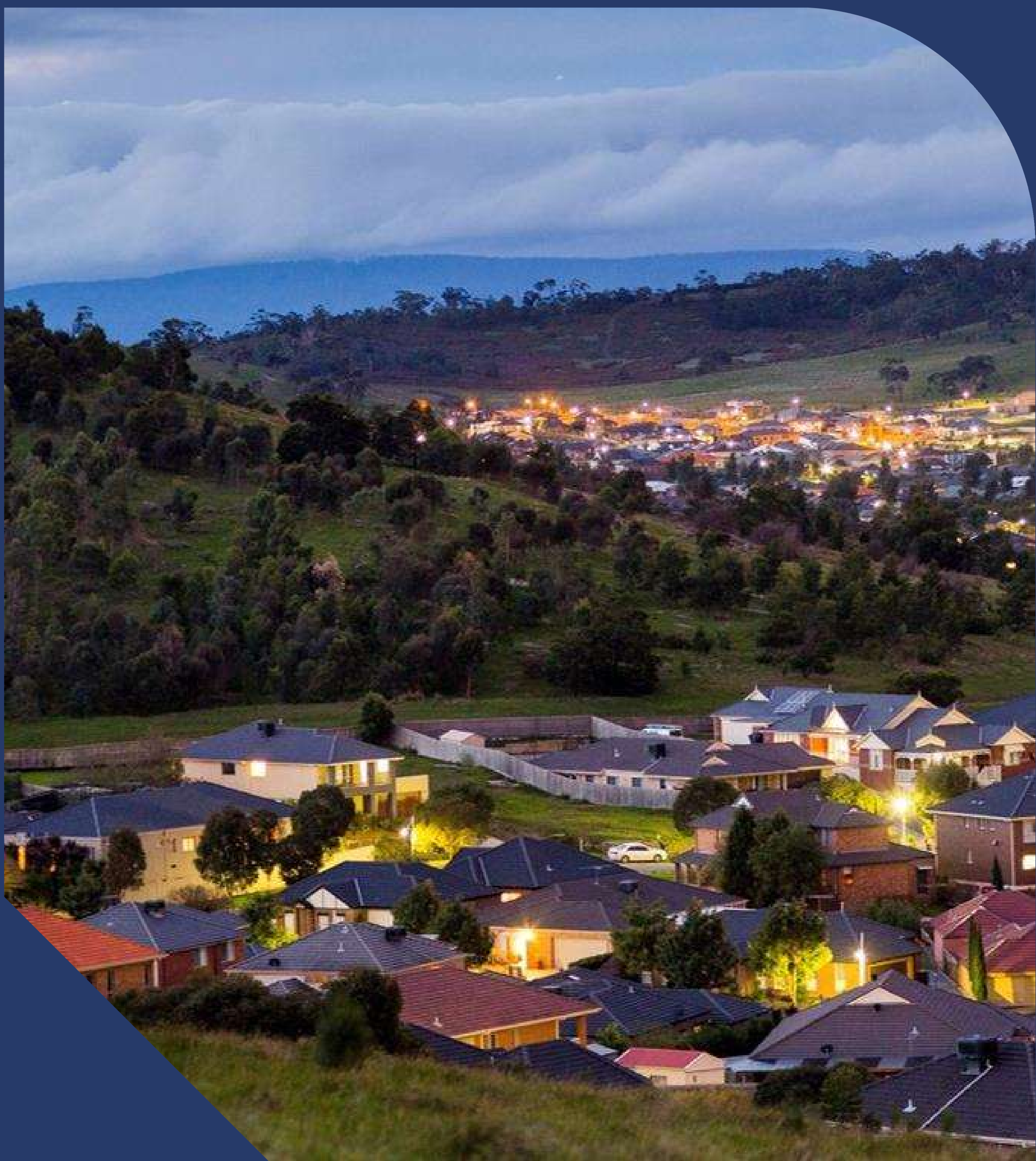
AusNet

Electricity Distribution Price Review (EDPR 2026-31)

Business case: Distributed Under Frequency Load Shedding

Date: 31 January 2025



AusNet

Table of contents

1. Executive summary

AusNet is a regulated Victorian Distribution Network Service Provider (DNSP) that supplies electricity distribution services to more than 800,000 customers. Our electricity distribution network covers eastern rural Victoria and the outer suburbs of the northern and eastern Melbourne metropolitan area. As expected by our customers and required by the various regulatory instruments that we operate under, AusNet aims to maintain mandated service levels at the lowest possible cost to our customers. To achieve this, we develop forward looking plans that aim to maximise the Net Present Value to all those who produce, consume and transport electricity in the National Electricity Market (NEM).

The National Electricity Rules (NER) defines the power system security requirements of a distributor to support the Australian Energy Market Operator (AEMO) in its role in maintaining power system security. NER schedule S5.1.10, and clauses 4.3.1(k), 4.3.4, detail the regulatory obligations for power system security in relation to the Under Frequency Load Shedding (UFLS) control scheme, the subject of this business case. UFLS is an existing load-shedding control scheme comprising a system of under-frequency tripping relays installed at each terminal station, that are triggered in a coordinated way by a major loss of generation that causes an under-frequency event due to an undersupply condition for the network load (demand) at the time. This may require a rebalancing of load to supply by dropping some of the load on the network at the time. If this is not done in a timely manner, the UFLS condition could worsen and significantly threaten system security. UFLS relays at substations can shed blocks of load (typically at the sub-transmission level) until the supply-demand balance is restored, thereby returning the power system back to a secure state.

UFLS scheme can become ineffective with the presence of reverse power flows from distributed embedded generation which can cause net generation to be seen within available load shedding blocks. This would typically happen where the CER generation within that part of the network exceeds the load in the same section. Shedding net generation blocks during an under-frequency event would make an UFLS situation worse by reducing supply further. This in turn may cause the power system to collapse, with the system frequency decline unable to be arrested as more generation is removed from the system. With the ongoing increases in the uptake of distributed roof-top solar photo-voltaic panels (DPV) within the distribution networks over the last 15 years, there is an increased risk of the load-shed blocks armed within the UFLS scheme being net generation sources at certain times of day, because local demand is exceeded by local generation.

NER clause 4.3.1(k)(2) requires AEMO to ensure there is sufficient reserve available within the UFLS scheme to arrest the impacts of a range of significant multiple contingency events affecting up to 60% of the total power system load. Clause 4.3.4(a) requires each Network Service Provider (NSP) to use reasonable endeavours to exercise and assist AEMO in the proper discharge of its power system security responsibilities. AusNet's interpretation of these clauses is that each NSP should within reason, be able to provide up to 60% of that NSP's total *underlying (or gross) load* under the control of the UFLS scheme. Meeting this requirement with the existing UFLS scheme installed at the terminal station level will become increasingly difficult as DPV growth continues, and the net demand as measured by the UFLS scheme reduces as a proportion of the underlying load. Load blocks with reverse power flow, and the reduced numbers of load blocks available for the UFLS scheme, are a threat to the effectiveness of the UFLS scheme in responding to a widespread loss of transmission generation.

In May 2023, AEMO released a report titled "Victoria: UFLS load assessment update" which presented an analysis of under frequency load shedding data up to 2022. In that report AEMO recommended that Victorian NSPs:

1. Remove large generating units from the UFLS scheme.
2. Update generator connection processes to prevent further large generating units from being connected behind UFLS relays in future.
3. Explore implementation of systems to facilitate monitoring of UFLS load in real time (such as a SCADA feed).
4. Explore options to address the impacts of DPV on the UFLS scheme.

With works largely in-train or completed for the first three recommendations, this business cases focuses on the options to address the impacts of DPV on the UFLS scheme.

In October 2023, AEMO released a report titled "UFLS: Exploring dynamic arming options for adapting to distributed PV" which presented options available to NSPs based on Victorian case studies. In that report AEMO recommended that Victorian NSPs consider options including:

1. Dynamic arming of load blocks (i.e., reverse power flow blocking).
2. More granular load blocks as an alternative to sub-transmission load shedding, including the use of AMI.

Subsequent to these reports, AusNet has investigated the credible options available to us in relation to maintaining the integrity of the UFLS scheme and has prepared this business case to select the option that is both technically feasible and achieves the desired compliance outcomes at least cost. We have assessed four options[1] as part of this business case:

- **Do nothing** – no expenditure on addressing UFLS scheme -compliances (i.e., retaining the existing terminal station schemes which will continue to reduce in UFLS effectiveness due to increasing CER).
- **Option 1 – Distributed UFLS at all zone substations and dynamic blocking**: installing under-frequency relays at all zone substations to provide more granular load blocks for the UFLS, with dynamic reverse power blocking implemented at each zone substation.
- **Option 2 – Distributed UFLS at all distribution feeders and dynamic blocking:** installing under-frequency relays at all zone substations to provide even more granular load blocks for the UFLS than under option 1, with dynamic reverse power blocking implemented on each distribution feeder (this is more refined compared to option 1).
- **Option 3 – Network storage supported UFLS:** installing network storage to increase the net load as a proportion of the underlying load on the network by charging (pre-contingent).
- **Option 4 – Emergency backstop mechanism supported UFLS**: leverage the emergency backstop mechanism only (pre-contingent) to curtail distributed embedded generation to increase the net load on the network. This option is considered unviable on its own as it only applies to new DPV systems and does not address legacy UFLS compliance issues.

AusNet proposes Option 2 at a cost of $18.1 million (Real, 30th June 2024 dollars) over the 2027-31 regulatory control period, which represents a prudent and efficient network augmentation investment to maintain system security compliance with respect to the UFLS scheme. At a discount rate of 5.56% per annum, this option has a net present value of $2.8 million (Real, 30th June 2024 dollars) as shown in Table 1. We have proposed Option 2 as the preferred option as it is the least cost, technically acceptable solution to improve compliance of all the options considered. The capex requirement associated with Option 2 is $17.8m.

Over the 2027-31 regulatory control period, for an Option 2 investment, the worst case

- percentage of net load as a proportion of underlying load under the control of the UFLS is expected to be 13% (compared to a do nothing of 0%).
- percentage of the year the net load as a proportion of underlying load under the control of the UFLS is expected to be less than the 60% regulatory requirement is expected to be 15% (compared to a do nothing of 18%).
- shortfall in net load available to the UFLS requiring DPV to be curtailed to achieve full compliance is 279 GWh pa (compared to a do nothing of 488 GWh pa) calculated as the amount of underlying energy needing to be exposed to the UFLS by way of generation reductions to achieve the 60% compliance target, aggregated annually from each half hour, based on the AER CECV and VER methodologies.

For the purposes of this business case, any shortfalls in compliance being achieved by the options considered, are assumed to be met by curtailing Consumer Energy Resources (CER). The only benefits considered in this business case (summarised in Table 1) are therefore the relative values of avoided greenhouse gas emissions and CER generation curtailment offered by each option in meeting our compliance obligations.

[1] Note, post-contingent solutions involving AMI, CSIP-AUS, SCADA or other forms of communications to customer loads or generation installations are not regarded by AusNet as credible solutions except for some specific applications where direct inter-trips are in place. This is because the communications systems in place are not fast enough and cannot be graded satisfactory to respond to the required operating performance requirements required by the UFLS scheme. Furthermore, the end-devices (e.g. AMI meters) often do not have the capability to detect and act on frequency deviations.

Table 1: Economic Evaluation of Distributed UFLS Program Options ($m, 30th June 2024 dollars)

	FY27 to FY31 (undiscounted)			Full assessment period (discounted)			Comments
	Capex	Opex	Total cost	Total cost	Total benefits	NPV	
Do nothing	-	-	-	-	0.0 [2]	-	This option does not address the identified need
Option 1 – Distributed UFLS at all zone substations and dynamic blocking	14.6	0.3	14.9	(14.8)	12.9	(1.9)	This option provides marginal compliance improvement.
Option 2 – Distributed UFLS at all zone substations with distribution feeders dynamic blocking	17.8	0.4	18.1	(18.0)	20.8	2.8	This option achieves material compliance improvement.
Option 3 – Network storage supported UFLS	5,175	11.0	5,186	(4,585)	46.8	(4,538)	This option achieves full compliance but is the most expensive option
Option 4 – Emergency backstop mechanism supported UFLS	1.5	0.4	1.9	(3.8)	-	(3.8)	This option requires CER curtailment and is unviable.

Source: AusNet analysis (relative to the base case of do nothing)

[2] The present value of total risk of greenhouse gas emissions and CER generation needing to be curtailed to achieve full compliance for the UFLS scheme, is valued at $46.8 million over the analysis period (real 30th June 2024 dollars).

