# Cardiff Central & Cardiff West BSPs incl. associated 33 kV networks

Network Development Report – South Wales

**May 2024**

Electricity Distribution

nationalgrid

# Contents

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## 1. Network Overview

Cardiff Central and Cardiff West Bulk Supply Points (BSPs) supply an area of 33 kV network within the city of Cardiff and operate in parallel via several 33 kV circuits under intact network conditions. The associated 33 kV network supplies close to 65,000 customers and includes the following 33/11 kV Primary substations:

- Canton, Ely, Fairwater, Highmead, Llandough, Penarth, Sanatorium, Sandon Street, Taff Bank and Wood Street.

Cardiff Central and Cardiff West BSPs currently have a maximum demand of 102 MVA and under NGEDs DFES Best View scenario this is projected to rise to 114 MVA by the year 2034.

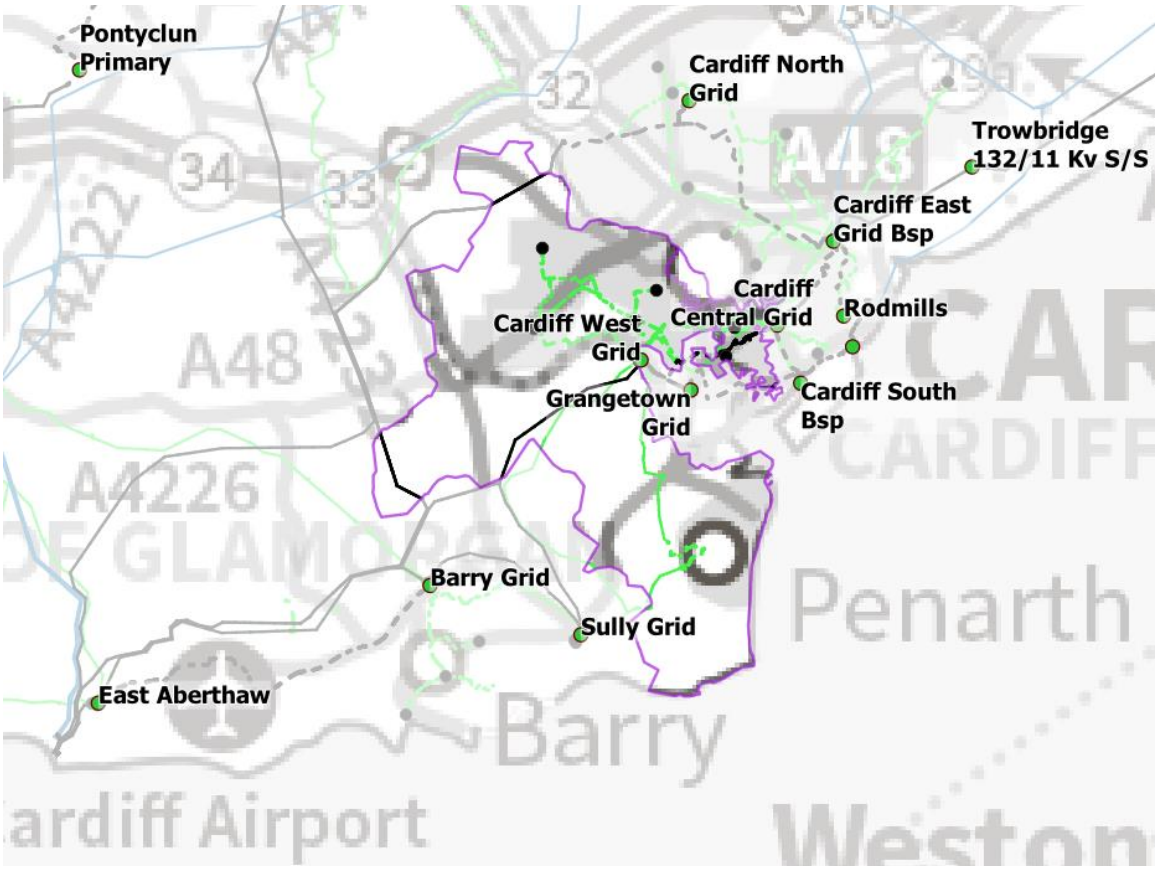


*Figure 1.1 Cardiff Central and Cardiff West BSPs geographic network coverage*

This report discusses all existing and future network constraints over a 0-10 year horizon associated with the 33/11 kV transformers, 33 kV circuits, 132/33 kV transformers and 132 kV circuits which supply and are supplied by Cardiff Central and Cardiff West BSPs. This uses the methodology outlined in the Network Development Plan Methodology Report with Network Operability Modelling applied as outlined below.

