AUGMENTATION

UNDER FREQUENCY LOAD SHEDDING

PAL BUS 3.10 – PUBLIC
2026–31 REGULATORY PROPOSAL

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1. Overview

Under frequency load shedding (UFLS) is an emergency frequency control scheme that maintains the stability of the power system and returns the frequency to normal operating areas when a generator or transmission line trips offline, known as a contingency event.

For example, when a generator trips offline, the frequency of the power system drops because demand is higher than supply. If left unchecked, this could cause further cascading failures that could lead to a system black. The UFLS scheme in this instance would shed customer load to return supply and demand back to balance and restore normal operating frequencies.

The UFLS scheme relies on load being available to be shed during a contingency event because load needs to be shed to restore the supply demand balance. The effectiveness of the UFLS scheme is reducing over time as more renewable generation connects to the grid, which reduces the amount of net load available to be shed.

AEMO's analysis in 2021 shows that UFLS in Victoria is becoming less effective as an emergency control system during periods of high renewable generation, and that UFLS effectiveness will continue to decline in the future as CER uptake continues to grow. This increases the risk of UFLS not arresting frequency declines, and increases the risk of severe energy system outcomes including system black.

We have obligations to maintain a safe, reliable and efficient energy system, which extend to ensuring that backstop protections such as the UFLS scheme operate as intended.

UFLS in Victoria is currently installed at the sub-transmission level, meaning all load and generation below the sub-transmission network must be shed together. Shedding generation during a contingency event would make the problem worse.

AEMO have recommended installing UFLS at lower voltage levels. This would increase the effectiveness of the scheme because we would have more granularity to target feeders that have net load and avoid those with no load or generation.

We are proposing to install independent new relays on our medium voltage 22kV feeder breakers in our zone substations to improve the effectiveness of the UFLS scheme through increased granularity to trip net load and avoid tripping generation during contingency events. This will reduce the likelihood of cascading system failure and minimise the number of customers that are tripped offline during contingency events.

Our program to install independent new relays on our medium voltage 22kV feeder breakers would continue through the 2026–31 and 2031–36 regulatory periods, starting with high-value feeders that have high amounts of connected CER.

The capital expenditure required to deliver this proposal is shown in table 1 below.

TABLE 1 EXPENDITURE FORECASTS FOR PREFERRED OPTION ($M, 2026)

CAPITAL EXPENDITURE FORECAST	FY27	FY28	FY29	FY30	FY31	TOTAL
Implement UFLS at zone substations – relay installation	0.6	4.1	6.0	6.0	5.6	22.3

2. Background

Australia's power system operates within a normal operating frequency band of 49.85 hertz and 50.15 hertz. Maintaining frequency within this range is essential for the safe, secure, and reliable operation of the power system.

2.1 Under frequency load shedding is an emergency frequency control scheme

The national electricity market (NEM) has several frequency control responses to manage frequency deviation from the safe operating range.

During normal operating conditions or credible contingency events, regulation frequency control ancillary services (FCAS) and contingency FCAS respond to address frequency deviations.

However, in rare circumstances following multiple unlikely or non-credible contingency events, the frequency deviation can be significant and reach the limits of the operating frequency tolerance band[1] – currently set to between 49 hertz and 51 hertz. In such cases, emergency frequency control schemes (EFCS) such as under frequency load shedding (UFLS) serves as a mechanism to maintain the stability of the power system and return the frequency to the operating frequency tolerance band when multiple contingencies occur on the network.

UFLS has been used in power networks around the world for decades. It is a critical protective measure designed to address the challenges posed by sudden and substantial reductions in system frequency. It operates by sensing the reduction in system frequency that occurs when there is a significant imbalance between supply and demand and is designed to trip load to bring supply and demand back into balance, arrest a significant decline in frequency and return system frequency to its nominal 50 hertz, keeping the system stable. Generally, the scheme is designed to operate in less than half a second.

2.1.1 AEMO and network regulatory obligations in relation to UFLS

Under the National Electricity Rules (NER), AEMO has several power system security responsibilities that involve assessing the availability and adequacy of EFCS, with the objective of ensuring sufficient reserves to arrest the impacts of multiple contingency events, affecting up to 60 per cent of the total power system load.[2]

The NER includes a range of obligations and standards to be met by networks and other registered participants to support the achievement of the power system security responsibilities relating to UFLS[3]. Broadly, these obligations require us to act reasonably to ensure that UFLS schemes operate efficiently and effectively. A summary of our obligations is available in appendix A.