2. Background

2.1. Purpose

The purpose of this business case is to describe the identified need in relation to maintaining compliance with the National Electricity Rules (NER) in relation to the Under Frequency Load Shedding (UFLS) scheme across the AusNet electricity distribution network, and to present credible options for programs of work that are able to address that identified need. The purpose is to design a program that ensures we meet our power system security obligations and maintain a secure power system for our customers.

This business case quantifies the

- current and estimated future levels of identified power system security compliance limitations across the network based on the existing UFLS scheme.
- costs and benefits of potential credible options to mitigate identified power system security compliance limitations,
- forward looking programs of work for implementation in the 2027-31 regulatory control period that ensure our regulatory compliance obligations are met at least cost.

2.2. Scope

The scope of this UFLS business case is limited only to managing power system security compliance across the AusNet electricity distribution network as is required by the NER, rather than the power system as a whole.

NER schedule S5.1.10, S5.1.8 and clauses 4.3.1(k), 4.3.4 in relation to the UFLS scheme are the only components of the NER that are the subject of this business case.

2.3. Asset management objectives

AusNet's strategic asset management objectives (as stated in Document No. AMS 01-01 Asset Management System Overview), are to:

- Comply with legal and contractual obligations (including regulatory compliance);
- Maintain safety;
- Be future ready;
- Maintain network performance at the lowest sustainable cost; and
- Meet customer needs.

This UFLS business case supports those objectives, by

- Maximising the levels of regulatory power system security compliance;
- Minimising the safety risk to customers by minimising the amount of customer load shed to achieve our power system security obligations;
- Preparing the network to support growth in CER (including DPV) both now and into the future whilst maintaining power system security;
- Applying a least cost approach while striking an optimal balance between cost, risk and performance; and
- Supporting customer needs by minimising the amount of customer load shed and CER curtailment needed to achieve our power system security obligations.

2.4. Under frequency load shedding regulatory requirements

The security of the power system is protected from under-frequency events (triggered by the coincident loss of multiple generating units) by an Under-Frequency Load Shedding (UFLS) scheme. The scheme is currently implemented at each terminal station with under-frequency relays graded to achieve a coordinated tripping of sub-transmission load blocks across the system until the frequency decline is arrested and the system is stabilised.

NER clause 4.3.1(k)(2) requires AEMO to ensure there is sufficient reserve available within the UFLS scheme to arrest the impacts of a range of significant multiple contingency events affecting up to 60% of the total power system load. Clause 4.3.4(a) requires Each Network Service Provider (NSP) to use reasonable endeavours to exercise and assist AEMO in the proper discharge of its power system security responsibilities. AusNet's interpretation of these clauses is that each NSP should with reason, ensure (for AEMO), provide 60% of that NSP's total underlying (or gross) load under the control of the UFLS scheme.:

$$A \geq 60\% \times B \quad , \text{where } B = C + D$$

A = Aggregated net load within the control of the UFLS scheme.

B = Aggregated gross (underlying) load across the entire AusNet distribution network.

C = Aggregated gross generation output across the entire AusNet distribution network.

D = Aggregated net load across the entire AusNet distribution network.

The relevant clauses within the NER relating to UFLS compliance are as follows:

- **clause 4.3.1(k)** – "*The AEMO power system security responsibilities are … to assess the availability and adequacy, including the dynamic response, of contingency capacity reserves and reactive power reserves in accordance with the power system security standards and to ensure that appropriate levels of contingency capacity reserves and reactive power reserves are available:*

    (1) to ensure the power system is, and is maintained, in a satisfactory operating state; and

    (2) to arrest the impacts of a range of significant multiple contingency events (affecting up to 60% of the total power system load) or protected events to allow a prompt restoration or recovery of power system security, taking into account under-frequency initiated load shedding capability provided under connection agreements, by emergency frequency control schemes or otherwise;"

- **clause 4.3.4(a)** – "*Each Network Service Provider must use reasonable endeavours to exercise its rights and obligations in relation to its networks so as to co-operate with and assist AEMO in the proper discharge of the AEMO power system security responsibilities*".

- **clause 4.3.4(b)** – "*Each Network Service Provider must use reasonable endeavours to ensure that interruptible loads are provided as specified in clause 4.3.5 and clause S5.1.10 of schedule 5.1 (including without limitation, through the inclusion of appropriate provisions in connection agreements)*".

- **clause 4.3.4(b1)** – "*Each Network Service Provider must, in accordance with clause S5.1.10.1a of schedule 5.1, cooperate with AEMO in relation to, design, procure, commission, maintain, monitor, test, modify and report to AEMO in respect of, each emergency frequency control scheme which is applicable in respect of the Network Service Provider's transmission system or distribution system*".

Further details on the regulatory requirements are summarised in Appendix 6.1.

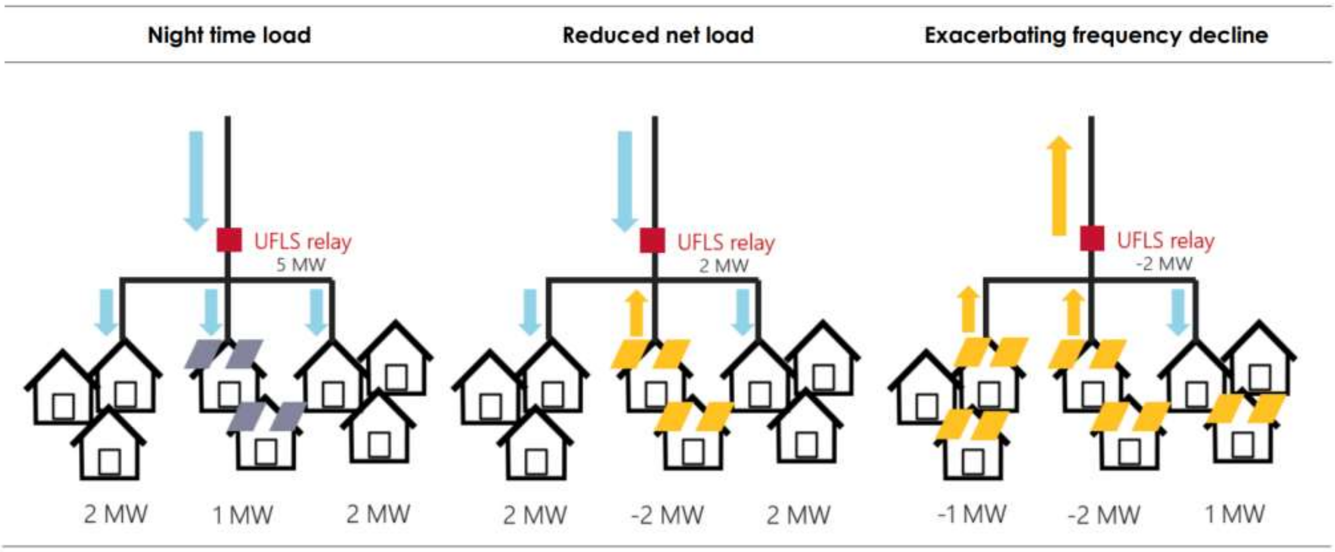
3. Identified need

3.1. Power system security

Maintaining power system security regulatory compliance has traditionally been achieved for the UFLS scheme by implementing at each terminal station, under-frequency protection relays that are graded to achieve a coordinated tripping of nominated sub-transmission load blocks across the system to stabilise the power system frequency. This implementation of the UFLS scheme was effective in achieving net load levels under the control of the UFLS scheme of at least 60% of the underlying load when there was very little embedded generation within the distribution system. This was because the net aggregated load measured across the network was essentially the same as the underlying load under the control of the UFLS scheme.

UFLS schemes were designed on the assumption that they would shed blocks of load (one-way power flow), however with the uptake of distributed embedded rooftop solar photovoltaic panels (DPV) within the distribution networks, there is an increasing risk of the load-shed blocks being net generation sources. The effect of shedding net generation blocks through UFLS can worsen the situation and cause a state-wide collapse of the power system from an uncontrolled under-frequency decline as illustrated in Figure 1.

Figure 1: Effect of DPV on UFLS scheme load block

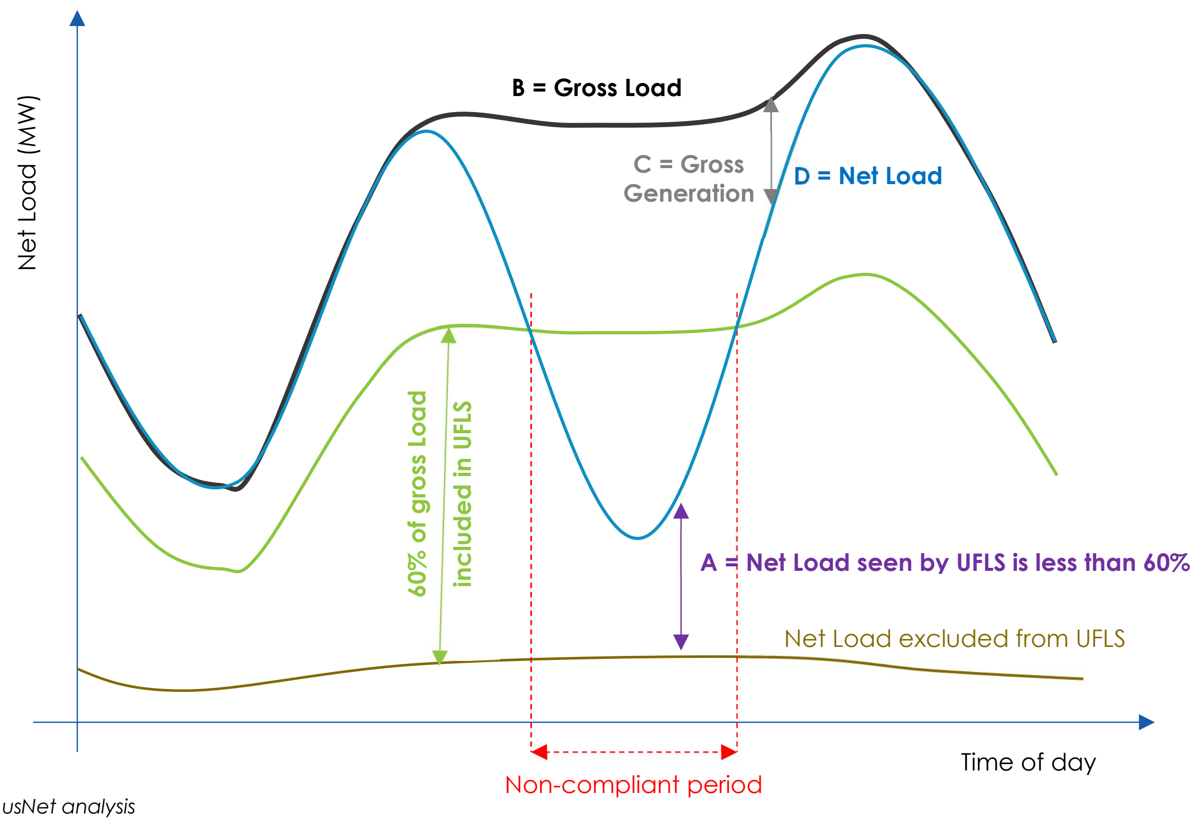


Source: AEMO, "Under Frequency Load Shedding: Exploring dynamic arming options for adapting to distributed PV", October 2023

The requirement to achieving net load levels under the control of the UFLS scheme of at least 60% of the underlying load is becoming increasingly difficult as DPV growth continues and the net demand as measured by the UFLS scheme reduces. Load blocks with reverse power flow, and the reduced numbers of load blocks available for the UFLS scheme, are a threat to the effectiveness of the UFLS scheme in responding to a widespread loss of transmission generation.

Figure 2 illustrates how compliance is achieved, and the potential for non-compliance if load is excluded from the UFLS scheme (e.g. critical customers), and if distributed embedded generation output increases (e.g. from DPV).

Figure 2: Network-wide daily load profile - UFLS non-compliant example



Source: AusNet analysis

Whilst the sub-transmission load blocks available to the UFLS scheme could be adjusted by dynamically reprioritising load blocks, adding more load blocks, or excluding all blocks with reverse power flow, this is only a short-term approach, and may have an undesirable impact on customers that would otherwise normally be excluded or tripped as a last resort by the UFLS scheme, such as critical customer loads.

