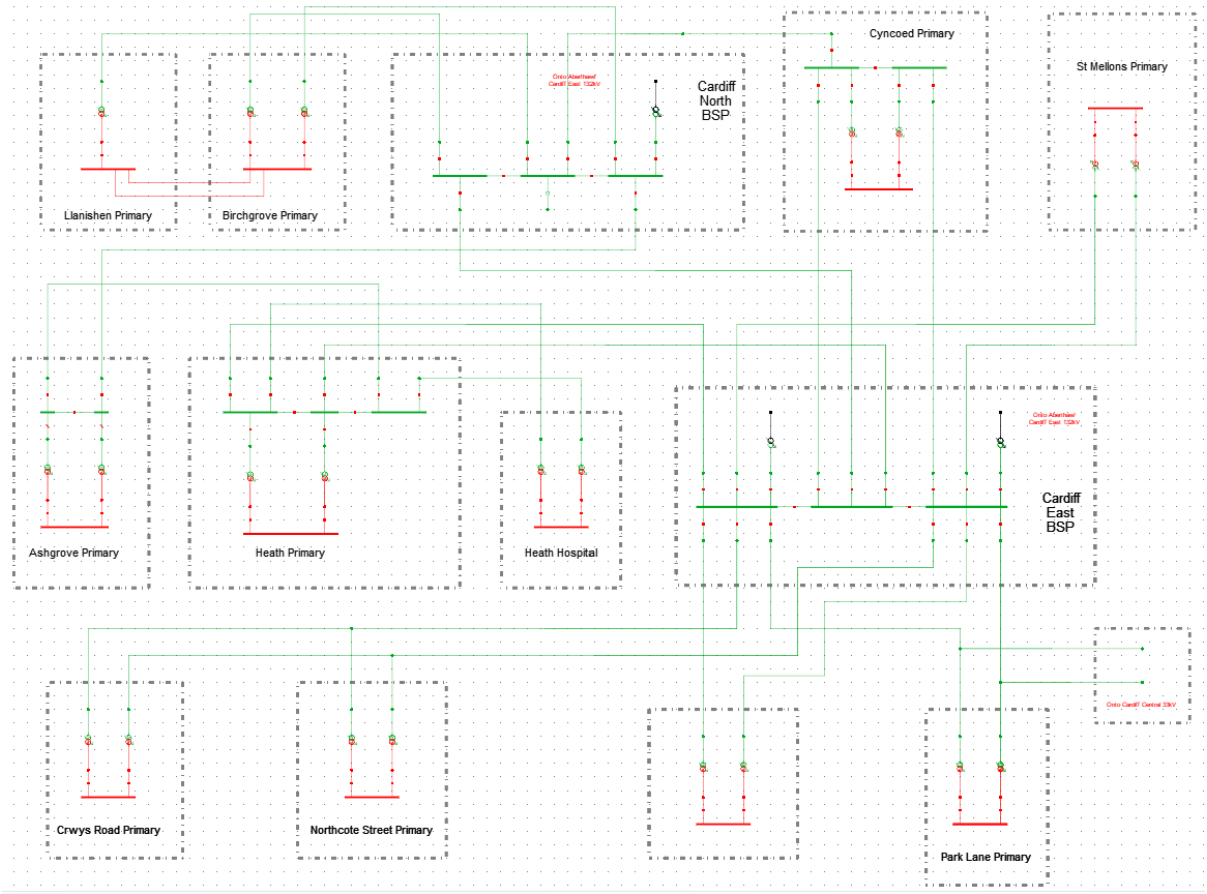

Figure 11: Cardiff East & Cardiff North 33 kV network schematic diagram

Future Network Constraints

Cardiff East & Cardiff North 33 kV Group Capacity

Following the completion of the RIIO-ED1 load-related reinforcement works both Cardiff East & Cardiff North BSP substations will benefit from two 132/33 kV Grid Transformers and firm capacities of 90 MVA based on transformer rating.

However, due to the unequal distribution of load and different circuit impedances across the 33 kV parallel group, while adequate transformer capacity is available to support the forecast group demand under FCO and SCO conditions it does not have sufficient 33 kV circuit capacity. This effectively eliminates the outage access window for planned maintenance activities on certain network assets on the basis that the demand would not be secure for a subsequent fault.

The most onerous SCO condition would occur when one of the Cardiff East 132/33 kV GTs was out of service for planned maintenance and a subsequent fault occurred on the remaining GT also at Cardiff East BSP. Under this scenario the interconnecting 33 kV circuits would be required to support the entire Cardiff East BSP substation load.

Constraint summary

Generation Demand

The table below outlines the nature of the network constraints identified in the network analysis.

Constrained assets	33 kV interconnecting circuits between Cardiff East and Cardiff North BSPs	
Type(s) of constraint	Thermal overload	
Constrained condition(s)	Winter Peak Demand Intermediate Warm Peak Demand Summer Peak Demand	
Limiting factor of constrained assets	When considering this SCO condition, network modelling has demonstrated that once the group peak demand reaches 130 MVA, the thermal rating of the interconnecting 33 kV circuits will be reached.	
Outage combination which causes the constraint	Second Circuit Outage	For the arranged outage of one of the Cardiff East 132/33 kV GTs followed by a subsequent fault on the remaining GT also at Cardiff East BSP.

Scenario identification

The table below highlights when the constraints occur during the 0-10 year period across the different scenarios studied from the 2021 Distribution Future Energy Scenarios.

Scenario	Study year			
	Baseline	**2025**	**2028**	**2032**
Steady Progression	✓	✓	✓	✓
System Transformation		✓	✓	✓
Consumer Transformation		✓	✓	✓
Leading the Way		✓	✓	✓
WPD Best View		✓	✓	✓

Solution options

All of the solutions identified below could alleviate the projected constraints in all scenarios out to 2032 subject to cost benefit analysis.