Under the NER, distribution networks are required to develop processes and coordinate with transmission networks to achieve improvements in connections processes and prevent adverse impacts on the UFLS scheme effectively. For distribution networks, key responsibilities include exploring options that involve distribution network changes and determining the most appropriate long-term remediation strategies to facilitate timely action when AEMO requires.

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1 Australian Energy Market Commission Reliability Panel, The Frequency operating standard, table A.1.1
2 NER clause 4.3.1(k).
3 NER clauses 4.3.4, S5.1.10 and S5.1.8

Section 2.2 outlines how Victorian networks meet these NER obligations.

2.2 How under frequency load shedding operates

The operation of UFLS schemes varies around the country, with current Victorian arrangements trailing behind the capabilities of other states.

2.2.1 Victorian arrangements

In Victoria, the scheme is a distributed scheme where independent UFLS relays are installed at 66kV supply points to the distribution network. This means that entire sub-transmission feeders and everything below them including zone substations and all customers supplied by zone substations would need to be shed all at once. This means that generators connected to these assets would also be shed, which could make the frequency event worse.

Generally, sub-transmission loops are prioritised and made available in multiple blocks of loads for connection to the relay. We nominate and advise load priorities on our network by sub-transmission loops. AEMO acting as the Victorian transmission network service provider allocates frequency settings and time delays to co-ordinate the UFLS response across the network. The relevant declared transmission system operator, which owns the terminal stations is responsible for implementing UFLS settings.

The load blocks connected to the relays across the Victorian network have varying frequency trip settings, meaning they are programmed to disconnect loads at different frequency thresholds. This staged disconnection helps to progressively shed load in a controlled manner to minimise the amount of load shed .

Once the frequency disturbance has been arrested and the system imbalance corrected, and when sufficient generation is available, the disconnected loads can be manually reconnected to the power system.

2.2.2 Other states

All other NEM jurisdictions have UFLS schemes, signifying their importance in maintaining stable operation of the power system.

While networks in other NEM jurisdictions have UFLS schemes, they are implemented at lower voltage levels than in Victoria. This means that schemes in other NEM jurisdictions are more granular in how they shed load during UFLS events, for example at the zone substation level or often at the feeder level.

In New South Wales, the UFLS relays are located at various voltage levels, ranging from the 66 kV transmission level down to the 11 kV distribution level.[4] In Queensland, UFLS relays are installed at the 11 kV and 22 kV levels, and these relays trip feeders of the distribution network.[5] In South Australia, most UFLS relays are currently located at 11 kV feeders, and dynamic arming[6] is being progressively rolled out through 2024.[7]

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4 AEMO 2021 | Phase 1 UFLS Review: New South Wales
5 AEMO 2021 | Phase 1 UFLS Review: Queensland
6 Dynamic arming ensure that only feeders with net positive load are shed during UFLS events
7 AEMO 2023 | Under Frequency Load Shedding: Exploring Dynamic Arming Options for Adapting to Distributed PV

3. Identified need

The identified need of this business case is to deliver sufficiently granular UFLS capability to ensure that the scheme functions as intended in a high-CER world and credibly arrests contingency events.

The purpose of UFLS schemes is to shed load to balance supply and demand when a generator trips offline. Continuing to rely on the existing UFLS scheme without any modifications or investments poses several significant risks, including inability to prevent a system black.

Increasing CER is leading to a reduction in the amount of net load available that can be interrupted by UFLS. Many sub-transmission loops in the UFLS scheme already have low levels of load or reverse flows at certain times of day, which can exacerbate under-frequency events rather than arrest them.

Other jurisdictions' experience managing severe under-frequency events highlights the potential significant impacts of inadequate protections and the effectiveness of UFLS to safeguard the network during a non-credible contingency event.

As outlined above, the NER requires all networks to implement necessary frequency control measures in consultation with AEMO to operate the UFLS system. Transmission networks and connected Distribution networks must cooperate to agree arrangements to implement load shedding.