In May 2023, AEMO released a report titled "Victoria: UFLS load assessment update" which presented an analysis of under frequency load shedding data up to 2022. In that report AEMO provided a forecast of the minimum net Victorian load under control of the UFLS scheme as reproduced in Table 2 below. The assessment shows that Victoria is well below 60% when looking at worst case scenario.

Table 2: AEMO's 2023 forecast of Victorian load under the control of the UFLS scheme

	Historical					Projected (based on ISP *Step Change* scenario)			
	2018	2019	2020	2021	2022	2023	2024	2025	2026
Minimum Operational demand in VIC (MW)	3,484	3,363	2,529	2,333	2,195	2,192	2,017	1,600	1,148
Minimum net UFLS load in VIC (MW)	1,925	1,699	1,262	1,184	1,233	1,230	1,141	870	576
Minimum net UFLS load (minimum % of total underlying load)	45%	35%	30%	26%	26%	25%	22%	17%	11%

Source: AEMO, "Victoria: UFLS load assessment update", May 2023

As the current and projected minimum level of coverage is less than the required 60% level in Victoria, AEMO recommended in its report that Victorian NSPs should:

1. Remove large generating units from the UFLS scheme.
2. Update generator connection processes to prevent further large generating units from being connected behind UFLS relays in future.
3. Explore implementation of systems to facilitate monitoring of UFLS load in real time (such as a SCADA feed).
4. Explore options to address the impacts of DPV on the UFLS scheme.

Details of these recommendations are reproduced in Appendix 6.2.

With works largely in-train or completed for the first three recommendations, this business cases focuses on the options to address the impacts of DPV on the UFLS scheme.

In October 2023, AEMO released a report titled "UFLS: Exploring dynamic arming options for adapting to distributed PV" which presented options available to NSPs based on Victorian case studies. In that report AEMO recommended that Victorian NSPs consider options including:

1. Dynamic arming of load blocks (i.e., reverse power flow blocking).
2. More granular load blocks as an alternative to sub-transmission load shedding, including the use of AMI.

Subsequent to these reports, AusNet has investigated the credible options available to us in relation to maintaining the integrity of the UFLS scheme and has prepared this business case to select the option that is both technically feasible and achieves the desired compliance outcomes at least cost.

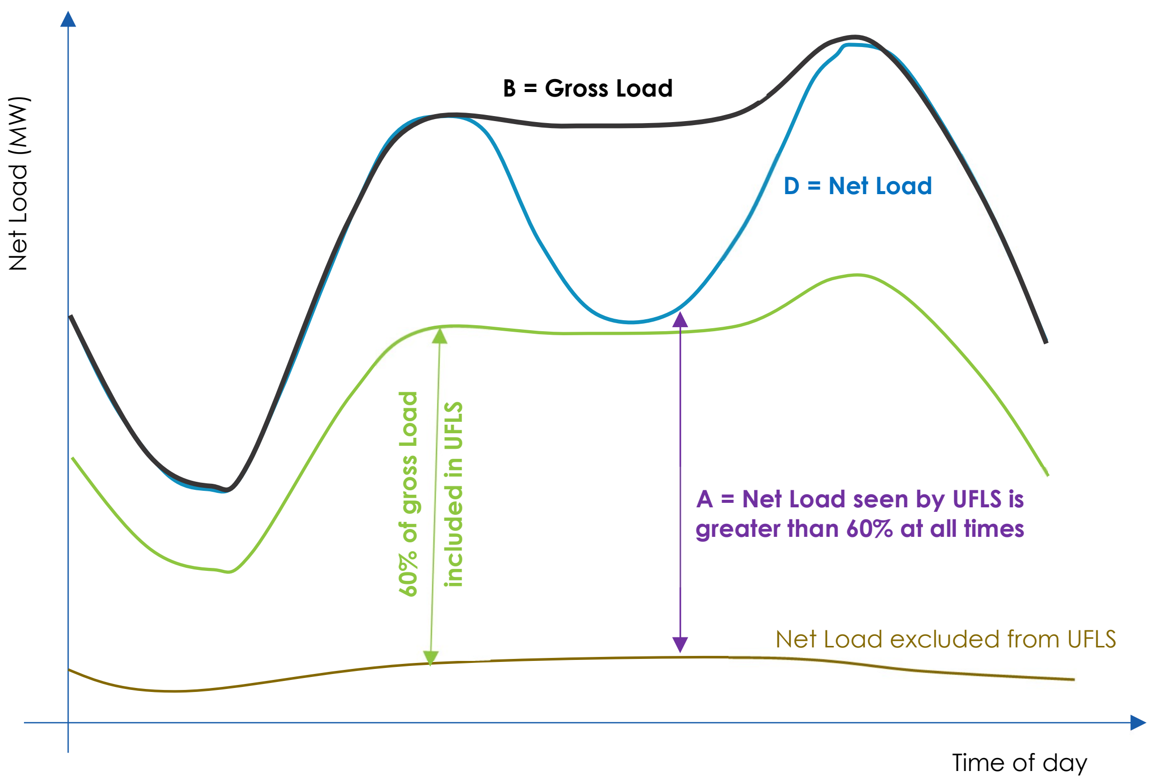
AusNet plans to establish dynamic arming of its sub-transmission lines at the transmission connection points as a preliminary measure.

In addition, AusNet is considering a distributed UFLS architecture that sheds load on selected zone substations or distribution feeders and apply dynamic blocking for those assets with reverse power flow. The solution would be designed to operate alongside the existing UFLS scheme, to augment the existing sub-transmission level capability implemented at the terminal stations and set to trip first such that tripping at the sub-transmission level becomes a backup, last resort measure. This will provide a much more secure, reliable, granular approach to load shedding for under-frequency events and expose much more of the underlying load available to the UFLS scheme. These options are described by options 1 and 2 in this business case.

An alternative approach being considered by AusNet is to curtail the distributed embedded generation that has remote control capability in place to allow centralised transmission connected generation to be dispatched in its place. This would need to be done pre-contingent, given the speed of response required to respond to a frequency decline is too fast for a communication signal to act in the case of AMI, SCADA or public internet communication systems. This option is described by option 4 in this business case.

Solutions that expose more of the underlying load or reduce the output of the distributed embedded generation as seen by the UFLS, whether they be dynamic arming/blocking, more granular load blocks, generation curtailment or a combination of, will aid in achieving compliance as shown in Figure 3.

Figure 3: Network-wide daily load profile - UFLS compliant example



Source: AusNet analysis

A final alternative approach involves installing grid-scale batteries within the distribution network that act to charge to artificially increase the net load as seen by the UFLS on the distribution network to achieve compliance. Provided that the battery charging is not included in the gross (underlying) load value, the effects should be similar to that shown in Figure 3. This option is described by option 3 in this business case.

Figure 4 and Figure 5 shows a forecast of AusNet's UFLS scheme compliance levels based on a do-nothing approach (the base case). Over the 2027-31 regulatory control period, for a do-nothing approach, the worst case

- percentage of net load as a proportion of underlying load under the control of the UFLS is expected to be 0%.
- percentage of the year the net load as a proportion of underlying load under the control of the UFLS is expected to be less than the 60% regulatory requirement is expected to be 18% of the time.
- shortfall in net load available to the UFLS requiring DPV to be curtailed to achieve full compliance is 488 GWh pa.

Figure 4: AusNet forecast net load under control of the UFLS – 2032 compliance duration, do nothing

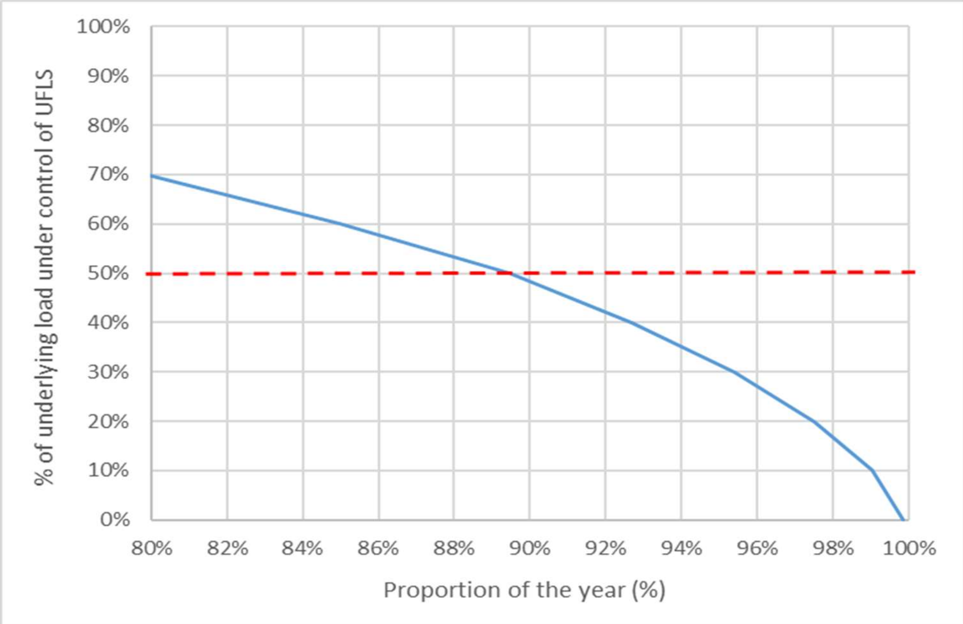
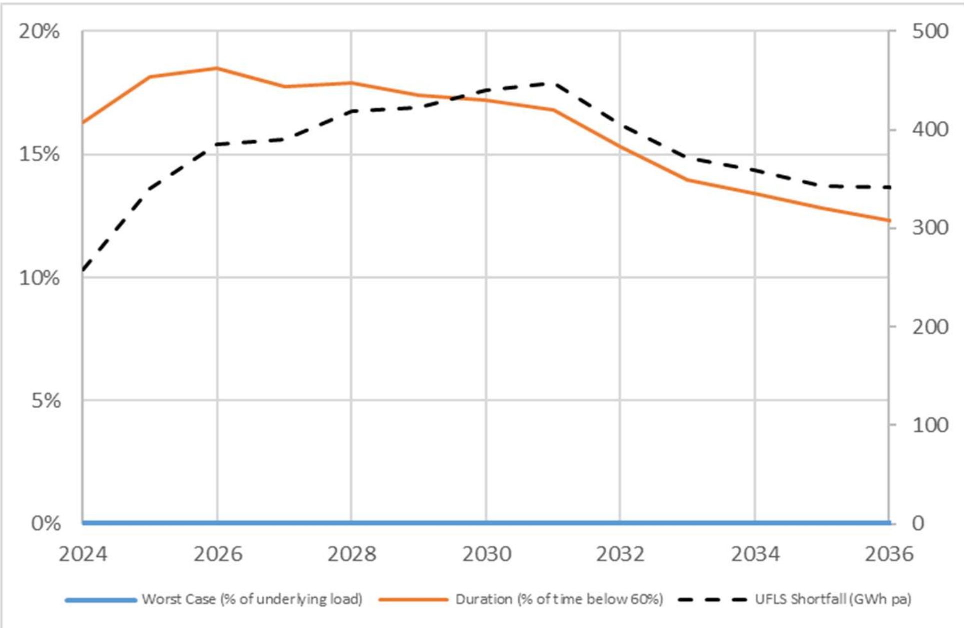


Figure 5: AusNet forecast net load under control of the UFLS – 2024 to 2037 worst case, do nothing



Source: AusNet analysis

Meeting our compliance obligation is difficult as DPV uptake is high and continues to increase, and the net demand as measured by the UFLS schemes reduces. Load blocks with reverse power flow and the reduced numbers of available block loads are a threat to the effectiveness of the UFLS schemes in responding to a widespread loss of larger, transmission-connected generation sources.

We need to invest in our network over the next FY27-31 regulatory period to address in this identified need and to facilitate regulatory compliance.

4. Options assessed

4.1. Credible solutions

In developing the options for this business cases, AusNet has considered a range of credible solutions that are able to address the power system security compliance limitations identified in relation to the UFLS scheme.

The range of credible solutions[3] considered are as follows:

- **Option 1 – Distributed UFLS at all zone substations and dynamic blocking**: installing under-frequency relays at all zone substations to provide more granular load blocks for the UFLS, with dynamic reverse power blocking implemented at each zone substation.
- **Option 2 – Distributed UFLS at all zone substations with distribution feeders dynamic blocking:** installing under-frequency relays at all zone substations to provide more granular load blocks for the UFLS, with dynamic reverse power blocking implemented on each distribution feeder.
- **Option 3 – Network storage supported UFLS:** installing network storage to increase the net load as a proportion of the underlying load on the network by charging (pre-contingent).
- **Option 4 – Emergency backstop mechanism supported UFLS**: leverage the emergency backstop mechanism only (pre-contingent) to curtail distributed embedded generation to increase the net load on the network.