Solution option	Summary
Reinforcement	Installation of two 3.5 km 33 kV 630 mm^2 Cu Ethylene Propylene Rubber (EPR) underground circuits between Cardiff North BSP substation and Heath Primary substation. This is the minimum amount of cable installation works required to split the Cardiff East and Cardiff North 33 kV group while maintaining firm security of supply to existing Primary substations. Once the proposed works are completed the Cardiff East and Cardiff North 33 kV group will be split into two smaller independent networks under intact conditions. This has the benefits of maintaining demand security compliance, provides an outage access window and improves network resilience and flexibility in the long term. This option is expected to add a further 50 MVA of capacity, with a new firm capacity of 180 MVA (90 MVA at both Cardiff East and Cardiff North).
Operational mitigation	Very limited due to the times at which this constraint occurs.
Load Management Schemes	Any additional connections into this group may be included in an ANM scheme, which could also be utilised to manage constraints on over-committed networks.
Flexibility services	Generation turn up and/or demand turn down flexibility services via a ‘Secure’ product could benefit this area in the short-medium term, but this will become less effective and economical as load further grows in the area.

Cardiff East & Cardiff North 33 kV Group Load Distribution

The previous constraint proposed the installation of two 33 kV underground circuits between Cardiff North 132/33 kV BSP substation and Heath Primary substation to allow the group to be split under intact network conditions. Whilst this is the most economical solution to rationalise the network under intact network conditions it does not result in an equal distribution of load between the Cardiff East & Cardiff North BSP substations.

Once the network has been split under intact network conditions, Cardiff North BSP shall supply Llanishen, Birchgrove, Ashgrove, Heath and Heath Hospital Primary substations. This group will benefit from a firm capacity of 90 MVA.

Cardiff East BSP shall supply St Mellons, Park Lane, Northcote Street, Crwys Road, Cyncoed Primary and one 33 kV metered demand connection. While this group will also benefit from a firm capacity of 90 MVA, the remaining Cardiff East 132/33 kV GT begins to overload from 2028 under future growth scenarios, for an outage (arranged or fault) resulting in the loss of one GT at Cardiff East BSP.

Constraint summary

The table below outlines the nature of the network constraints identified in the network analysis.

Constrained assets	132/33 kV Grid Transformer at Cardiff East BSP	
Type(s) of constraint	Thermal overload	
Constrained condition(s)	Winter Peak Demand	
Limiting factor of constrained assets	Rating of 132/33 kV Grid Transformer (60/90 MVA)	
Outage combination which causes the constraint	First Circuit Outage	For the arranged or fault outage of one of the Cardiff East 132/33 kV grid transformers, the remaining transformer in service overloads.

Scenario identification

The table below highlights when the constraint occurs during the 0-10 year period across the different scenarios studied from the 2021 Distribution Future Energy Scenarios.

Scenario	Study year			
	Baseline	**2025**	**2028**	**2032**
Steady Progression				
System Transformation				✓
Consumer Transformation			✓	✓
Leading the Way			✓	✓
WPD Best View			✓	✓

Solution options

All of the solutions identified below could alleviate the projected constraints in all scenarios out to 2032 subject to cost benefit analysis.

Solution option	Summary
Reinforcement	Installation of a new 4 km 33 kV 630 mm^2 Cu EPR underground circuit between Cardiff North BSP and Cyncoed Primary to alleviate the projected overload of the Cardiff East 132/33 kV Grid Transformer across the forecast load growth period under FCO conditions. This will allow Cyncoed Primary substation to be transferred on to Cardiff North BSP substation and will result in an equal distribution of demand between the Cardiff East & Cardiff North BSP substation groups which will both have firm capacities of 90 MVA.
Operational mitigation	The proposed split results in a suitable running arrangement providing network resilience and flexibility in the long term. The distribution of load should be regularly reviewed as there is scope for load transfers between Cardiff East and Cardiff North to mitigate the risk of 33kV circuit overloads in the future following outage conditions if the group is to remain split. This is however alleviated if the group can be run as a three GT group if one GT is out of service.
Load Management Schemes	Any additional connections into this group may be included in an ANM scheme, which could also be utilised to manage constraints on over-committed networks.
Flexibility services	Generation turn up or demand turn down flexibility services could be procured via a 'Secure' product to help alleviate projected overloads. Dispatch of services may be required for an extended period of time given constraint occurs for a first circuit fault outage.

Cardiff East – Crwys Road / Northcote Street Tee 33 kV Circuit Capacities

For a first circuit outage (arranged or fault) which results in the loss of either Cardiff East to Crwys Road / Northcote Street Tee 33 kV circuit, the remaining circuit in service begins to overload in 2028 under the Leading the Way scenario.

Constraint summary

Generation Demand

The table below outlines the nature of the network constraints identified in the network analysis.

Constrained assets	Cardiff East to Crwys Road T1 / Northcote Street T1 Tee 33 kV circuit Cardiff East to Crwys Road T2 / Northcote Street T2 Tee 33 kV circuit	
Type(s) of constraint	Thermal overload	
Constrained condition(s)	Winter Peak Demand Intermediate Warm Peak Demand (from 2032)	
Limiting factor of constrained assets	Circuits limited by sections of 33 kV underground cable (0.3 in² Cu and 185 mm² Cu).	
Outage combination which causes the constraint	First Circuit Outage	FCO (arranged or fault) which results in the loss of either Cardiff East to Crwys Road / Northcote Street Tee 33 kV circuit

Scenario identification

The table below highlights when the constraint occurs during the 0-10 year period across the different scenarios studied from the 2021 Distribution Future Energy Scenarios.

Scenario	Study year			
	Baseline	**2025**	**2028**	**2032**
Steady Progression				
System Transformation				
Consumer Transformation				✓
Leading the Way			✓	✓
WPD Best View				✓

Solution options

All of the solutions identified below could alleviate the projected constraints in all scenarios out to 2032 subject to cost benefit analysis.

Solution option	Summary
Reinforcement	Splitting the Crwys Road and Northcote Street 33kV arrangement by installing dedicated 33kV feeds to Cardiff East BSP. This proposal would require new 33 kV circuit installation and two 33 kV circuit breakers to be installed at Cardiff East BSP to facilitate this arrangement. This will alleviate any of the projected overloads in the 0-10 year period for the projected load growth. Overlaying the limiting sections of each 33 kV circuit with 240mm² Cu EPR cable is an alternative option. However given the projected load increase of Crwys Road and Northcote Street by 2032, this will likely necessitate further reinforcement in the future.
Operational mitigation	As constraint could occur during a first circuit fault outage condition, operational mitigation is not possible.
Load Management Schemes	Any additional connections into this group may be included in an ANM scheme, which could also be utilised to manage constraints on over-committed networks.
Flexibility services	Generation turn up or demand turn down flexibility services could be procured via a 'Secure' product to help alleviate projected overloads. Dispatch of services may be required for an extended period of time given the first circuit outage constraint.