For the purposes of this analysis the NGED Best View Distribution Future Energy Scenario (DFES) has been used to study the years 2022 (baseline), 2028 and 2034, with consideration given to how proposals could change under the other scenarios.

The two most onerous half-hours have been studied for each of the five representative days considered: Winter Peak Demand, Intermediate Warm Peak Demand, Intermediate Cool Peak Demand, Summer Peak Demand and Summer Peak Generation.

## 1.1 Network Topology

The Cardiff Central and Cardiff West 33 kV network is arranged as follows:

- Cardiff Central BSP has two 132/33 kV GTs: GT1 rated at 60/90 MVA and GT2 rated at 45/90 MVA. GT2 supplies the 33 kV group and GT1 is dedicated to an NGED 33 kV connected customer.
- Cardiff West BSP has two 132/33 kV GTs (GT1 and GT2) both rated at 60/90 MVA.
- The outgoing 132 kV circuits from each BSP are supplied from the Aberthaw and Cardiff East 132 kV group.
- Outgoing 33 kV circuits from Cardiff Central and Cardiff West BSPs supply the following 33/11 kV primary substations:
    - Canton: Two 10/14 MVA primary transformer substation (T1 & T2)
    - Ely: Two 12/24 MVA primary transformer substation (T1 & T2)
    - Fairwater: Two primary transformer substation

      T1 (7.5/15 MVA) and T2 (12/24 MVA)
    - Highmead: Two 12/24 MVA primary transformer substation (T1 & T2)
    - Llandough: Two 7.5/15 MVA primary transformer substation (T1 & T2)
    - Penarth: Two 12/24 MVA primary transformer substation (T1 & T2)
    - Sanatorium: Two 7.5/15 MVA primary transformer substation (T1 & T2)
    - Sandon Street: Two 12/24 MVA primary transformer substation (T1 & T2)
    - Taff Bank: Two 12/24 MVA primary transformer substation (T1 & T2)
    - Wood Street: Two 20/40 MVA primary transformer substation (T1 & T2)