These solutions are discussed in further detail below.

4.2. Assessment approach

4.2.1. Assessment methodology

In the absence of a control scheme or other investment that meets our regulatory obligations with regard to the UFLS, AusNet will need to curtail CER generation embedded within the electricity distribution network to achieve compliance.

The regulatory framework facilitates quantifying the value of CER curtailment through the AER's Customer Export Curtailment Value (CECV)[4] and Value of Emissions Reductions methodologies. AusNet has adopted these as an economic approach to valuing the impact of UFLS compliance on CER generation in this business case.

4.2.2. Valuing curtailed energy

This distributed UFLS business case utilises the CECV methodology and the CER assessment guideline. On 30th June 2022, the AER made a final decision[5] on its CECV methodology and published an explanatory statement. Oakley Greenwood was the consultant that had worked with the AER in developing the methodology and a model for calculating CECV. At this time, the AER published a set of CECV which it expected distributors utilise in justifying investments associated with alleviating CER export curtailment.

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[3] Note, post-contingent solutions involving AMI, CSIP-AUS, SCADA or other forms of communications to customer loads or generation installations are not regarded by AusNet as credible solutions except for some specific applications where direct inter-trips are in place. This is because the communications systems in place are not fast enough and cannot be graded satisfactory to respond to the required operating performance requirements required by the UFLS scheme. Furthermore, the end-devices (e.g. AMI meters) often do not have the capability to detect and act on frequency deviations.

[4] Customer export curtailment value methodology, Australian Energy Regulator, 2023.

[5] https://www.aer.gov.au/networks-pipelines/guidelines-schemes-models-reviews/customer-export-curtailment-value-methodology/final-decision

The AER published updates to the CECV[6] values on 1st July 2024. These updates have been used verbatim, filtered for the Victorian region. They cover every half hour period from 1/7/2024 to 30/6/2045 and are expressed in Australian dollars per MWh (Real, 2023).

The assessment approach in this business case applies CECV to the amount CER generation that is necessary for AusNet to curtail in order to achieve full UFLS compliance, for each distributed UFLS option that is applied.

4.2.3. Valuing emissions

This business case is also supported by the quantification of greenhouse gas emissions. The curtailment of CER generation could result in higher emissions of greenhouse gasses if additional fossil-fuel generation is dispatched to meet the increased demand. The AER has released draft guidance on applying value of emissions reduction for network capital investments utilising a Value of Emissions Reduction (VER) Methodology[7], as well as forecasts VER for use by DNSPs in economic evaluations.

4.2.4. Economic evaluation approach

The proposed program expenditure is derived from an assessment approach that aims to maximise the net economic benefit to customers by using the costs and avoided risks (calculated from the do nothing risks above) of the identified credible solutions, the net present value (NPV) of the solution at each asset location is calculated.

The present values are calculated using a discount rate over a 20-year planning horizon, keeping forecasts of risk and benefits beyond 10-years constant at the year 10 value.

4.2.5. Key assumptions

Key inputs, calculations and assumptions used in this business case are summarised in Table 3.

Table 3: Key assumptions

Parameter	Value	Comments
Discount rate	5.56%	Average of 4.11% and AEMO's central discount rate of 7% (from its 2023 Inputs, Assumptions and Scenario Report).
Evaluation period	20 years	Benefits calculated for the first 10-years, then maintained from years 11 to 20. No benefits assumed beyond year 20.
CECV & VER	AER 2024 Values	Used for curtailment of CER that is required to achieve compliance after an option is applied.

Source: AusNet analysis

[6] https://www.aer.gov.au/system/files/Oakley%20Greenwood%20-%20CECV%20workbook%20-%202023.xlsx

[7] AER releases draft guidance on applying value of emissions reduction | Australian Energy Regulator (AER), 28th March 2024.

4.3. Do nothing

The do nothing (counterfactual) option assumes that AusNet would not undertake any ongoing investment in power system security compliance in respect of the UFLS scheme – that is, none of the UFLS options are adopted. Under a do-nothing approach with no expenditure on addressing UFLS scheme non-compliances (i.e., retaining the existing terminal station schemes), could lead to potential non-compliance penalties.

The present value of total risk is valued at $46.8 million over the analysis period (real 30th June 2024 dollars) as shown in Table 4. It is assumed mandatory CER curtailment for UFLS compliance applies from FY28.

Table 4: Do nothing risk ($m, discounted, 30th June 2024 dollars)

	FY27	FY28	FY29	FY30	FY31	Total FY27-31	Full assessment period
Do nothing risk	-	1.7	1.5	1.6	1.8	**6.7**	**46.8**

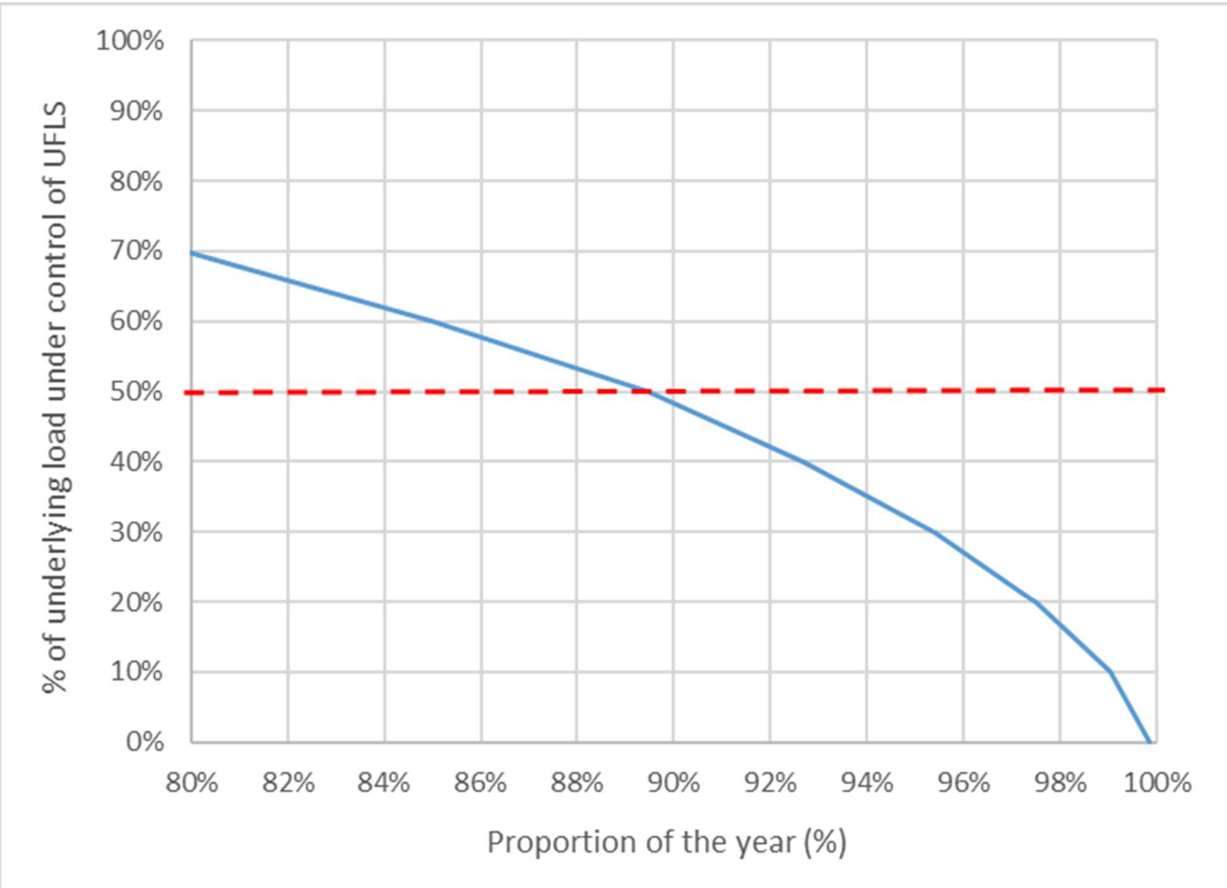
Source: AusNet analysis

The incremental investment cost of do nothing is zero.

Figure 6 and Figure 7 shows a forecast of AusNet's UFLS scheme compliance levels based on a do-nothing approach (the base case). Over the 2027-31 regulatory control period, for a do-nothing approach, the worst case

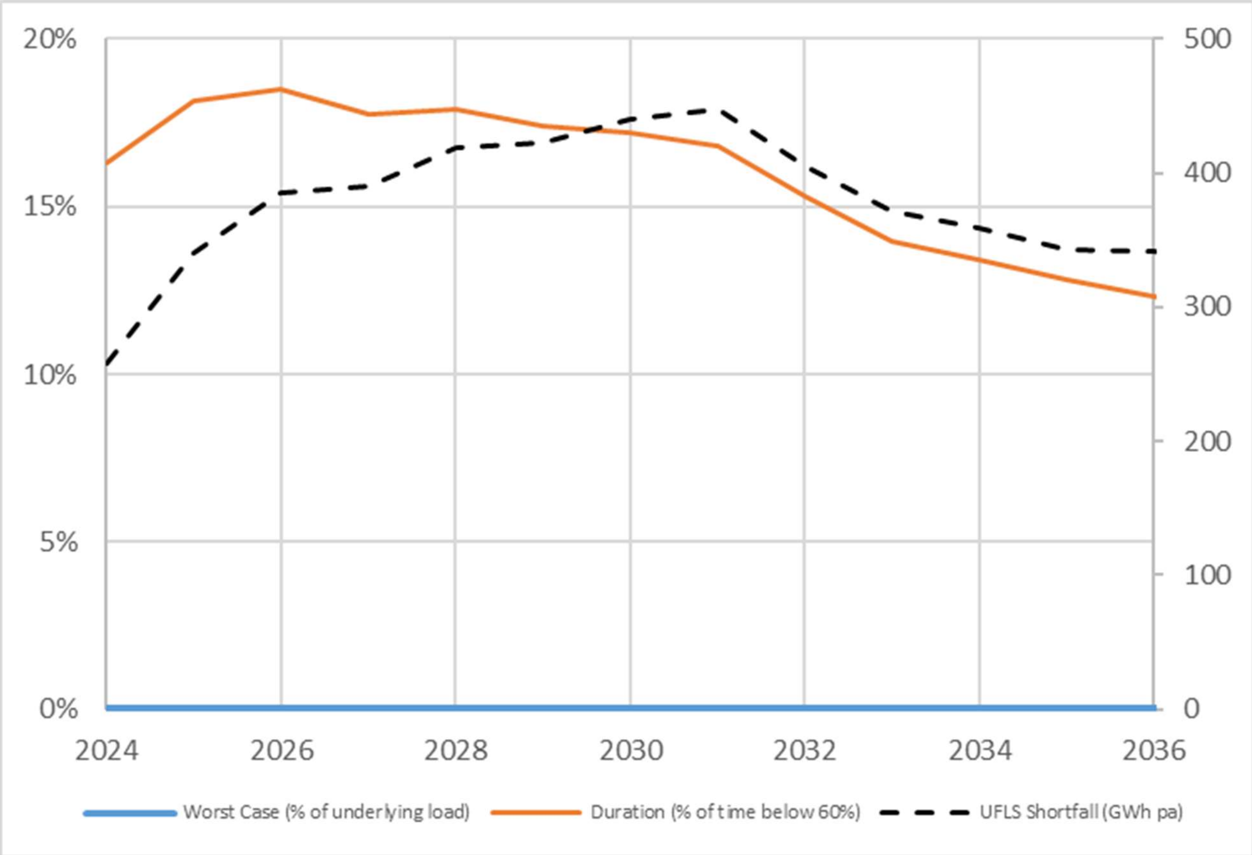
- percentage of net load as a proportion of underlying load under the control of the UFLS is expected to be 0%.
- percentage of the year the net load as a proportion of underlying load under the control of the UFLS is expected to be less than the 60% regulatory requirement is expected to be 18%.
- shortfall in net load available to the UFLS requiring DPV to be curtailed to achieve full compliance is 488 GWh pa.