Ashgrove 33/11 kV Primary Transformer Capacity

For a first circuit outage (arranged or fault) which results in the loss of either Ashgrove 33/11 kV Primary Transformer (T1 and T2), the remaining transformer in service could overload in 2028 under the WPD Best View (T2), Consumer Transformation (T2) and Leading the Way scenarios (T1 & T2).

Constraint summary

The table below outlines the nature of the network constraints identified in the network analysis.

Constrained assets	Ashgrove 33/11 kV Primary Transformers (T1 and T2)	
Type(s) of constraint	Thermal overload	
Constrained condition(s)	Winter Peak Demand Intermediate Warm Peak Demand	
Limiting factor of constrained assets	Ashgrove T1 (7.5/15 MVA) Ashgrove T2 (7.5/14 MVA) - ancillary rating limitation of 11.43 MVA	
Outage combination which causes the constraint	First Circuit Outage	FCO (arranged or fault) which results in the loss of either Ashgrove Primary Transformer

Scenario identification

The table below highlights when the constraint occurs during the 0-10 year period across the different scenarios studied from the 2021 Distribution Future Energy Scenarios.

Scenario	Study year			
	Baseline	**2025**	**2028**	**2032**
Steady Progression				
System Transformation				
Consumer Transformation			✓	✓
Leading the Way			✓	✓
WPD Best View			✓	✓

Solution options

All of the solutions identified below could alleviate the projected constraints in all scenarios out to 2032 subject to cost benefit analysis.

Solution option	Summary
Reinforcement	Replacing both Ashgrove Primary Transformers with larger 12/24 MVA units (including removal of any ancillary rating limitations) will alleviate any of the projected overloads in the 0-10 year period for the projected load growth.
Operational mitigation	As the constraint occurs towards the end of the 0-10 year period, all Primary substations across the group project significantly increases in demand. Given the close proximity between Primary substations and urban area supplied by this network, permanent 11 kV reconfiguration following load growth could be used to alleviate projected overloads. Further assessment of the geographical distribution of load within the Cardiff area is recommended to understand how network reconfiguration can best utilise Primary Transformer capacity.
Load Management Schemes	Any additional connections into this group may be included in an ANM scheme, which could also be utilised to manage constraints on over-committed networks.
Flexibility services	Generation turn up or demand turn down flexibility services could be procured via a ‘Secure’ product to help alleviate projected overloads. Dispatch of services may be required across multiple seasons.

Birchgrove & Llanishen 33/11 kV Group Capacity

Birchgrove and Llanishen are both 33/11 kV Primary substations supplied via Cardiff North BSP, comprising the following:

- Birchgrove T1, 33/11 kV 10/14 MVA
- Birchgrove T2, 33/11 kV 10/14 MVA
- Llanishen T1, 33/11 kV 12/24 MVA

Llanishen Primary is a single transformer site and is interconnected at 11 kV with Birchgrove Primary.

For an SCO condition resulting in a single Birchgrove 33/11 kV transformer left in service, this remaining transformer begins to overload in 2028 under Best View, Consumer Transformation and Leading the Way scenarios.

Constraint summary

The table below outlines the nature of the network constraints identified in the network analysis.

Constrained assets	Birchgrove 33/11 kV Primary Transformers (T1 and T2)	
Type(s) of constraint	Thermal overload	
Constrained condition(s)	Winter Peak Demand Intermediate Warm Peak Demand Summer Peak Demand (from 2032)	
Limiting factor of constrained assets	Birchgrove T1 (10/14 MVA) Birchgrove T2 (10/14 MVA)	
Outage combination which causes the constraint	Second Circuit Outage	SCO condition which results in a single Birchgrove Primary Transformer left in service supplying the entire Llanishen and Birchgrove group.

Scenario identification

The table below highlights when the constraint occurs during the 0-10 year period across the different scenarios studied from the 2021 Distribution Future Energy Scenarios.

	Study year			
Scenario	**Baseline**	**2025**	**2028**	**2032**
Steady Progression				
System Transformation				
Consumer Transformation			✓	✓
Leading the Way			✓	✓
WPD Best View			✓	✓

Solution options

All of the solutions identified below could alleviate the projected constraints in all scenarios out to 2032 subject to cost benefit analysis.

Solution option	Summary
Reinforcement	Installation of a second 12/24 MVA 33/11 kV transformer at Llanishen Primary will alleviate any of the projected overloads in the 0-10 year period for the projected load growth. This improves network resilience under SCO and provides less dependency on 11 kV interconnectivity under FCO conditions. This proposal will also require the installation of a new approximate 1.8 km 33 kV underground circuit to Cardiff North BSP including a new 33 kV circuit breaker and associated equipment to enable connection at Cardiff North BSP. Replacing the existing Primary Transformers at Birchgrove with larger 12/24 MVA units (to match T1 at Llanishen) is an alternative option. However given the projected load of the Birchgrove and Llanishen group will exceed 25 MVA in 2032, this will likely necessitate further replacement or an additional transformer in future.
Operational mitigation	Very limited due to the times at which this constraint occurs under higher load growth scenarios 2028 and onwards.
Load Management Schemes	Any additional connections into this group may be included in an ANM scheme, which could also be utilised to manage constraints on over-committed networks.
Flexibility services	Generation turn up or demand turn down flexibility services could be procured via a ‘Secure’ product to help alleviate projected overloads, but this will become less effective and economical as the demand grows in the area. Dispatch of services may be required for extended periods of time at peak demand.