3.1 The risk of ineffective UFLS in a high CER world

UFLS is a critical EFCS measure used for maintaining system stability. However, the increasing uptake of consumer energy resources (CER) such as rooftop solar installations in Victoria is reducing the effectiveness of current approaches.

Increasing adoption of CER and embedded generation has significantly reduced the available net load on our network during times of high renewable generation, and the effectiveness of the current ULFS scheme has consequently been significantly reduced. AEMO stated:[8]

> *Distributed photovoltaics (DPV) reduces the net load on UFLS circuits, which reduces the ability of the scheme to arrest an under frequency disturbance. Furthermore, the operation of UFLS relays on circuits that are operating in reverse flows can act to exacerbate an under-frequency disturbance, rather than helping to correct it.*

UFLS is a last resort measure. Although the probability of events requiring UFLS is low, the potential impact of ineffective UFLS measures is significant and could lead to system black if system stability is not maintained.

UFLS at 66 kV transmission supply points is becoming less effective as more sub-transmission circuits experience reverse power for longer periods, meaning generation would be shed instead of load, increasing the impact of a contingency event rather than arresting it. Increasing reverse power flows reduces the ability of UFLS to effectively stabilise the power system during emergencies.

Many feeders in our network have high levels of distributed generation. AEMO analysis highlighted below shows a significant downward trend in the net load available for shedding. The annual minimum

[8] AEMO, Victoria: UFLS load assessment update, May 2023, p. 7.

net load in the Victorian UFLS scheme has decreased significantly between 2018 and 2022, with further reductions projected as the penetration of renewables increases.

During periods of high generation, feeders can experience significant reverse power flows, where more power is generated locally than consumed. This situation results in net export conditions seen on the sub-transmission network. When UFLS is activated under these conditions, it may inadvertently disconnect sub-transmission loops that are net generation instead of load, which can exacerbate frequency disturbances rather than mitigate them.

The dynamic nature of CER and renewable generation further complicates the situation because feeders may alternate between net loading and net generating. During periods of peak solar generation, the net load on certain feeders can drop significantly, making it challenging to ensure that sufficient load can be shed during a frequency event. At other times during the day, these feeders may represent a significant load on the network, with the difference between maximum and minimum demands becoming more pronounced. The frequent changes in load profiles due to CER make it more difficult to operate UFLS effectively.

To ensure that UFLS protection is effective, it is necessary to ensure that sufficient load can be interrupted to bring the system back to supply and demand balance after a significant generator trip, or other large system contingency.

3.2 AEMO investigation and findings

AEMO's reviews have confirmed the significant challenges we face in maintaining the effectiveness of the UFLS scheme. AEMO has highlighted that Victoria's current arrangements where UFLS relays are installed at the 66kV level are less effective in a high CER environment.

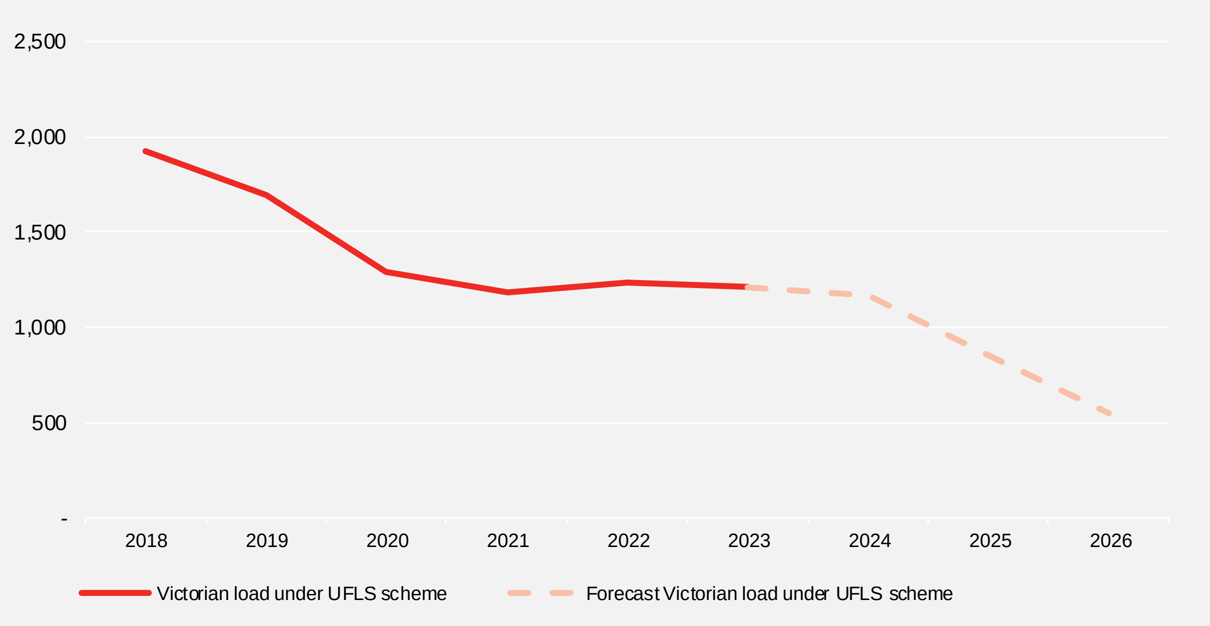
AEMO identified the following examples that are creating significant challenges for maintaining the effectiveness of the UFLS scheme – as outlined in its 2021 Phase 1 UFLS Review and 2023 UFLS load assessment update reports for Victoria.