Figure 6: AusNet forecast net load under control of the UFLS – 2032 compliance duration, do nothing



Source: AusNet analysis

Figure 7: AusNet forecast net load under control of the UFLS – 2024 to 2037 worst case, do nothing



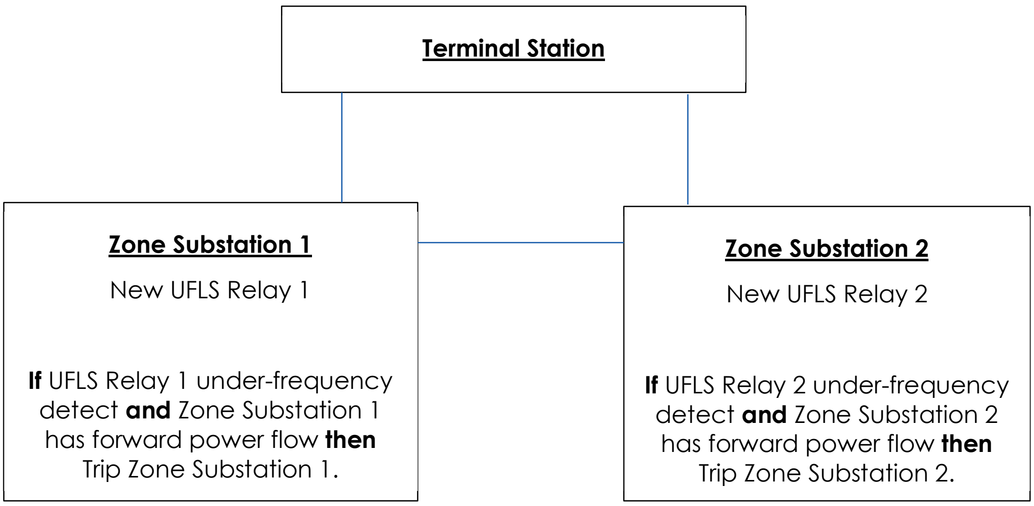
Source: AusNet analysis

4.4. Option 1 – Distributed UFLS at all zone substations and dynamic blocking

4.4.1. Summary

This Option 1 involves installing under-frequency relays at all zone substations to provide more granular load blocks for the UFLS, with dynamic reverse power blocking implemented at each zone substation as shown in Figure 8. Dynamic blocking is expected to Increase the amount of net load in AusNet's supply area. To do this, each zone substation will require the installation of a dedicated under-frequency relay that measures the local frequency, and for a defined under-frequency event, sends a trip signal (based on a remotely programmable under-frequency and time delay settings to be advised by AEMO) to trip the zone substation if it is not in reverse power flow. The SCADA master-station shall aggregate the active power on all enabled zone substations, and by terminal station to be able to report in near-real time how much demand is available to the UFLS scheme.

Figure 8: Option 1 Concept



The sites which have been identified under this option are shown in Table 5. Zone substations with very little load are excluded from this option.

Table 5: Option 1 Projects

Year	Zone Substations
FY27	CBTS Supply Area: BWN, CLN, CRE, LLG, LYD, NRN, OFR, PHM TTS Supply Area: TT, WT
FY28	SMTS Supply Area: DRN, EPG, KLO, KMS, RUBA, SMG, SMR TSTS Supply Area: ELM
FY29	RWTS Supply Area: BRA, BWR, CPK, CYN, LDL, RWN, WYK WOTS Supply Area: BWA, WO
FY30	ERTS Supply Area: BGE, FGY, HPK, RVE GNTS Supply Area: BN, MSD, WN MBTS Supply Area: BRT, MYT
FY31	MWTS Supply Area: BDL, FTR, LGA, MFA, MOE, MWL, PHI, SLE, TGN, WGI, WGL

Source: AusNet analysis

The net present value of Option 1 is negative $1.9 million over the analysis period (real 30th June 2024 dollars) as shown in Table 6.

Table 6: Option 1 ($m, discounted, 30th June 2024 dollars)

	FY27	FY28	FY29	FY30	FY31	Total FY27-31	Full assessment period
Cost	(2.7)	(2.6)	(2.6)	(2.5)	(2.5)	**(13.0)**	**(14.8)**
Benefits	-	0.3	0.3	0.3	0.4	**1.4**	**12.9**
NPV	**(1.9)**						

Source: AusNet analysis (benefits are relative to do nothing, representing reduced do-nothing risk)

4.4.2. Cost

4.4.2.1. Capex

Table 7: Option 1 ($m, discounted, 30th June 2024 dollars)

	FY27	FY28	FY29	FY30	FY31	Total FY27-31	Full assessment period
Capex	(2.7)	(2.6)	(2.5)	(2.5)	(2.4)	**(12.7)**	**(12.7)**

Source: AusNet analysis

This represents the forecast capital expenditure for AusNet to be investing in the network to meet its UFLS scheme obligations for compliance as required by the NER. The unit rate applied for each zone substation with UFLS implemented is C-I-C.

4.4.2.2. Opex

Table 8: Option 1 ($m, discounted, 30th June 2024 dollars)

	FY27	FY28	FY29	FY30	FY31	Total FY27-31	Full assessment period
Opex	-	(0.0)	(0.1)	(0.1)	(0.1)	**(0.2)**	**(2.1)**

Source: AusNet analysis

This represents the forecast incremental operational expenditure for AusNet to be investing in the network to meet its UFLS scheme obligations for compliance as required by the NER being 1% of the capital expenditure for ongoing O&M.

4.4.3. Benefits

Table 9: Option 1 ($m, discounted, 30th June 2024 dollars)

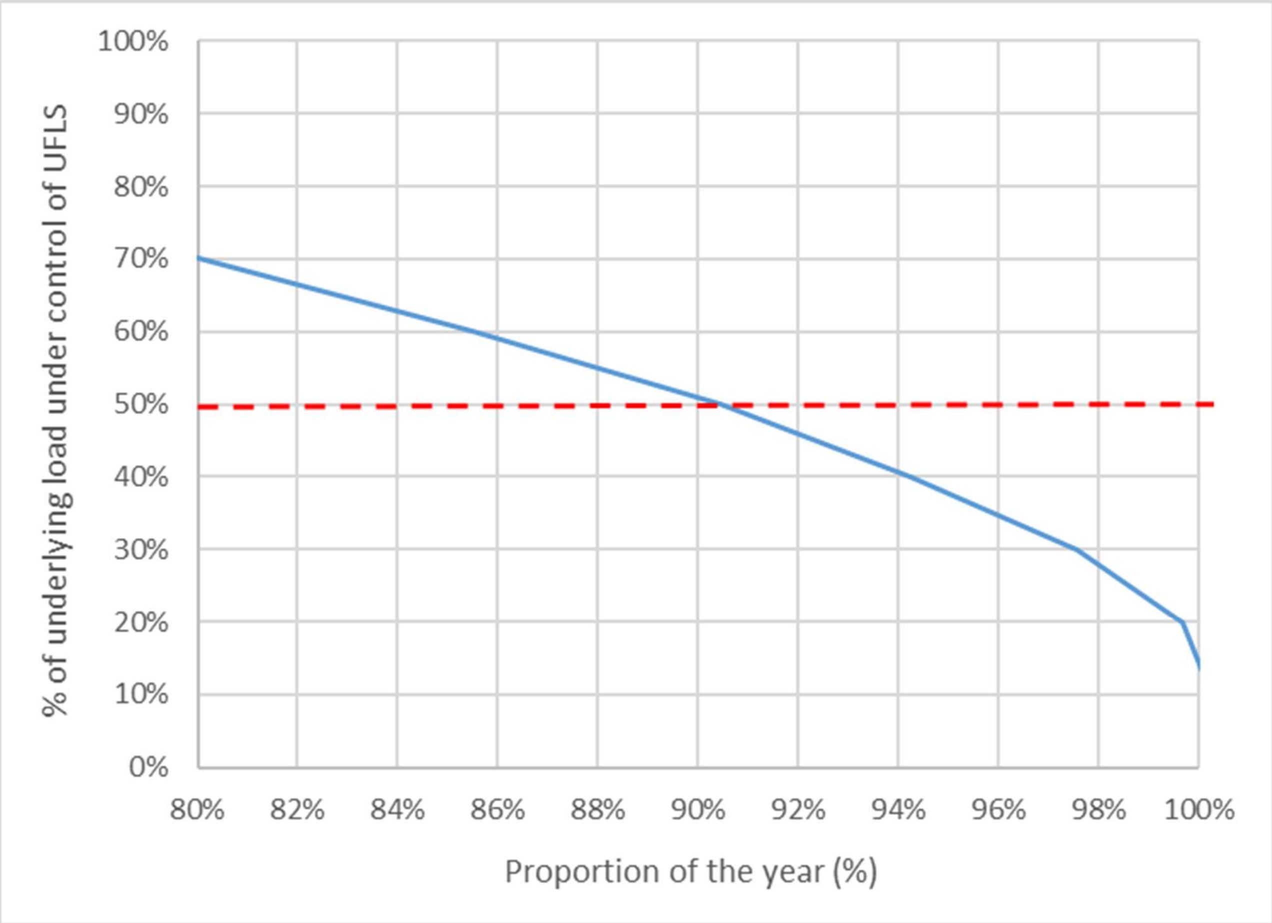
	FY27	FY28	FY29	FY30	FY31	Total FY27-31	Full assessment period
CECV & VER	-	0.3	0.3	0.3	0.4	**1.4**	**12.9**

Source: AusNet analysis (benefits are relative to do nothing, representing reduced do-nothing risk)

Figure 9 and Figure 10 shows a forecast of AusNet's UFLS scheme compliance levels based on an Option 1 investment. Over the 2027-31 regulatory control period, for an Option 1 investment, the worst case

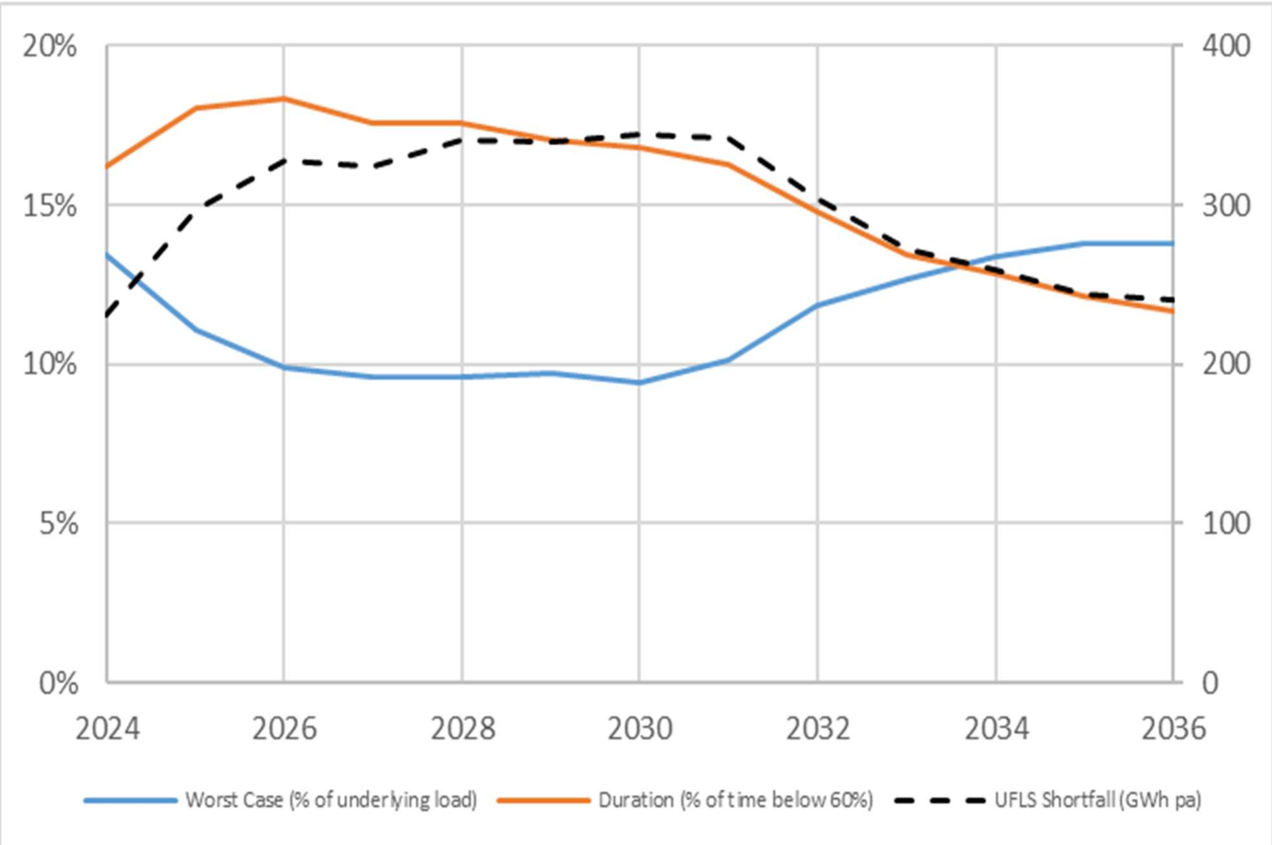
- percentage of net load as a proportion of underlying load under the control of the UFLS is expected to be 9% (compared to a do nothing of 0%).
- percentage of the year the net load as a proportion of underlying load under the control of the UFLS is expected to be less than the 60% regulatory requirement is expected to be 16% (compared to a do nothing of 18%).
- shortfall in net load available to the UFLS requiring DPV to be curtailed to achieve full compliance is 344 GWh pa (compared to a do nothing of 488 GWh pa) calculated as the amount of underlying energy needing to be exposed to the UFLS by way of generation reductions to achieve the 60% compliance target, aggregated annually from each half hour, based on the AER CECV and VER methodologies.