Mid Wales 66 kV Network

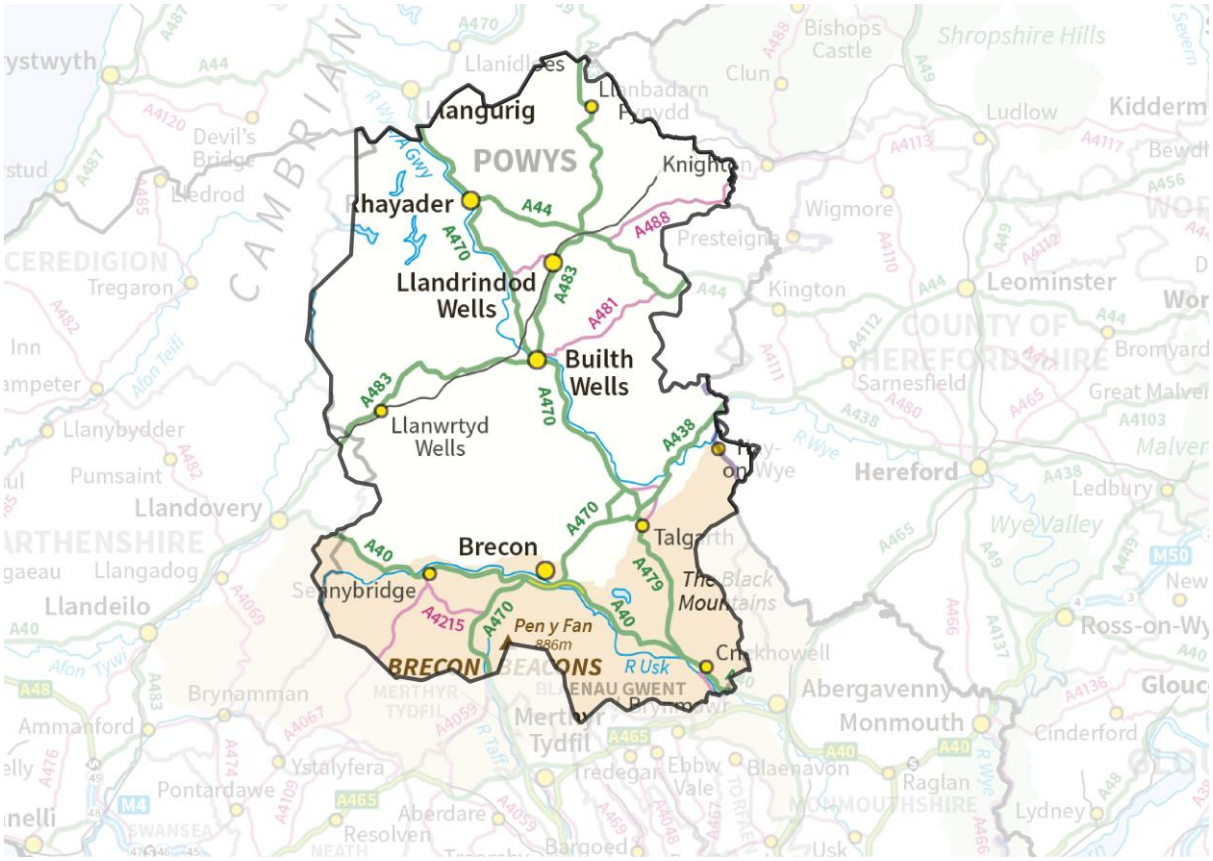

Figure 12: Mid Wales 66 kV Network Coverage

Network Overview

Forming part of the Rassau group, the Mid Wales 66 kV network is normally supplied by Abergavenny BSP (Northern Ring) and interconnected with Panteg BSP (Southern Ring). The network operates in parallel via several 66 kV circuits under intact network conditions and is currently supplied by three 132/66 kV Grid Transformers (GTs):

- Abergavenny GT1, 132/66 kV 30/60 MVA
- Abergavenny GT2, 132/66 kV 45/90 MVA
- Panteg GT2, 132/33 kV 30/60 MVA

The Mid Wales 66 kV Ring is formed via two 66 kV overhead line circuits from Abergavenny BSP (Northern Ring), supplying over 28,000 customers and comprising the following 66/11 kV Primary substations:

- Crickhowell, Brecon, Builth Wells, Glasbury, Llandrindod Wells and Rhayader
- Rhayader is supplied by a single 66/11 kV transformer.

66 kV circuits are connected north from Abergavenny BSP towards Builth Wells Primary. The total length of this 66 kV overhead ring is approximately 114 km with additional 66 kV radial circuits heading north from Builth Wells to Llandrindod Wells and Rhayader substations.

There are existing generation connections to both the 66 kV and 11 kV networks in the area and this large geographical area has significant renewable energy potential notwithstanding voltage and thermal limitations imposed by the 66 kV network and load growth forecast.

Network Operability Modelling

The group operates such that:

- Under intact network conditions, six 66/11 kV Primary substations operate in a 66 kV ring network supplied via Abergavenny BSP.
- For a first circuit outage, the remaining in-service 66 kV infeed from Abergavenny BSP picks up the group demand.
- The Mid Wales 66 kV ring has no alternative 66 kV interconnection and minimal 11 kV interconnection with primaries outside the Abergavenny group.
- Curtailment of 66 kV connected generators within the group are modelled at a variety of arranged outages, as outlined in customer connection agreements.

Network automation has been modelled on this basis.