3.2.1 Declining overall net load

AEMO states annual minimum total net load in the Victorian UFLS scheme has decreased from close to 2 gigawatts (GW) in 2018 to 1.2 GW in 2022. This trend is projected to continue as the installation of solar PV continues, with minimum total UFLS load in Victoria projected to reach close to 870 megawatts (MW) by late 2025, and 576 MW by late 2026.

Figure 1 below shows AEMO's projected reduction in Victorian UFLS available over time.

FIGURE 1 VICTORIAN LOAD AVAILABLE UNDER THE UFLS SCHEME



Source: Australian Energy Market Operator, Victoria: UFLS load assessment update, 2023

Increasing reverse power flows and decreasing net load on 66kV sub-transmission loops

AEMO found that reverse power flows are becoming more common. For example, five sub-transmission loops have already been identified to have large wind and solar generators located on UFLS circuits, meaning they will be disconnected when UFLS relays operate.[9] This reduces the capability of our existing UFLS scheme.

Approximately 65 per cent of distributed PV is connected to 66kV sub-transmission loops, where most UFLS relays are located in Victoria.[10]

This is detrimental to UFLS functionality. These loops are in reverse flow up to 60 per cent of the time, and experience reverse power flows as high as 115 MW. Further, 26 sub-transmission loops on the UFLS scheme that did not have reverse power flows in 2018 exhibited reverse power flows in 2022.[11] Finally, some sub-transmissions loops are also now showing periods of reverse flows related to the generation of CER. Some of these sub-transmission loops are showing reverse flows around 5–10 MW in the lowest load periods, and showing reverse flows up to 2.5 per cent of the time.[12]

This variability in net load, especially during periods of high solar PV generation, has increased the occurrence of net UFLS load levels falling below 60 per cent of the underlying load. In AEMO's scenario modelling, PV generation exceeding 1 GW leads to net UFLS load under 60 per cent of underlying load more than half of the time.[13]

9 AEMO, Victoria: UFLS load assessment update, May 2023, p. 14.
10 AEMO, Phase 1 UFLS Review: Victoria, 2021, p. 19.
11 AEMO, Victoria: UFLS load assessment update, May 2023, p. 3; 14.
12 AEMO, Phase 1 UFLS Review: Victoria, 2021, p. 23.
13 AEMO, Victoria: UFLS load assessment update, May 2023, p. 9.

3.2.2 AEMO recommendations

To address increasing reverse flows and declining net loads, particularly on sub-transmission loops, AEMO has broadly recommended that Victorian networks improve their UFLS capabilities. AEMO's specific recommendations are described below:[14]