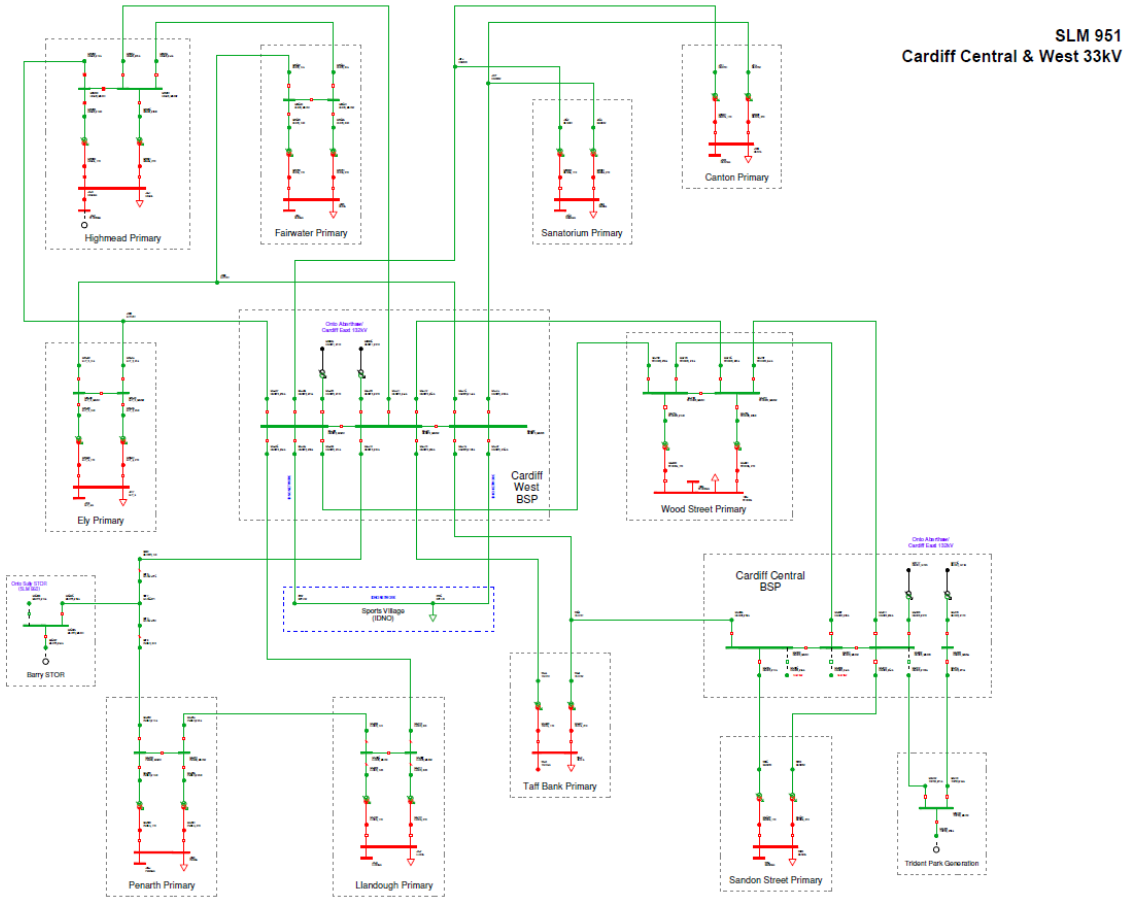


*Figure 1.1 Cardiff Central & Cardiff West 33 kV network single line diagram*

## 1.2 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, as well as proposed actions, to manage some constraints identified operationally.

- Two 33 kV circuits from Cardiff Central BSP tee into the Park Lane to Cardiff East 33 kV feeders. These circuits, which are normally run open at Cardiff Central, can provide support to the Cardiff East and Cardiff North 33 kV group under select outage conditions. Typically, for an arranged GT outage at either Cardiff East or Cardiff North BSP, the 33 kV normally open points at Cardiff Central can be moved to 9L5 and 10L5 at Cardiff East BSP. This allows Park Lane to be supplied from Cardiff Central, de-loading this group in the process. Due to fault level restrictions, it is not possible to operate the two groups in parallel except for switching time.
- A 33 kV interconnection to the Cardiff Central and Cardiff West 33 kV group is available via an outgoing 33 kV circuit at Brynhill BSP. This circuit, which is normally run open, is primarily utilised to support either BSP group following SCO outage conditions.
- For the loss of an infeed to a transformer at any of the primaries fed from within the Cardiff Central and Cardiff West 33 kV network under arranged outages, the lower voltage side circuit breaker is opened to prevent back-energisation.
- Curtailment of all connected load management schemes within the group are modelled at a variety of outage conditions, as outlined in customer connection agreements.
- Various winter arranged outages not permitted due to SCO overloads.
- Various SCO overloads solved by network reconfiguration for arranged outages.

# 2. Summary of Network Constraints

The following constraints were identified for the Best View Scenario, for which mitigation options will be discussed:

- 33 kV circuit constraints between Cardiff Central and Cardiff West under SCO conditions. This includes both 33 kV circuits from Cardiff West to Wood Street, Wood Street to Cardiff Central as well as the 33 kV circuit from Cardiff West to Central via the Taff Bank tee off.
- 33 kV circuit constraints under SCO conditions on the Ely / Highmead / Fairwater 33 kV ring.
- Fairwater 33/11 kV transformer constraints.

# 3. Network Constraint Details and Solution Options

## 3.1 Cardiff Central and Cardiff West 33 kV Group

The table below summarises the scale of the background load growth forecast to connect to the Cardiff Central and Cardiff West 33 kV network up to 2034 under NGEDs DFES Best View scenario.

*Table 3.1.1 Maximum demand forecast to Cardiff Central & Cardiff West 33 kV network*

| DFES Scenario | Demand | | |
|---|---|---|---|
| | Baseline | 2028 | 2034 |
| Best View | 102 MW | 106 MW | 114 MW |

*Table 3.1.2 Maximum generation forecast to Cardiff Central & Cardiff West 33 kV network*

| DFES Scenario | Generation | | |
|---|---|---|---|
| | Baseline | 2028 | 2034 |
| Best View | 62 MW | 72 MW | 92 MW |

With new developments proposed to connect within the group at 11 kV and at 33 kV in the near future, the load forecast is expected to increase. However, this will vary depending if such developments materialise.