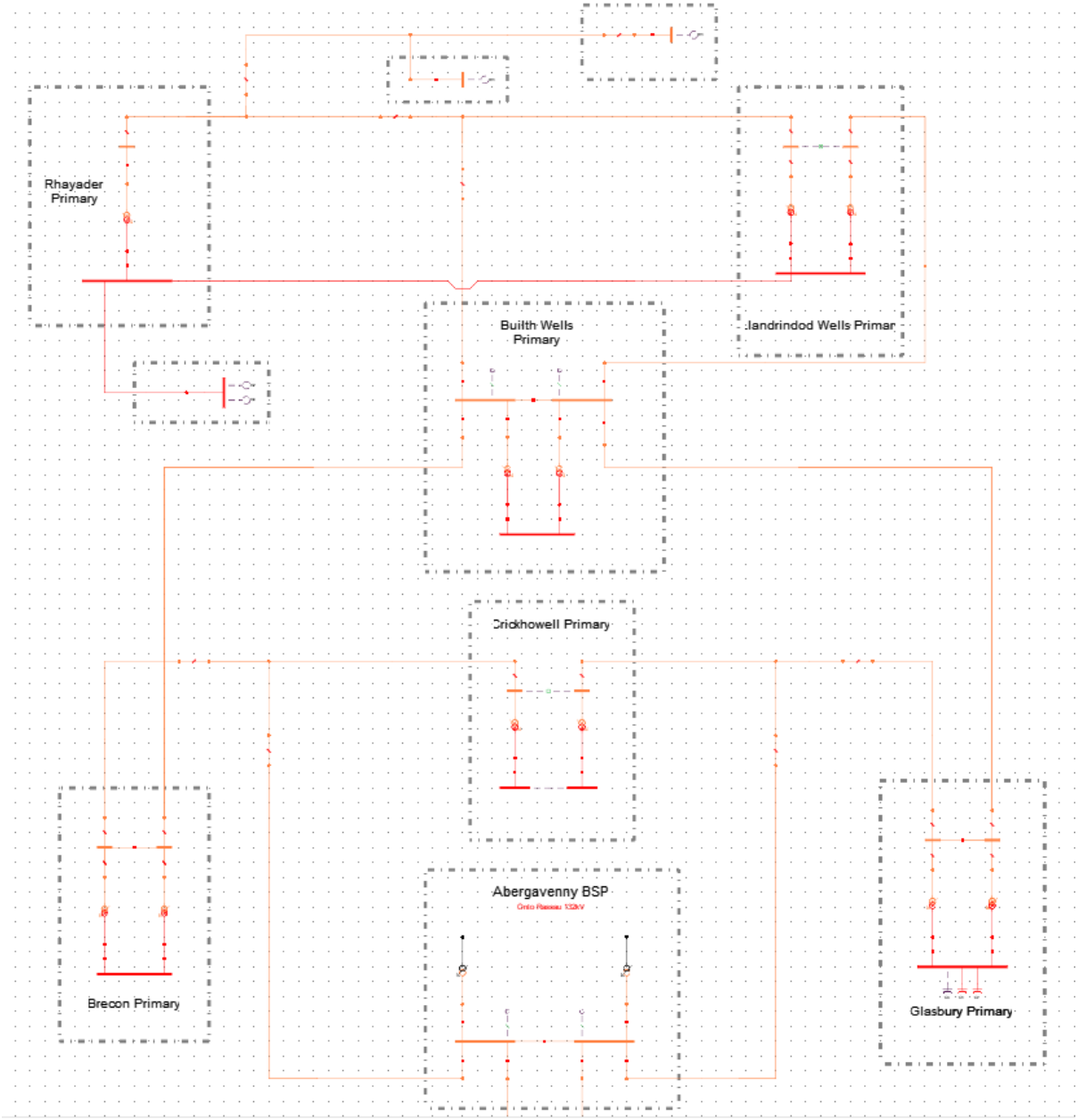

Figure 13: Mid Wales 66 kV network schematic diagram

Future Network Constraints

Mid Wales 66 kV Network

The capacity of the Mid Wales 66 kV Ring is primarily limited by the thermal rating of the Abergavenny to Brecon/Crickhowell T1 and Abergavenny to Glasbury/Crickhowell T2 66 kV overhead line circuits.

Under FCO conditions, future load growth scenarios suggest that the current network running arrangement will not be able to support the forecasted load growth in the area. Such FCO conditions would include the outage of the Abergavenny to Brecon/Crickhowell T1 or Abergavenny to Glasbury/Crickhowell T2 66 kV circuits.

If the demand on the Mid Wales 66 kV ring continues to increase in accordance with the future load growth scenarios then the thermal rating of the Mid Wales 66 kV network will soon be exceeded and reinforcement will be required in order to restore the group demand under FCO conditions. In addition, this level of load increase will exacerbate existing under voltage regulation issues on the 66 kV network during FCO conditions.

The Mid Wales 66 kV network supplies a particularly large rural area with the total length of the 66 kV overhead line ring being in the order of 114 km. As a result, in addition to the thermal rating limits, the network capacity is also restricted by statutory voltage limits which at 66 kV are +/- 6%. Therefore, even if the thermal rating of the 66 kV overhead line circuits could be increased following reconductoring works this would only result in a modest improvement to the network voltage profile under FCO conditions.

Constraint summary

The table below outlines the nature of the network constraints identified in the network analysis.

Constrained assets	Abergavenny to Brecon/Crickhowell T1 66 kV circuit Abergavenny to Glasbury/Crickhowell T2 66 kV circuit	
Type(s) of constraint	Thermal overload of 66 kV circuits and voltage excursions outside statutory limits	
Constrained condition(s)	Winter Peak Demand Intermediate Warm Demand Summer Peak Demand (Best View and Leading the Way 2028 onwards)	
Limiting factor of constrained assets	Both 66 kV circuits have the following seasonal ratings: Winter: 441 A (50.4 MVA at 66 kV) Intermediate Warm: 408 A (46.6 MVA at 66 kV) Summer: 393 A (44.9 MVA at 66 kV)	
Outage combination which causes the constraint	First Circuit Outage	For the arranged or fault outage of one of the circuits which feeds into this 66 kV group, the remaining circuit in service could overload.

Scenario identification

The table below highlights when the constraint occurs during the 0-10 year period across the different scenarios studied from the 2021 Distribution Future Energy Scenarios.

Scenario	Study year			
	Baseline	**2025**	**2028**	**2032**
Steady Progression				✓
System Transformation			✓	✓
Consumer Transformation			✓	✓
Leading the Way		✓	✓	✓
WPD Best View		✓	✓	✓

Solution options

All of the solutions identified below could alleviate the projected constraints in all scenarios out to 2032 subject to cost benefit analysis.

Solution option	Summary
Reinforcement	To alleviate the projected overloads and limitations across the Mid Wales 66 kV network, this reinforcement strategy proposes installation of a new 25 km 132 kV circuit, predominantly underground cable construction, from Rassau to a new 132/66 kV BSP to be located near Brecon. It is proposed that the new 132/66 kV BSP will feature two outgoing 66 kV feeder circuit breaker bays to inject into the 66 kV ring between Brecon and Builth Wells 66/11 kV Primary substations. This strategy is expected to add 90 MVA of capacity, with a new firm capacity of 140.4 MVA. This solution would also add significant capacity to allow the connection of low carbon generating technologies across this large geographical area An alternative option could be to reconductor the existing 66 kV overhead line circuits. However, it has very limited benefit in terms of improving the voltage profile under FCO conditions and as a result, it only provides a modest increase in demand and generation headroom. Alternatively, installing a new 66 kV circuit from Abergavenny BSP. This option would yield significantly less additional demand and generation capacity compared to the preferred solution. The Mid Wales group would also still be vulnerable to a SCO condition. A further alternative would be to install a new 66 kV circuit from Rassau. This would yield less additional demand and generation capacity compared to the reinforcement strategy and there is not adequate space within the existing Rassau GSP substation compound to establish a new 132/66kV GT or 66kV outdoor circuit breaker bay.
Operational mitigation	It is noted that there are limitations to the existing technique of voltage analysis. The reactive behaviour of load, in particular projected load, modelled at the 11 kV bars of Primary substations does not take detailed account of the reactive behaviour of individual customers nor the effects of secondary network impedance. Development of load survey and analysis techniques will enable the materiality of these effects to be better understood.
Load Management Schemes	Any additional connections into this group may be included in an Active Network Management scheme, which could also be utilised to manage constraints on over-committed networks.
Flexibility services	Flexibility services could be procured to help alleviate projected overloads. Dispatch of services may be required for an extended period of time given the first circuit outage constraint. The product recommended for this network condition would be secure to procure demand reduction and/or generation turn up services.