Figure 9: AusNet forecast net load under control of the UFLS – 2032 compliance duration, option 1



Source: AusNet analysis

Figure 10: AusNet forecast net load under control of the UFLS – 2024 to 2037 worst case, option 1



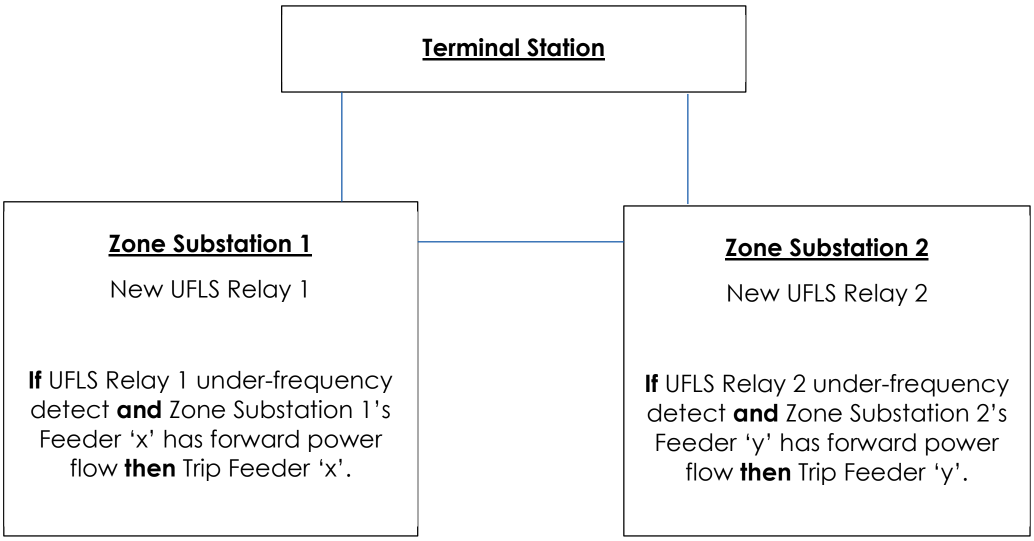
Source: AusNet analysis

4.5. Option 2 – Distributed UFLS at all zone substations with distribution feeders dynamic blocking

4.5.1. Summary

This Option 2 involves installing under-frequency relays at all zone substations to provide more granular load blocks for the UFLS, with dynamic reverse power blocking implemented on **each distribution feeder** (under option 1, this is only implemented at the Zone Sub) as shown in Figure 11. To do this, each zone substation will require the installation of a dedicated under-frequency relay that measures the local frequency, and for a defined under-frequency event, sends a trip signal (based on a remotely programmable under-frequency and time delay settings to be advised by AEMO) to trip those distribution feeders (at the zone substation) that are enabled for the distributed UFLS scheme from the SCADA master-station and when the direction of active power flow as measured by each feeder management relay is down the feeder, toward the customers. A feeder can be disabled using the SCADA master-station if deemed to be supplying large critical customers. The SCADA master-station shall aggregate the active power on all enabled feeder by zone substation, and by terminal station to be able to report in near-real time how much demand is available to the UFLS scheme.

Figure 11: Option 2 Concept



The sites which have been identified under this option are shown in Table 10. Zone substations with very little load are excluded from this option.

Table 10: Option 2 Projects

Year	Zone Substations and Feeders
FY27	CBTS Supply Area: BWN (4), CLN (8), CRE (6), LLG (4), LYD (4), NRN (5), OFR (4), PHM (8) TTS Supply Area: TT (8), WT (10)
FY28	SMTS Supply Area: DRN (8), EPG (13), KLO (4), KMS (2), RUBA (3), SMG (7), SMR (6) TSTS Supply Area: ELM (10)
FY29	RWTS Supply Area: BRA (12), BWR (10), CPK (6), CYN (11), LDL (8), RWN (7), WYK (4) WOTS Supply Area: BWA (12), WO (9)
FY30	ERTS Supply Area: BGE (6), FGY (10), HPK (8), RVE (3) GNTS Supply Area: BN (5), MSD (3), WN (7) MBTS Supply Area: BRT (3), MYT (4)
FY31	MWTS Supply Area: BDL (8), FTR (4), LGA (9), MFA (6), MOE (8), MWL (11), PHI (3), SLE (4), TGN (8), WGI (8), WGL (9)

Source: AusNet analysis

The net present value of Option 2 is $2.8 million over the analysis period (real 30th June 2046 dollars) as shown in Table 11.

Table 11: Option 2 ($m, discounted, 30th June 2024 dollars)

	FY27	FY28	FY29	FY30	FY31	Total FY27-31	Full assessment period
Cost	(3.3)	(3.2)	(3.1)	(3.1)	(3.0)	**(15.7)**	**(18.0)**
Benefits	-	0.6	0.5	0.6	0.7	**2.6**	**20.8**
NPV	**2.8**						

Source: AusNet analysis (benefits are relative to do nothing, representing reduced do-nothing risk)

4.5.2. Cost

4.5.2.1. Capex

Table 12: Option 2 ($m, discounted, 30th June 2024 dollars)

	FY27	FY28	FY29	FY30	FY31	Total FY27-31	Full assessment period
Capex	(3.3)	(3.2)	(3.1)	(3.0)	(2.9)	**(15.4)**	**(15.4)**

Source: AusNet analysis

This represents the forecast capital expenditure that is economically prudent for AusNet to be investing in the network to meet its UFLS scheme obligations for compliance as required by the NER. The unit rate applied for each zone substation with UFLS implemented is C-I-C and for each distribution feeder is C-I-C.

4.5.2.2. Opex

Table 13: Option 2 ($m, discounted, 30th June 2024 dollars)

	FY27	FY28	FY29	FY30	FY31	Total FY27-31	Full assessment period
Opex	-	(0.0)	(0.1)	(0.1)	(0.1)	**(0.3)**	**(2.5)**

Source: AusNet analysis

This represents the forecast incremental operational expenditure that is economically prudent for AusNet to be investing in the network to meet its UFLS scheme obligations for compliance as required by the NER being 1% of the capital expenditure for ongoing O&M.

4.5.3. Benefits

Table 14: Option 2 ($m, discounted, 30th June 2024 dollars)

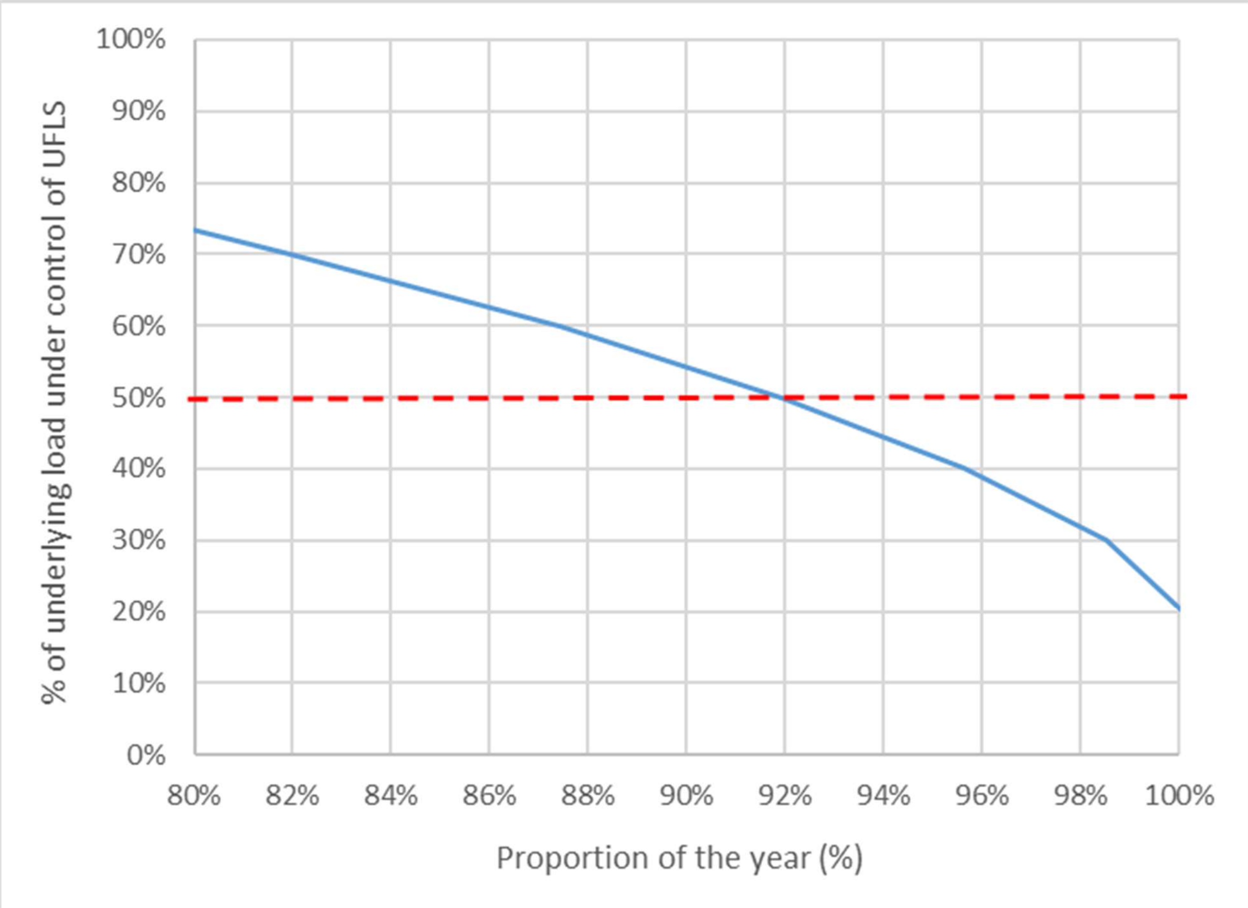
	FY27	FY28	FY29	FY30	FY31	Total FY27-31	Full assessment period
CECV & VER	-	0.6	0.5	0.6	0.7	**2.6**	**20.8**

Source: AusNet analysis (benefits are relative to do nothing, representing reduced do-nothing risk)

Figure 12 and Figure 13 shows a forecast of AusNet's UFLS scheme compliance levels based on an Option 2 investment. Over the 2027-31 regulatory control period, for an Option 2 investment, the worst case