This group becomes vulnerable to outage conditions throughout the 0-10 year horizon period as a result of the load growth projections. These limitations are highlighted below.

## 3.2 Cardiff Central/West via Wood Street 33 kV circuit constraints

### Constraint Overview

Generation Demand

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

*Table 3.2.1 constraint(s) and condition under which constraint occurs*

| Constraint | N-1 Condition | Subsequent N-2 Condition | First year constraint is observed in each season under Best View | | | |
|---|---|---|---|---|---|---|
| | | | Winter | Int Cool | Int Warm | Summer |
| Cardiff West 6L5 to Wood Street 2L5<br><br>Cardiff West 1L5 to Wood Street 2L5<br><br>Taff 3T to Cardiff Central 3L5<br><br>Taff 3T to Cardiff West 12L5<br><br>Wood Street 1L5 to Cardiff Central 2L5 | Arranged main 1/2 bar outage at Cardiff West. | Fault on Cardiff West GT 1/2 | Baseline | Baseline | Baseline | Baseline |

**Uncertainty under other Distribution Future Energy Scenarios:** As this constraint occurs under baseline, there is no uncertainty about future forecasts. There is a risk that demand reduces, however this is not forecast under any scenario so mitigation against this constraint is required.

### Solution Options

A list of each of the options considered for this constraint is given in the table below.

*Table 3.2.2 solution options to solve constraint(s)*

| Solution Options | Description | Solves Constraint | Wider Area Benefit | Potential to be cost effective | Viable or Discounted |
|---|---|---|---|---|---|
| 0 | No Intervention | × | × | × | Discounted |
| **Reinforcement** | | | | | |
| 1 | Uprate 33 kV circuits between Cardiff Central and Cardiff West | ✓ | ✓ | ✓ | Viable |
| 2 | Add Cardiff Central GT1 to main bar 1 | ✓ | ✓ | ✓ | Viable |
| 3 | Install additional 33 kV circuits/reinforce circuits to transfer demand to Cardiff Central | ✓ | ✓ | ✓ | Viable |
| 4 | Combination of options 1,2 and 3 | ✓ | ✓ | ✓ | Viable |
| **Operational Mitigation** | | | | | |
| 5 | Transfer demand to other BSPs | × | × | ✓ | Discounted |
| **Flexibility services** | | | | | |
| 6 | Procure flexibility at Cardiff Central/West | × | × | × | Discounted |

### Solution Development

These options have been assessed on their technical viability and their likely cost-effectiveness pending a full cost benefit analysis (CBA). This CBA will be subsequently carried out by the DNO to determine the optimal reinforcement solution, which will then be tested against market provided flexibility by the DSO as part of the Distribution Network Options Assessment (DNOA) process.

#### Option 0 – No Intervention

**Capacity Released for constraint(s) considered:** 0 MVA

Discounted

**Detailed description:** Doing nothing to mitigate the constraint would result in thermal overloads for the conditions described above.

**New limiting factor for constraint(s) considered:** N/A

## Option 1 – Uprate 33 kV circuits between Cardiff Central - Wood Street – Cardiff West

**Capacity Released for constraint(s) considered:** approx. 40 MVA ↑ **Viable**

**Detailed description:** The 33 kV circuits from Cardiff Central to Wood Street, and Wood Street to Cardiff West could be uprated to match the capacity of the Wood Street transformers (38 MVA). Cardiff Central to Wood Street should be the first 33 kV section to be uprated.

**New limiting factor for constraint(s) considered:** While this means overloads are avoided for the 33 kV circuits between Cardiff West-Wood Street-Cardiff Central, Taff Bank tee off is still heavily overloaded, as well as Cardiff Central GT2. Furthermore, this would be a challenging task to carry out as the 33 kV underground cable circuit route goes right through the built up area within the centre of Cardiff.

Even though this is a necessary change from a network integrity point of view, additional detailed design is required to understand the delivery challenges of any solution.

## Option 2 – Install a 33 kV interplant cable between Cardiff Central 33 kV main 1 and main 4 busbars in order to add GT1 to the group capacity

**Capacity released for constraint(s) considered:** 90 MVA ↑ **Viable**

**Detailed description:** Due to space constraints at Cardiff Central BSP, a 33 kV bus section circuit breaker cannot be added to the existing GIS 33 kV switchgear. Therefore, a 33 kV interplant cable could be installed between the 33 kV main 1 and main 4 busbars.