Llandrindod Wells and Rhayader 66/11 kV Group Capacity

Llandrindod Wells and Rhayader are both 66/11 kV Primary substations in the northern section of the Mid Wales 66 kV group, comprising the following Primary Transformers:

- Llandrindod Wells T1, 66/11 kV 7.5/13 MVA
- Llandrindod Wells T2, 66/11 kV 7.5/13 MVA
- Rhayader T1, 66/11 kV 6/7.6 MVA

Rhayader Primary is a single transformer site and is reliant on 11 kV interconnection to Llandrindod Wells for the loss of supply to its transformer.

In the scenario projections, a large amount of generation is forecast to connect at Rhayader. If the expected generation is to connect at 11 kV, additional Primary Transformer capacity would be required. For intact running conditions the Primary Transformer at Rhayader begins to overload from 2025 under the WPD Best View and Leading the Way scenarios for Summer Peak Generation.

Under peak demand conditions, a fault of the Builth Wells to Rhayader and Llandrindod Wells T1 circuit leaves all of the Rhayader and Llandrindod Wells 11 kV demand supplied via Llandrindod Wells T2. The step voltage change in this area following this FCO condition results in the 66 kV network voltage to fall below statutory limits. This is expected to overload both the 11 kV interconnection from Rhayader and T2 at Llandrindod Wells under all scenarios from 2028.

Constraint summary

Generation Demand

The table below outlines the nature of the network constraints identified in the network analysis.

Constrained assets	Llandrindod Wells 66/11 kV T1 Llandrindod Wells 66/11 kV T2 Rhayader 66/11 kV T1	
Type(s) of constraint	Thermal overload and voltage operating below statutory limits	
Constrained condition(s)	Winter Peak Demand Intermediate Warm Peak Demand Summer Peak Demand (Best View and Leading the Way 2028 onwards) Summer Peak Generation (Best View and Leading the Way 2025)	
Limiting factor of constrained assets	Llandrindod Wells 66/11 kV T1 (7.5/13 MVA) Llandrindod Wells 66/11 kV T2 (7.5/13 MVA) Rhayader 66/11 kV T1 (6 MVA) 11 kV Rhayader to Llandrindod Wells interconnection (4.6 MVA Winter)	
Outage combination which causes the constraint	Intact	Generation overloads driven on intact network due to the large amount of forecast generation connected.
	First Circuit Outage	For an outage of the Builth Wells to Rhayader and Llandrindod Wells T1 circuit, leaving all of the Rhayader and Llandrindod Wells 11 kV demand supplied via Llandrindod Wells T2.

Scenario identification

The table below highlights when the constraint occurs during the 0-10 year period across the different scenarios studied from the 2021 Distribution Future Energy Scenarios.

Scenario	Study year			
	Baseline	**2025**	**2028**	**2032**
Steady Progression				✓
System Transformation			✓	✓
Consumer Transformation			✓	✓
Leading the Way		✓	✓	✓
WPD Best View		✓	✓	✓

Solution options

All of the solutions identified below could alleviate the projected constraints in all scenarios out to 2032 subject to cost benefit analysis.

Solution option	Summary
Reinforcement	Establishment of a new 66/11 kV substation in the Rhayader area would alleviate the projected overloads by transferring load from the Rhayader 11 kV network. This new substation could utilise the nearby 66 kV infeed from the WPD West Midlands 66 kV network. An alternative option would be to install a second 66/11 kV transformer at Rhayader Primary. This improves network resilience and provides less dependency on 11 kV interconnectivity under FCO conditions. This proposal would however require the installation of a considerable new 66 kV overhead line circuit to either Builth Wells or Llandrindod Wells 66/11 kV substations. A further option would be to replace the existing Primary Transformers at Rhayader and Llandrindod Wells with larger 12/24 MVA units. However, greater 11 kV interconnectivity would be required under FCO conditions.
Operational mitigation	There is an existing motorised isolator 1L3 at Llandrindod Wells. Following the first circuit fault condition which results in the loss of the Builth Wells to Rhayader and Llandrindod Wells T1 66 kV circuit, the motorised isolator could be opened and T1 at Llandrindod Wells brought back into service. This requires detailed assessment of short term ratings of 66/11 kV Primary Transformers to confirm if the operational mitigation could alleviate any potential overload on T2. This is currently reliant on control room intervention but could be automated through sequential switching schemes to operate within short term rating timescales.
Load Management Schemes	Any additional connections into this group may be included in an Active Network Management scheme, which could also be utilised to manage constraints on over-committed networks.
Flexibility services	Flexibility services could be procured to help alleviate projected overloads, but this will become less effective and economical as the demand grows in the area. Dispatch of services may be required for extended periods of time during times of high network loading. The product recommended for this network condition would be secure to procure both generation turn up and/or demand turn down for generation constraints, also generation turn down and/or demand turn up for demand constraints.

Newport Substation Capacity

Figure 14: Newport East, South and West geographic network coverage

Network Overview

Forming part of the Uskmouth group, the Newport area is predominantly supplied by three BSP substations:

- Newport South 132/11 kV & 132/33 kV BSP
- Newport East 132/11 kV BSP
- Newport West 132/11 kV BSP

These BSPs are all supplied from Uskmouth GSP via the 132 kV R and M routes. The R-route has an interconnection to Cardiff East via Trowbridge and the M-route carries on to Llantarnam 132/11 kV.

Newport South BSP is supplied by two 132/11 kV Grid Transformers:

- Newport South GT3, 132/11 kV 15/30 MVA
- Newport South GT4, 132/11 kV 15/30 MVA

The firm capacity of the site is 30 MVA with reserved but unutilised capacity of 7.81 MVA. Newport South also has two 132/33 kV GTs supplying a separate 33 kV network.