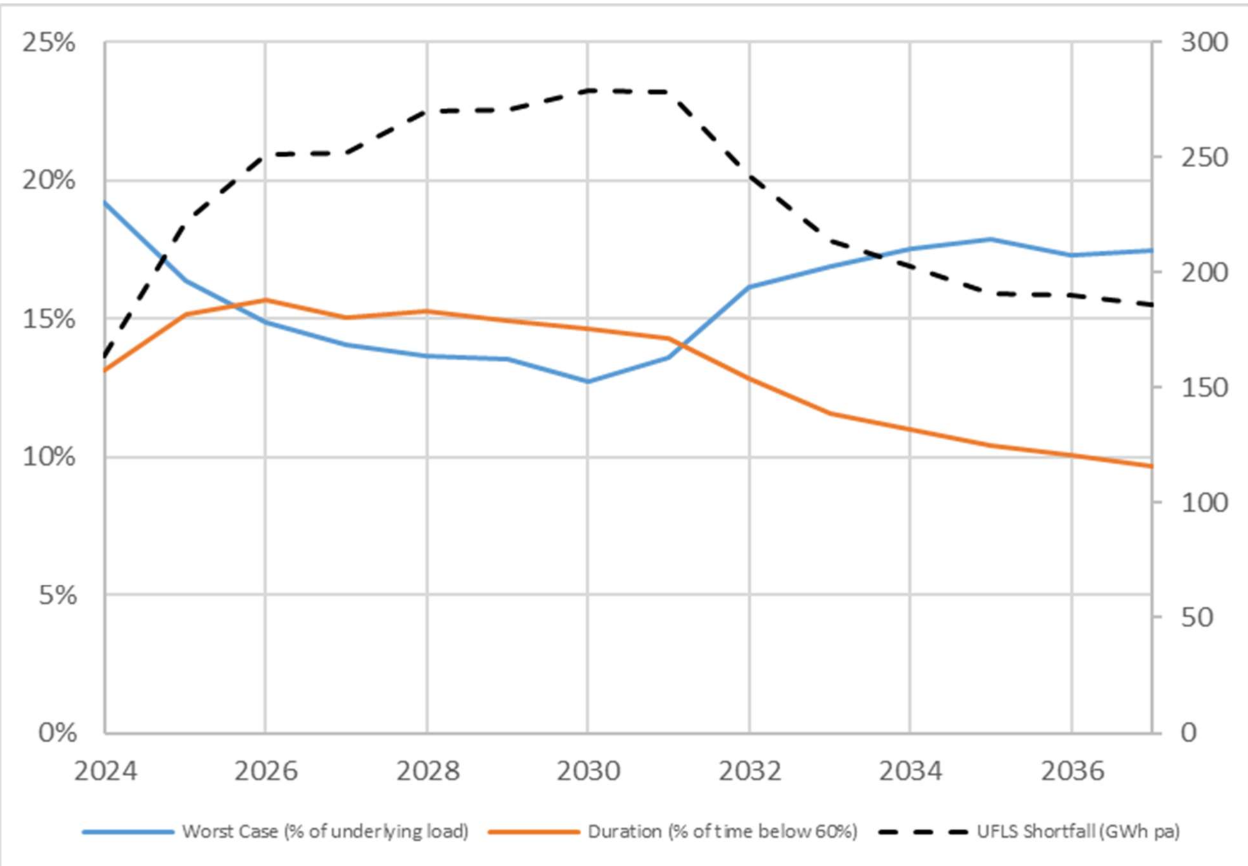
- percentage of net load as a proportion of underlying load under the control of the UFLS is expected to be 13% (compared to a do nothing of 0%).
- percentage of the year the net load as a proportion of underlying load under the control of the UFLS is expected to be less than the 60% regulatory requirement is expected to be 15% (compared to a do nothing of 18%).
- shortfall in net load available to the UFLS requiring DPV to be curtailed to achieve full compliance is 279 GWh pa (compared to a do nothing of 488 GWh pa) calculated as the amount of underlying energy needing to be exposed to the UFLS by way of generation reductions to achieve the 60% compliance target, aggregated annually from each half hour, based on the AER CECV and VER methodologies.

Figure 12: AusNet forecast net load under control of the UFLS – 2032 compliance duration, option 2



Source: AusNet analysis

Figure 13: AusNet forecast net load under control of the UFLS – 2024 to 2037 worst case, option 2



Source: AusNet analysis

4.6. Option 3 – Network storage supported UFLS

4.6.1. Summary

This Option 3 involves installing controllable storage within the AusNet distribution network in quantities that are able to meet shortfalls in the UFLS regulatory requirements. The storage would be operated such that it is charging at times while the UFLS levels are low (pre-contingent), to increase the net load seen by the UFLS scheme back to 60%.

It is assumed for the purposes of this business case that this charging would not be included in the underlying load calculation, so as not to dilute its contribution to the UFLS, and that any regulatory ring-fencing hurdles relating to this use of storage are ignored.

The storage sites which have been identified under this option are shown in Table 15.

Table 15: Option 3 Projects

Year	Storage Location and Size
FY27	CBTS Supply Area: 1000 MWh TTS Supply Area: 250 MWh
FY28	SMTS Supply Area: 1000 MWh TSTS Supply Area: 250 MWh
FY29	RWTS Supply Area: 1000 MWh WOTS Supply Area: 250 MWh
FY30	ERTS Supply Area: 500 MWh GNTS Supply Area: 250 MWh MBTS Supply Area: 250 MWh
FY31	MWTS Supply Area: 1000 MWh

Source: AusNet analysis

The net present value of Option 3 is negative $4,538 million over the analysis period (real 30th June 2024 dollars) as shown in Table 16.

Table 16: Option 3 ($m, discounted, 30th June 2024 dollars)

	FY27	FY28	FY29	FY30	FY31	Total FY27-31	Full assessment period
Cost	(1,035)	(1,006)	(977.8)	(760.9)	(739.6)	**(4,519)**	**(4,585)**
Benefits	-	1.7	1.5	1.6	1.8	**6.7**	**46.8**
NPV	**(4,538)**						

Source: AusNet analysis (benefits are relative to do nothing, representing reduced do-nothing risk)

4.6.2. Cost

4.6.2.1. Capex

Table 17: Option 3 ($m, discounted, 30th June 2024 dollars)

	FY27	FY28	FY29	FY30	FY31	Total FY27-31	Full assessment period
Capex	(1,035)	(1,005)	(975.9)	(758.1)	(736.1)	**(4,510)**	**(4,510)**

Source: AusNet analysis

This represents the forecast capital expenditure for AusNet to be investing in the network to meet its UFLS scheme obligations for compliance as required by the NER The unit rate applied for each battery installation (fully installed cost) with UFLS implemented is C-I-C per MWh.

4.6.2.2. Opex

Table 18: Option 3 ($m, discounted, 30th June 2024 dollars)

	FY27	FY28	FY29	FY30	FY31	Total FY27-31	Full assessment period
Opex	-	(0.0)	(0.1)	(0.1)	(0.1)	**(0.3)**	**(2.5)**

Source: AusNet analysis

This represents the forecast incremental operational expenditure for AusNet to be investing in the network to meet its UFLS scheme obligations for compliance as required by the NER being 0.1% of the capital expenditure for ongoing O&M.

4.6.3. Benefits

Table 19: Option 3 ($m, discounted, 30th June 2024 dollars)

	FY27	FY28	FY29	FY30	FY31	Total FY27-31	Full assessment period
CECV & VER	-	1.7	1.5	1.6	1.8	**6.7**	**46.8**

Source: AusNet analysis (benefits are relative to do nothing, representing reduced do-nothing risk)

Over the 2027-31 regulatory control period, for an Option 3 investment, the worst case

- percentage of net load as a proportion of underlying load under the control of the UFLS is expected to be 60% (compared to a do nothing of 0%).
- percentage of the year the net load as a proportion of underlying load under the control of the UFLS is expected to be less than the 60% regulatory requirement is expected to be 0% (compared to a do nothing of 18%).

- shortfall in net load available to the UFLS requiring DPV to be curtailed to achieve full compliance is 0 GWh pa (compared to a do nothing of 488 GWh pa) calculated as the amount of underlying energy needing to be exposed to the UFLS by way of storage charging to achieve the 60% compliance target, aggregated annually from each half hour, based on the AER CECV and VER methodologies.

5. Preferred option and sensitivity testing

This business case outlines the identified need and quantifies the investment needed in power system security UFLS compliance for the AusNet distribution network over the 2027-31 regulatory control period.

Option 2 is the preferred option at a cost of $18.1 million (Real, 30th June 2024 dollars) over the 2027-31 regulatory control period, which represents a prudent and efficient network augmentation investment to manage power system security compliance. Applying a discount rate of 5.56% per annum, this proposed program option has a NPV of $2.8 million (Real, 30th June 2024 dollars) over the 20-year assessment period, as shown in Table 20. Capex requirement is $17.8m.

With the current low levels of emergency backstop enabled CER, option 4 will not materially improve UFLS compliance capability in the short to medium term. Option 4 may be considered for supplementary support in addition to option 2 once emergency backstop enabled CER capacities increase.

Table 20: Economic Evaluation of Distributed UFLS Program Options ($m, 30th June 2024 dollars)

	FY27 to FY31 (undiscounted)			Full assessment period (discounted)			Comments
	Capex	Opex	Total cost	Total cost	Total benefits	NPV	
Do nothing	-	-	-	-	0.0 [8]	-	This option does not address the identified need
Option 1 – Distributed UFLS at all zone substations and dynamic blocking	14.6	0.3	14.9	(14.8)	12.9	(1.9)	This option provides marginal compliance improvement.
Option 2 – Distributed UFLS at all zone substations with distribution feeders dynamic blocking	17.8	0.4	18.1	(18.0)	20.8	2.8	This option provides material compliance improvement.
Option 3 – Network storage supported UFLS	5,175	11.0	5,186	(4,585)	46.8	(4,538)	This option achieves full compliance but is the most expensive option
Option 4 – Emergency backstop mechanism supported UFLS	1.5	0.4	1.9	(3.8)	-	(3.8)	This option requires CER curtailment and is unviable.

Source: AusNet analysis (relative to the base case of do nothing)

Over the 2027-31 regulatory control period, for an Option 2 investment, the worst case

- percentage of net load as a proportion of underlying load under the control of the UFLS is expected to be 13% (compared to a do nothing of 0%).
- percentage of the year the net load as a proportion of underlying load under the control of the UFLS is expected to be less than the 60% regulatory requirement is expected to be 15% (compared to a do nothing of 18%).
- shortfall in net load available to the UFLS requiring DPV to be curtailed to achieve full compliance is 279 GWh pa (compared to a do nothing of 488 GWh pa).

[8] The present value of total risk of greenhouse gas emissions and CER generation needing to be curtailed to achieve full compliance for the UFLS scheme, is valued at $46.8 million over the analysis period (real 30th June 2024 dollars).

Table 21 compares the costs and benefits of the four options for credible variations in input variables.

Table 21: Sensitivity of Net Present Value ($m, 30th June 2024 dollars)

	Central assumptions	4,.11% discount rate	15% reduction in costs	25% increase in benefits	7.00% discount rate	15% increase in costs	25% reduction in benefits	Comments
Do nothing	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Option 1	(1.9)	0.0	0.3	1.3	(3.2)	(4.1)	(5.1)	
Option 2	**2.8**	**6.4**	**5.5**	**8.0**	**0.3**	**0.1**	**(2.4)**	This generally remains the preferred option under the credible sensitivities.
Option 3	(4,538)	(4,856)	(3,850)	(4,526)	(4,249)	(5,226)	(4,550)	
Option 4	(3.8)	(4.9)	(3.2)	(3.8)	(3.2)	(4.4)	(3.8)	While this option may eventually provide a supplementary capability to maintain UFLS compliance, that will only be viable once sufficient CER is brought under control.

Source: AusNet analysis

This table illustrates that the decision to select Option 2 as the preferred option remains robust, being the option with the highest NPV and remaining positive under all but one credible sensitivity scenario.

The forecast expenditure of the preferred option is presented in Table 22.

Table 22: Forecast Expenditure (undiscounted, $m, 30th June 2024 dollars)

	FY27	FY28	FY29	FY30	FY31	Total FY27-31	Total allowance current period
Capex	(3.6)	(3.6)	(3.6)	(3.6)	(3.6)	**(17.8)**	**(0.0)**

Source: AusNet analysis

6. Appendix

6.1. UFLS Responsibilities

6.1.1. AEMO

Table 23: AEMO UFLS responsibilities under the NER

NER clause	AEMO responsibility
4.3.1(k)	Assess the availability and adequacy, including the dynamic response, of contingency capacity reserves and reactive power reserves in accordance with the power system security standards and to ensure that appropriate levels of contingency capacity reserves and reactive power reserves are available: (1) to ensure the power system is, and is maintained, in a satisfactory operating state; and (2) to arrest the impacts of a range of significant multiple contingency events (affecting up to 60% of the total power system load) or protected events to allow a prompt restoration or recovery of power system security, taking into account under-frequency initiated load shedding capability provided under connection agreements, by emergency frequency control schemes or otherwise.
4.3.1(n)	Refer to Registered Participants, as AEMO deems appropriate, information of which AEMO becomes aware in relation to significant risks to the power system where actions to achieve a resolution of those risks are outside the responsibility or control of AEMO.
4.3.1(p1)	Coordinate the provision of emergency frequency control schemes by Network Service Providers and determine the settings and intended sequence of response by those schemes.
4.3.2(h)	Develop, update and maintain schedules for each participating jurisdiction specifying, for each emergency frequency control scheme affecting each region in that participating jurisdiction, settings for operation of the scheme including the matters specified in paragraphs (m) to (p) (EFCS settings schedule).
4.3.2(ha)	In developing and updating EFCS settings schedules, in relation to an under-frequency scheme, consult with affected Network Service Providers and the relevant Jurisdictional System Security Coordinators.
5.20A.1(c)(4)	For its power system frequency risk review, assess the performance of existing EFCSs and identify any need to modify the scheme.
4.4.2 (d)	AEMO must use reasonable endeavours to ensure that adequate facilities are available and under the direction of AEMO to allow the managed recovery of the satisfactory operating state of the power system.
4.3.1(v)	Initiate action plans to manage any significant deficiencies which could reasonably threaten power system security, including power system frequencies outside those specified in the definition of satisfactory operating state.