**New limiting factor for constraint(s) considered:** 33 kV circuit constraints are not alleviated, although capacity added to the group that can be used to shift demand from Cardiff West to Cardiff Central. With this change, Wood Street and Taff Bank could be moved onto Cardiff Central.

## Option 3 – Install additional 33 kV circuits/reinforce circuits to transfer demand

**Capacity Released for constraint(s) considered:** 30 MVA ↑ **Viable**

**Detailed description:** Add another 33 kV tee off at Taff Bank in order to connect a new 33 kV circuit (rated around 25-30 MVA) that goes back to a new 33 kV bay at Cardiff Central. This would allow Taff Bank to be transferred to Cardiff Central.

**New limiting factor for constraint(s) considered**: this solution does not alleviate 33 kV circuit constraints on the Cardiff West-Wood Street-Cardiff Central circuits, furthermore this would not alleviate the constraint on the Cardiff Central GT.

## Option 4 – Combination of options 1, 2 and 3 (splitting the group)

**Capacity Released for constraint(s) considered:** 90 MVA ↑ **Viable**

**Detailed description:** This solution essentially involves splitting the Cardiff Central and Cardiff West group into two distinct BSPs that could support each other in the event of a major outage. The following network changes would be made:

- Overlay the 33 kV circuits from Cardiff West to Wood Street, as well as Wood Street to Cardiff Central (to a rating up to 40 MVA).
- Add a new 33 kV circuit from Taff Bank tee to Cardiff Central BSP.
- Install a 33 kV interplant cable between Main 1 and Main 4 busbars to allow for GT1 to be used at Cardiff Central.
- Transfer Wood Street and Taff Bank to Cardiff Central.

This solution allows for high security of supply, as either BSP could be used to transfer up to around 60 MVA of capacity to the other. Furthermore, the load between Cardiff West and Cardiff Central would be closer, and there would be less of an imbalance towards Cardiff West.

**New limiting factor for constraint(s) considered:** 90 MVA firm capacity per BSP group

## Option 5 – Transfer demand to other BSPs

**Capacity Released for constraint(s) considered:** 19 MVA ↓ **Discounted**

**Detailed description:** Llandough and Penarth primary substations could be transferred across to Brynhill/East Aberthaw.

**New limiting factor for constraint(s) considered:** The 33 kV circuits between Cardiff Central and Wood Street are still overloaded, as well as the Cardiff Central GT. Overloads still present between Cardiff Central and Taff Bank, as well as Wood Street and Cardiff West.

**Option 6 – Procure flexibility for Cardiff Central and Cardiff West**

**Flexibility service type:** Demand turn down or generation turn up **Discounted**

**Detailed description:** Flexibility services could be procured to help alleviate the projected overloads, in conjunction with a load transfer.

A potential use of flexibility could be used in conjunction with a load transfer of Llandough and Penarth, with 8 MW needed in flexibility to avoid the Cardiff West to Wood Street 33 kV circuits being overloaded. However, the 33 kV circuits from Wood Street to Cardiff Central would still be overloaded, as well as the GT at Cardiff Central.

The viability of utilising flexibility will be further considered as part of the DNOA process.

### Solution Recommendation

It is recommended to consider option 4 for the long term approach. This would guarantee security of supply as well as network integrity for a double GT outage at Cardiff Central. The order of work recommended would be as follows:

- Reinforce the 33 kV circuits from Wood Street to Cardiff Central.
- Install a 33 kV underground cable section to connect busbars main 4 and main 1 at Cardiff Central. This allows GT1 at Cardiff Central to be used to supply the group. At this point, flexibility could be used to alleviate the Cardiff West to Wood Street constraint. As previously mentioned, 8 MW would be required, as well as a load transfer of Llandough and Penarth over to East Aberthaw/Barry Brynhill.
- Install an additional 33 kV circuit from a new tee off at Taff Bank to a new 33 kV bay at Cardiff Central BSP.
- Transfer Taff Bank and Wood Street to Cardiff Central, and run the existing 33 kV circuits to Cardiff West from both primaries open.
- Overlay the 33 kV circuits between Cardiff West and Wood Street. This can be done at a later stage as the existing 26 MVA rating can accommodate up to 2028 growth projections.
- Eventually, the existing Taff Bank tee off will have to be uprated from 26 MVA up to 35 MVA. Growth projections by 2028 cause overloads on this 33 kV circuit.