Newport East BSP is supplied by two 'double bubble' 132/11 kV Grid Transformers, this means that great care needs to be taken to balance the loads on the two 11 kV switchboards sometimes requiring reconfiguration for new connections:

- Newport East GT3, 132/11 kV 20/40 MVA
- Newport East GT4, 132/11 kV 20/40 MVA

The firm capacity of the site is 40 MVA. Newport East does not have any significant reserved capacity.

Newport West BSP is supplied by four 132/11 kV Grid Transformers:

- Newport West GT1, 132/11 kV 15/30 MVA
- Newport West GT2, 132/11 kV 15/30 MVA

The firm capacity of the site is 30 MVA with a reserved but unreleased capacity of 17 MVA. GT3 and GT4 are dedicated for sole use of a large 11 kV metered connected customer.

Network Operability Modelling

This group operates with radial 132kV circuits and as a result network modelling operability is straightforward. Curtailment of connected generators within the group are modelled at a variety of arranged outages, as outlined in customer connection agreements.

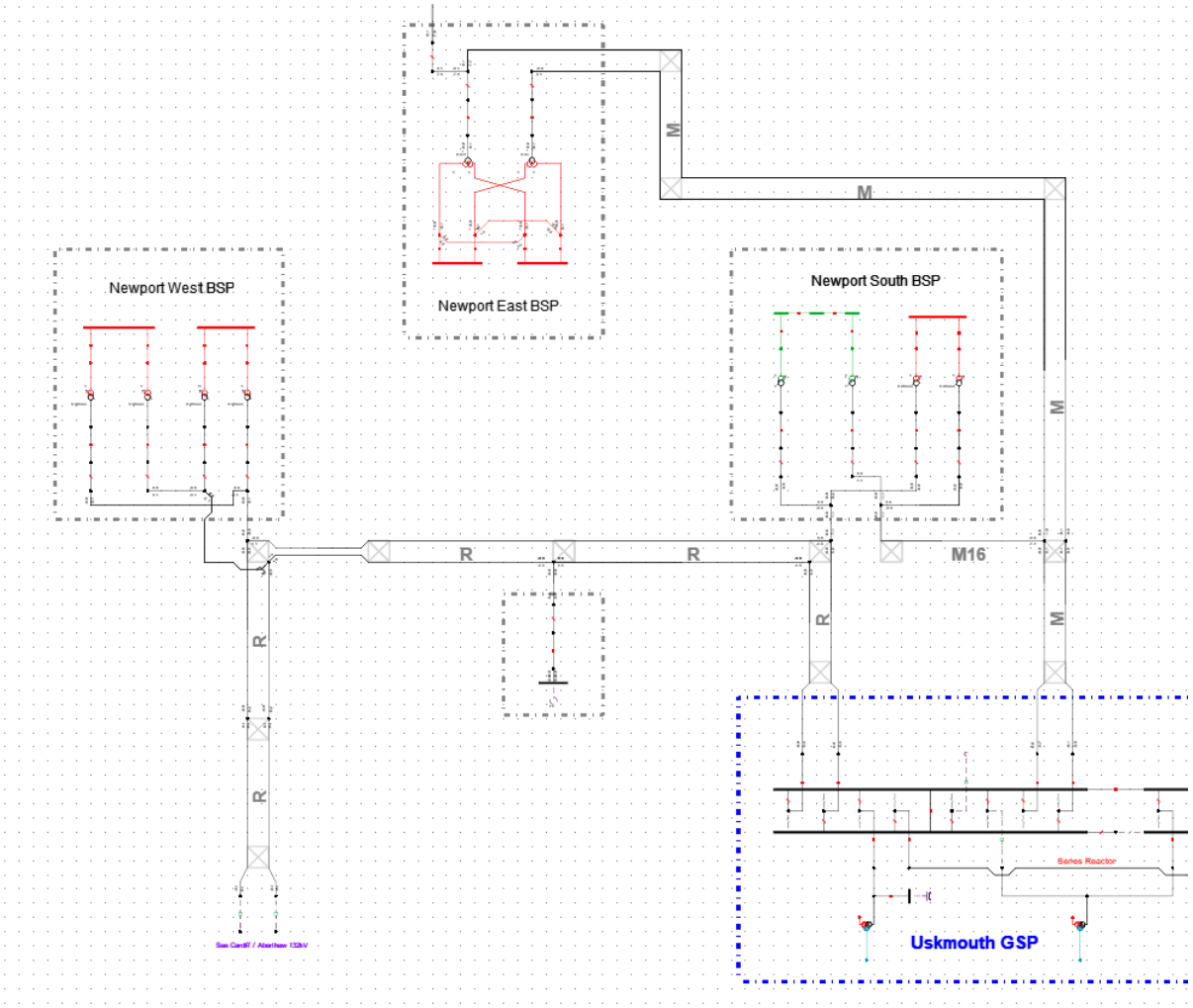

Figure 15: Newport East, South and West 132 kV network schematic diagram

Future Network Constraints

Newport East, West and South 132/11 kV Group Capacity

All substations in the Newport group are between 12 MW and 60 MW, putting them all individually into supply class C under ENA Engineering Recommendation P2/7.

This means that WPD is obligated to restore group demand minus 12 MW or 2/3 of group demand, whichever is smaller, within 15 minutes of a FCO condition. There are no requirements for a second circuit outage.

With projected load growth, FCO conditions have been carried out at each of Newport East, West and South 132/11 kV BSPs under all DFES scenarios to observe which grid transformers are likely to overload following an outage on the other.

Constraint summary

Generation Demand

The table below outlines the nature of the network constraints identified in the network analysis.

Constrained assets	132/11 kV Grid Transformers in the Newport area	
Type(s) of constraint	Thermal overload	
Constrained condition(s)	Winter Peak Demand	
Limiting factor of constrained assets	Rating of 132/11 kV Grid Transformers	
Outage combination which causes the constraint	First Circuit Outage	For the arranged or fault outage of one of the grid transformers, the remaining transformer in service may overload

Scenario identification

The table below highlights when the constraint occurs during the 0-10 year period across the different scenarios studied from the 2021 Distribution Future Energy Scenarios.