Source: AEMO, "Under Frequency Load Shedding: Exploring dynamic arming options for adapting to distributed PV", October 2023

6.1.2. NSPs

Table 24: NSP UFLS responsibilities under the NER

NER clause	NSP responsibility
4.3.4(a)	Use reasonable endeavours to exercise its rights and obligations in relation to its networks so as to co-operate with and assist AEMO in the proper discharge of the AEMO power system security responsibilities.
4.3.4(b)	Use reasonable endeavours to ensure that interruptible loads are provided as specified in clause 4.3.5 and clause S5.1.10 of schedule 5.1 (including without limitation, through the inclusion of appropriate provisions in connection agreements).
4.3.4(b1)	In accordance with clause S5.1.10.1a of schedule 5.1, cooperate with AEMO in relation to, design, procure, commission, maintain, monitor, test, modify and report to AEMO in respect of, each emergency frequency control scheme which is applicable in respect of the Network Service Provider's transmission or distribution system.
S5.1.10.1	In consultation with AEMO, ensure that sufficient load is under the control of under-frequency relays or other facilities where required to minimise or reduce the risk that in the event of the sudden, unplanned simultaneous occurrence of multiple contingency events, the power system frequency moves outside the extreme frequency excursion tolerance limits. Transmission Network Service Providers and connected Distribution Network Service Providers must cooperate to agree arrangements to implement load shedding. The arrangements may include the opening of circuits in either a transmission network or distribution network. The Transmission Network Service Provider must specify, in the connection agreement, control and monitoring requirements to be provided by a Distribution Network Service Provider for load shedding facilities including emergency frequency control schemes.
S5.1.10.1a(a)	Provide to AEMO all information and assistance reasonably requested by AEMO for the development and review of EFCS settings schedules.
S5.1.10.2	(for Distribution Network Service Providers): (a) provide, install, operate and maintain facilities for load shedding in respect of any connection point at which the maximum load exceeds 10MW in accordance with clause 4.3.5; (c) apply frequency settings to relays or other facilities as determined by AEMO in consultation with the Network Service Provider;
S5.1.8	In planning a network, consider non-credible contingency events such as busbar faults which result in tripping of several circuits, uncleared faults, double circuit faults and multiple contingencies which could potentially endanger the stability of the power system. In those cases where the consequences to any network or to any Registered Participant of such events are likely to be severe disruption a Network Service Provider and/or a Registered Participant must in consultation with AEMO, install, maintain and upgrade emergency controls within the Network Service Provider's or Registered Participant's system or in both, as necessary, to minimise disruption to any transmission or distribution network and to significantly reduce the probability of cascading failure.

Source: AEMO, "Under Frequency Load Shedding: Exploring dynamic arming options for adapting to distributed PV", October 2023

6.2. AEMO recommendations for NSPs

Recommendation	Description	Responsible
Remove large generating units from UFLS	As discussed in Section 4, there are several large wind and solar farms connected to sub-transmission loops within the UFLS scheme. This is detrimental to UFLS efficacy, and leads to more customers being shed than is necessary to arrest a frequency decline. It is recommended that these large generating units are removed from the UFLS scheme. Possible options could include: • Moving UFLS relays to a lower voltage level (within sub-transmission loops), so loads on the loop are tripped by UFLS relays, but large-scale generation remains connected. • Dynamically arming UFLS relays, so that they automatically disarm when the circuit is in reverse flows. • Removing the affected sub-transmission loops from the UFLS scheme and replacing them with loads at other locations. AEMO is aware that dynamic arming of UFLS relays could be complex to implement for the sub-transmission loops arrangement in Victoria, since determining whether the whole loop is a net load or net generator requires combining measurements of flows at both ends of the loop. Dynamic arming may therefore require communication between relays at different locations to determine the net load on the loop in real time.	TNSPs – explore options to remediate at 66 kV level DNSPs – explore options that involve distribution network changes
Improve connections processes	It is recommended that NSPs introduce improvements to the connections process for large generating units such that further new connections do not occur behind UFLS relays without suitable rectification. Ideally, Victorian NSPs will agree a consistent approach to handling cost recovery with the connecting parties involved, and the size thresholds where obligations may apply for these connecting parties. This should be negotiated and agreed between NSPs.	DNSPs – develop suitable connections processes, and coordinate with TNSPs
Establish real-time visibility of UFLS load	Establishing a SCADA feed of total net UFLS load in Victoria will allow real-time monitoring of UFLS load by both AEMO and the NSPs and will facilitate a broader range of active management strategies in periods where net UFLS load is low. A real-time SCADA feed of total UFLS load has been established in South Australia and is under development in Queensland. Similar approaches should be explored in Victoria.	TNSPs
Explore options to address DPV impacts	There are now some sub-transmission loops in the UFLS scheme that are demonstrating low levels of load and reverse flows at certain times related to high levels of DPV generation. AEMO recommends that NSPs establish processes to assess the incidence and level of reverse flows occurring at various UFLS circuits. It is also recommended that NSPs explore options for addressing DPV impacts on UFLS. Without ruling out other possibilities, options may include some combination of the following: • Adding further customer load into the UFLS scheme. • Removing sub-transmission loops from the UFLS scheme if they are heavily affected by DPV and often demonstrating reverse flows and replacing them with loads at other locations that are less affected by DPV. • Implementing dynamic arming (disarming UFLS relays when circuits are in reverse flows) at UFLS circuits where reverse flows are occurring. • Consider moving UFLS implementation from 66 kV to a lower voltage level (such as 22 kV), so dynamic arming can be implemented in a more granular manner (tripping some circuits that remain net loads, while others are dynamically disarmed). This will need to be explored based on costs and benefits on a case-by-case basis at each UFLS circuit and will only be beneficial at sites where DPV installations are not uniform. This could also provide benefit by facilitating shedding of the most sensitive customers last. • Consider the possible use of smart meter technology to facilitate selective shedding of load at the individual customer level. Trials and careful scheme design will be required. In particular, voltage rise following disconnection of load (while DPV remains operating) may need careful consideration. Disconnection of load may also lead to overload of network assets due to reverse power flow. DNSPs should develop suitable methodologies, models, and processes to investigate these effects. Given the exploratory nature of this work, AEMO recommends that NSPs explore these options now to determine the most appropriate remediation strategies. This will facilitate timely action when AEMO provides advice to NSPs on the amount of EUFR required in Victoria (anticipated in late 2023).	TNSPs – establish processes to monitor and improve UFLS in present configuration. DNSPs – explore options for long term remediation

Source: AEMO, "Victoria: UFLS load assessment update", May 2023

6.3. Option 4 – Leverage the emergency backstop mechanism for UFLS (unviable)

6.3.1. Summary

Given the investments made in implementing DPV backstop capability in the last year, this Option 4 is also designed to enhance (rather than replace) the preferred alternative options by meeting any shortfall in the ability of that alternative option to reach and maintain full compliance to the 60% level at all times.

This Option 4 involves using DPV backstop mechanism to curtail distributed embedded generation to increase the net load on the network, in quantities that are able to meet shortfalls in the UFLS regulatory requirements. The DPV backstop mechanism would be operated to include a use case that curtails generation while the UFLS levels are low (pre-contingent), to increase the net load seen by the UFLS scheme back to 60%.

It is assumed for the purposes of this business case that any issues relating to the increased use of the backstop mechanism and its associated impacts on CER customers are ignored.

The net present value of Option 4 is negative $2.5 million over the analysis period (real 30th June 2024 dollars) as shown in **Error! Reference source not found.**.

Table 25: Option 3 ($m, discounted, 30th June 2024 dollars)

	FY27	FY28	FY29	FY30	FY31	Total FY27-31	Full assessment period
Cost	(0.3)	(0.3)	(0.4)	(0.4)	(0.4)	**(1.9)**	**(3.8)**
Benefits	-	-	-	-	-	**0.0**	**0.0**
NPV	**(2.5)**						

Source: AusNet analysis (benefits are relative to do nothing, representing reduced do-nothing risk)

6.3.2. Cost

6.3.2.1. Capex

Table 26: Option 3 ($m, discounted, 30th June 2024 dollars)

	FY27	FY28	FY29	FY30	FY31	Total FY27-31	Full assessment period
Capex	(0.3)	(0.3)	(0.3)	(0.3)	(0.3)	**(1.5)**	**(1.5)**

Source: AusNet analysis

This represents the forecast capital expenditure for AusNet to be investing in the network to meet its UFLS scheme obligations for compliance as required by the NER.

6.3.2.2. Opex

Table 27: Option 3 ($m, discounted, 30th June 2024 dollars)

	FY27	FY28	FY29	FY30	FY31	Total FY27-31	Full assessment period
Opex	-	(0.0)	(0.1)	(0.1)	(0.1)	**(0.3)**	**(2.5)**

Source: AusNet analysis

This represents the forecast incremental operational expenditure for AusNet to be investing in the network to meet its UFLS scheme obligations for compliance as required by the NER. The O&M costs are expected to be similar to Option 2.

6.3.3. Benefits

Table 28: Option 3 ($m, discounted, 30th June 2024 dollars)

	FY27	FY28	FY29	FY30	FY31	Total FY27-31	Full assessment period
CECV & VER	-	-	-	-	-	**0.0**	**0.0**

Source: AusNet analysis (benefits are relative to do nothing, representing reduced do-nothing risk)

Over the 2027-31 regulatory control period, for an Option 4 investment, the worst case

- percentage of net load as a proportion of underlying load under the control of the UFLS is expected to be 60% (compared to a do nothing of 0%).
- percentage of the year the net load as a proportion of underlying load under the control of the UFLS is expected to be less than the 60% regulatory requirement is expected to be 0% (compared to a do nothing of 18%).
- shortfall in net load available to the UFLS requiring DPV to be further curtailed to achieve full compliance is 0 GWh pa (compared to a do nothing of 488 GWh pa).

This option is considered unviable on its own as it only applies to new DPV systems and does not address legacy UFLS compliance issues.

This option is also unviable from a customer experience perspective as the amount of curtailment required by customers would be onerous, increasing the likelihood of more claims against us for loss of revenue or increases in power bill. This could also potentially be influencing the supply of generation to the NEM which could have wholesale market impacts.

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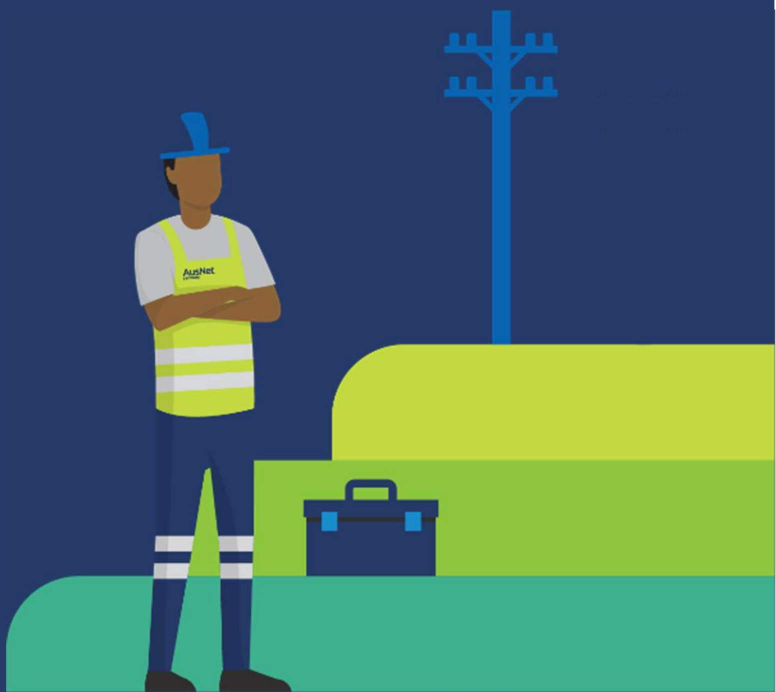

AusNet