## 3.3 Ely / Highmead / Fairwater SCO 33 kV circuit constraints

### Constraint Overview

Generation **Demand**

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

*Table 3.3.1 constraint(s) and condition under which constraint occurs*

| Constraint | N-1 Condition | Subsequent N-2 Condition | First year constraint is observed in each season under Best View | | | |
|---|---|---|---|---|---|---|
| | | | Winter | Int Cool | Int Warm | Summer |
| Various 33 kV circuits on the Ely / Highmead / Fairwater ring | Arranged 33 kV Busbar outage at Cardiff West BSP | Fault on Cardiff West / Ely / Fairwater 33 kV circuit | Baseline | Baseline | Baseline | Baseline |

**Uncertainty under other Distribution Future Energy Scenarios:** As this constraint occurs under baseline, there is no uncertainty about future forecasts. There is a risk that demand reduces, however this is not forecast under any scenario so mitigation against this constraint is required.

## Solution Options

A list of each of the options considered for this constraint is given in the table below.

*Table 3.3.2 solution options to solve constraint(s)*

| Solution Options | Description | Solves Constraint | Wider Area Benefit | Potential to be cost effective | Viable or Discounted |
|---|---|---|---|---|---|
| 0 | No Intervention | × | × | × | **Discounted** |
| **Reinforcement** | | | | | |
| 1 | Uprate 33 kV circuits between Ely / Highmead / Fairwater | ✓ | × | × | **Discounted** |
| 2 | Establish a new 132/11 kV BSP | ✓ | ✓ | ✓ | **Viable** |
| 3 | Install additional 33 kV circuits/reconfigure network | ✓ | ✓ | ✓ | **Viable** |
| **Flexibility services** | | | | | |
| 4 | Procure flexibility at Cardiff Central/West | × | × | × | **Discounted** |

## Solution Development

These options have been assessed on their technical viability and their likely cost-effectiveness pending a full CBA. This CBA will be subsequently carried out by the DNO to determine the optimal reinforcement solution, which will then be tested against market provided flexibility by the DSO as part of the DNOA process.

### Option 0 – No Intervention

**Capacity Released for constraint(s) considered:** 0 MVA **Discounted**

**Detailed description:** Doing nothing to mitigate the constraint would result in thermal overloads for the conditions described above.

**New limiting factor for constraint(s) considered:** N/A

### Option 1 – Uprate the 33 kV circuits between Cardiff West / Highmead / Ely

**Capacity Released for constraint(s) considered:** 1 MVA **Discounted**

**Detailed description:** Due to the future load growth, the group demand is projected to exceed 40 MVA by 2034 (with 39 MVA under credible outage window conditions). The current network configuration has the limitation of the 33 kV group demand of Ely, Fairwater and Highmead being supplied by a single 33 kV circuit under SCO conditions. Uprating the existing 33 kV circuits to accommodate such growth may not be a viable option.

**New limiting factor for constraint(s) considered:** Group demand of Ely, Fairwater and Highmead

### Option 2 – Establish a new 132/11 kV BSP on the Cardiff North 132 kV circuit

**Capacity released for constraint(s) considered:** 30 MVA **Viable**

**Detailed description:** A new BSP could be established from the Aberthaw / Cardiff East 132 kV network in order to release additional capacity for the 33 kV network by de-loading sufficient demand. This proposal could loop into the Cardiff North MM route 132 kV circuit and may have the dual benefit of also being able to de-load the nearby Ironbridge / Creigiau / Morlanga 33/11 kV primaries from Upper Boat GSP, alleviating multiple constraints.

**New limiting factor for constraint(s) considered:** Firm capacity of the new BSP

### Option 3 – Install additional 33 kV circuits/reconfigure network

**Capacity Released for constraint(s) considered:** 35 MVA **Viable**

**Detailed description:** This solution involves splitting Highmead away from Ely and Fairwater. A new 33 kV circuit should be built from a dedicated 33 kV bay at Cardiff West to Highmead primary substation. Additional works will be required to join the existing 33 kV circuits, combining Ely and Fairwater together into a 33 kV group.

There is a 200 m section of 33 kV underground cable section that should be replaced to increase the rating of the Cardiff West to Ely tee off 33 kV circuit to allow for future load growth. This would create two separate groups and will futureproof the network effectively.