Newport East BSP (A) Constraint

Scenario	Study year			
	Baseline	2025	2028	2032
Steady Progression				
System Transformation				
Consumer Transformation				✓
Leading the Way			✓	✓
WPD Best View				

Newport East BSP (B) Constraint

Scenario	Study year			
	Baseline	2025	2028	2032
Steady Progression				
System Transformation				
Consumer Transformation				✓
Leading the Way			✓	✓
WPD Best View				

Newport South 132/11 kV BSP Constraint

Scenario	Study year			
	Baseline	2025	2028	2032
Steady Progression				
System Transformation				
Consumer Transformation				
Leading the Way				✓
WPD Best View				

Newport West BSP Constraint

Scenario	Study year			
	Baseline	2025	2028	2032
Steady Progression				
System Transformation				
Consumer Transformation				✓
Leading the Way				✓
WPD Best View				

There currently appears to be a significant amount of demand headroom at Newport West BSP based on a substation firm capacity of 30 MVA and maximum demand of 20.4 MVA. However, there is approximately 17 MVA of reserved but not utilised capacity.

If a significant proportion of the reserved but not utilised import capacity is drawn from the network then the firm capacity of Newport West BSP substation will be exceeded under FCO conditions.

Newport West BSP Constraint (including reserved but not utilised demand)

The table below shows the forecast demands for Newport West (GT1 & GT2) if half of the reserved but not utilised demand listed above was added as a fixed load.

Scenario	Study year			
	Baseline	2025	2028	2032
Steady Progression				✓
System Transformation			✓	✓
Consumer Transformation		✓	✓	✓
Leading the Way			✓	✓
WPD Best View				✓

Solution options

All of the solutions identified below could alleviate the projected constraints in all scenarios out to 2032 subject to cost benefit analysis.

Solution option	Summary
Reinforcement	To alleviate the projected overloads, it is proposed to construct a new 33/11 kV Primary substation fed via two 33 kV circuits from Newport South BSP substation. This could be located at the nearby land off Usk Way. This solution would create a significant amount of network capacity to accommodate new connections and also provide an opportunity to de-load the adjacent Newport West and Newport East BSP substations. This option is expected to add an additional 38 MVA of primary capacity to the Newport area.
Operational mitigation	As constraint may occur for a first circuit fault outage, limiting outage windows is not suitable mitigation.
Load Management Schemes	Any additional connections into this group may be included in an ANM scheme, which could also be utilised to manage constraints on over-committed networks.
Flexibility services	Generation turn up or demand turn down services could be procured to help alleviate projected overloads. Dispatch of services may be required for an extended period of time given the first circuit outage constraint. The product recommended for this network condition is secure to procure demand reduction.

Appendices

Appendix 1

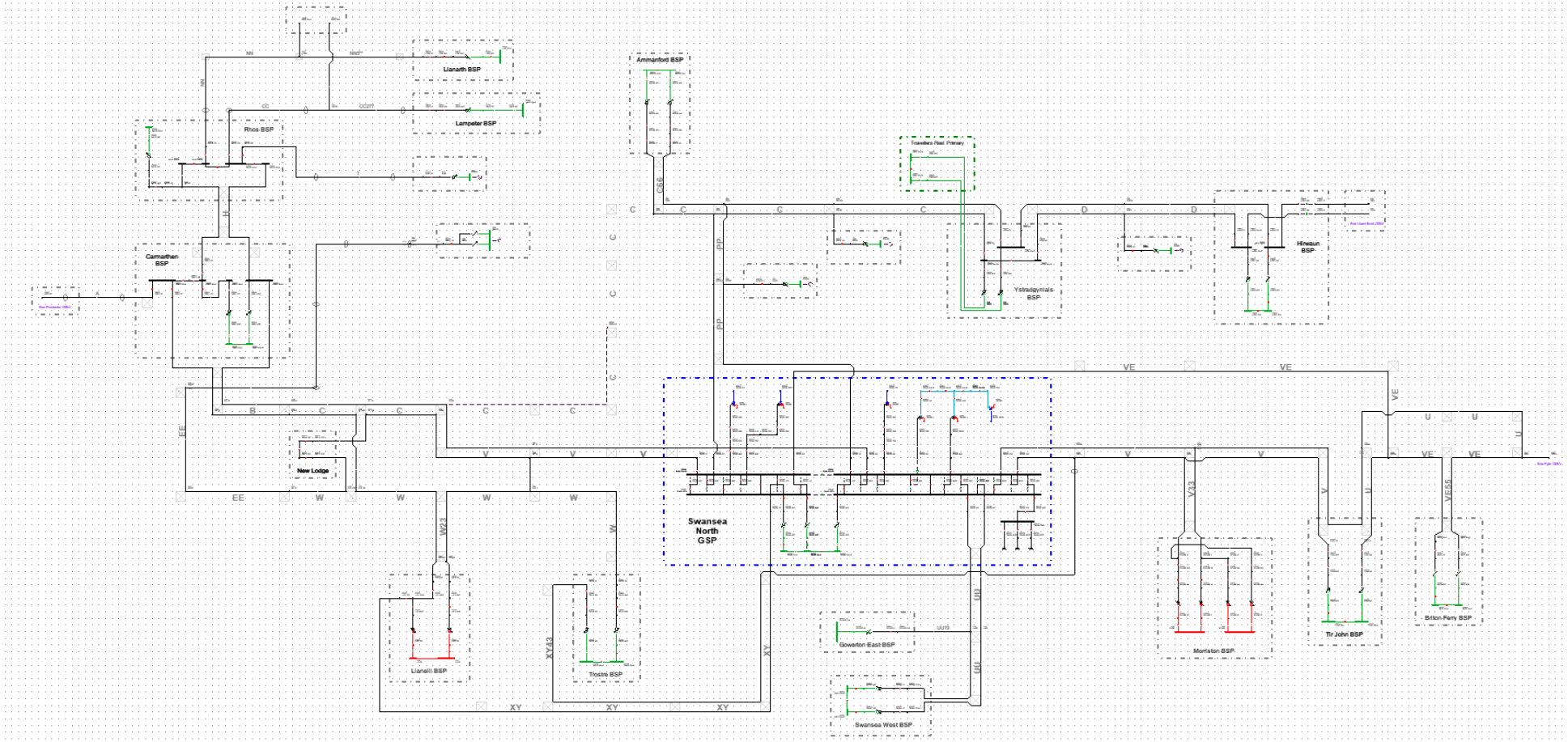

Figure 16: Swansea North 132 kV network schematic diagram