**New limiting factor for constraint(s) considered**:

33 kV circuit capacity from Cardiff West to Ely tee off

**Option 4 – Procure flexibility at the primaries on Cardiff West 33 kV**

**Estimated Flexibility Required (MVA):** 10 MVA+ **Discounted**

**Detailed description:** Flexibility services may not be a viable solution due to the very high amount of flexibility required to alleviate the constraint.

### Solution Recommendation

The preferred solution option would be to install additional 33 kV circuits and split the Highmead / Ely / Fairwater groups. This would effectively eliminate the constraints observed whilst also ensuring capacity is available for future load growth.

Adding a new 132/11 kV BSP would also be a viable solution as it could solve multiple network integrity issues, however it would be a prohibitively expensive scheme.

## 3.4 Fairwater 33/11 kV transformer constraints

### Constraint Overview

Generation **Demand**

The table below outlines the nature of the network constraints identified in the network analysis, with the worst overloads seen at intermediate warm/cool peak demand.

*Table 3.4.1 constraint(s) and condition under which constraint occurs*

| Constraint | N-1 Condition | Subsequent N-2 Condition | First year constraint is observed in each season under Best View | | | |
|---|---|---|---|---|---|---|
| | | | Winter | Int Cool | Int Warm | Summer |
| Fairwater T1 | Fairwater T2 outage | Null | - | 2034 | 2034 | - |

**Uncertainty under other Distribution Future Energy Scenarios:** As this constraint occurs in 2034 under best view conditions, there is a degree of uncertainty over when this constraint would arise.

### Solution Options

A list of each of the options considered for this constraint is given in the table below.

*Table 3.4.2 solution options to solve constraint(s)*

| Solution Options | Description | Solves Constraint | Wider Area Benefit | Potential to be cost effective | Viable or Discounted |
|---|---|---|---|---|---|
| 0 | No Intervention | × | × | × | **Discounted** |
| **Reinforcement** | | | | | |
| 1 | Upgrade T1 at Fairwater | ✓ | ✓ | ✓ | **Viable** |
| **Operational Mitigation** | | | | | |
| 2 | Transfer demand to other primaries | ✓ | ✓ | ✓ | **Viable** |
| **Flexibility services** | | | | | |
| 3 | Procure flexibility at Fairwater primary | ✓ | × | × | **Viable** |

### Solution Development

These options have been assessed on their technical viability and their likely cost-effectiveness pending a full cost benefit analysis (CBA). This CBA will be subsequently carried out by the DNO to

determine the optimal reinforcement solution, which will then be tested against market provided flexibility by the DSO as part of the DNOA process.

### Option 0 – No Intervention

**Capacity Released for constraint(s) considered:** 0 MVA

**Discounted**

**Detailed description:** Doing nothing to mitigate the constraint would result in overloads for the conditions described above. This would lead to an inability to meet the Security of Supply requirements of Engineering Recommendation P2 for Fairwater primary.

**New limiting factor for constraint(s) considered:** N/A

### Option 1 – Uprate Transformer T1 at Fairwater

**Capacity Released for constraint(s) considered:** 10 MVA

**Viable**

**Detailed description:** Uprate 33/11 kV transformer T1 at Fairwater to match the existing 12/24 MVA CER T2. This would secure Fairwater primary throughout this period of assessment and beyond.

**New limiting factor for constraint(s) considered:** Fairwater T1/T2 12/24 MVA CER units

### Option 2 – Permanently transfer demand to Ely or Highmead primaries

**Capacity released for constraint(s) considered:** 2.5 MVA

**Viable**

**Detailed description:** This would involve switching normally open points at Fairwater and Highmead/Ely primaries to transfer 2.5 MW of demand away from Fairwater.

This may require some reinforcement of 11 kV circuits.

**New limiting factor for constraint(s) considered:** Capacity of the 11 kV circuits around Fairwater

### Option 3 – Procure flexibility at Fairwater Primary

**Estimated Flexibility Required (MVA):** 2+ MVA

**Viable**

**Detailed description:** Flexibility services could be used at Fairwater primary, however considering this is an FCO condition it is not recommended as consistently attaining 2 MVA+ of flexibility services at a small primary could be challenging.

## Solution Recommendation

It is recommended to firstly consider flexibility as an option to gauge the level of procurement available within the area, subject to a cost benefit analysis and confirmation through the DNOA process.

Following this, it is recommended to upgrade the T1 transformer to a 12/24 CER unit to match the existing T2 at Fairwater primary.

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