- **Removing large generating units from the UFLS scheme**: This involves moving UFLS relays to a lower voltage level or dynamically arming relays to disarm when circuits are in reverse flows. This aims to prevent large wind and solar farms from being disconnected during UFLS activation, which is detrimental to UFLS functionality. AEMO sought advice from networks on possible options which should include an assessment of technical and economic feasibility. These potential options could include:
  - Removing the affected sub-transmission loops from the UFLS scheme, and replacing them with loads at other locations.
  - Dynamically arming UFLS relays, so that they automatically disarm when the circuit is in reverse flows.
  - Moving UFLS relays to a lower voltage level (within sub-transmission loops), so that loads on the loop are tripped by UFLS relays, but the large-scale generation remains connected.
  - Or any combination of the above approaches, to be considered on a case-by-case basis.
- **Improving connections processes**: networks should introduce improvements to the connections process for large generating units to ensure that new connections do not occur behind UFLS relays without suitable rectification. Ideally, Victorian networks 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.
- **Exploring Dynamic arming options of UFLS relays**: Implement dynamic arming (reverse flow blocking) of UFLS relays to prevent circuits experiencing reverse power flows from being tripped. This helps to ensure that only net loads are disconnected during an under-frequency event, thereby maintaining the balance between generation and load. AEMO considered the following options for implementation of dynamic arming of UFLS:[15]
  - **Option 1**: Dynamic arming at 66kV – Implement reverse flow blocking (disarming) of UFLS relays at the existing 66kV level – UFLS relays automatically disarm when the circuit moves into reverse flows, preventing reverse operation of the UFLS scheme.
  - **Option 2**: Dynamic arming at 22kV – Move UFLS functionality to a lower voltage level (such as 22kV), with reverse flow blocking. This facilitates more granular load shedding (tripping only 22kV circuits that are net loads, while leaving those that are net exporters connected).
  - **Option 3**: Dynamic arming at AMI – Move UFLS functionality to individual customer sites via advanced metering infrastructure (AMI). This facilitates even more granular load shedding, tripping only individual customers that are net loads, while leaving exporting customers connected.

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14 AEMO, Victoria: UFLS load assessment update, May 2023, pp. 17–18.
15 AEMO 2023 | Under Frequency Load Shedding: Exploring dynamic arming options for adapting to distributed PV.

AEMO subsequently conducted case studies on the different dynamic arming options for UFLS and highlighted the effectiveness of each option to different loops. The following four case studies of archetypal sub-transmission loops in Victoria were explored, based on data from the 2021 year:[16]

- **Household and small business loops**: enabling UFLS via AMI is capable that is capable of this functionality might offer a similar level of net UFLS load as implementing new UFLS relays at the 22kV level. The AMI option could represent a lower-cost alternative in some locations and may also be more robust over the long term as levels of distributed resources continue to grow. While networks should keep explore further.
- **Commercial loops**: moving UFLS functionality to the 22kV level appears to be a suitable option in the near term. There are minimal UFLS-capable AMI on commercial loops, so the AMI option is not available with present hardware. It may be worthwhile for distribution networks to explore other alternatives to enable UFLS functionality at individual commercial/industrial customer sites.
- **Loops with large wind or solar farms**: moving UFLS functionality to the 22kV level offers a significant and immediate increase in net UFLS load by excluding the large wind and solar generators from tripping via UFLS. This may be a suitable option for these loops in the near term.

We have had regard to AEMO's recommendations in forming our approach to managing declining net load available under the UFLS scheme.

3.3 Case study: effective use of UFLS to prevent worst case scenario

The current UFLS scheme's diminishing effectiveness means that during significant frequency disturbances, the UFLS scheme may fail to stabilise the system. This failure could lead to widespread blackouts, affecting both residential and commercial customers, and more broadly potentially impacting the entire state. South Australia experienced these types of blackouts in 2016.

The economic impact of such blackouts can be substantial, including lost productivity, damage to electrical equipment and increased costs for emergency response and recovery. In the worst-case scenario, if UFLS fails to operate as intended during a major contingency event, the entire power system could be at risk of a system black event. This would result in a complete loss of power supply across the network, causing significant disruption, impacting general safety across the state and requiring extensive time and resources to restore normal operations.

3.3.1 2021 QLD UFLS Event

The activation of UFLS to stabilise a contingency event was experienced in central Queensland on 25 May 2021 when an event occurred that caused multiple generator and line trips. This event provides a clear example of the effectiveness of UFLS in protecting the power network from severe under-frequency events.

Following the Callide C4 fault at 2pm, the UFLS scheme was activated, effectively arresting the frequency decline and preventing a more widespread blackout. The UFLS scheme operated as intended, disconnecting customer load to increase system frequency. Figure 2 below shows the sequence of events during the Callide C4 fault.[17]

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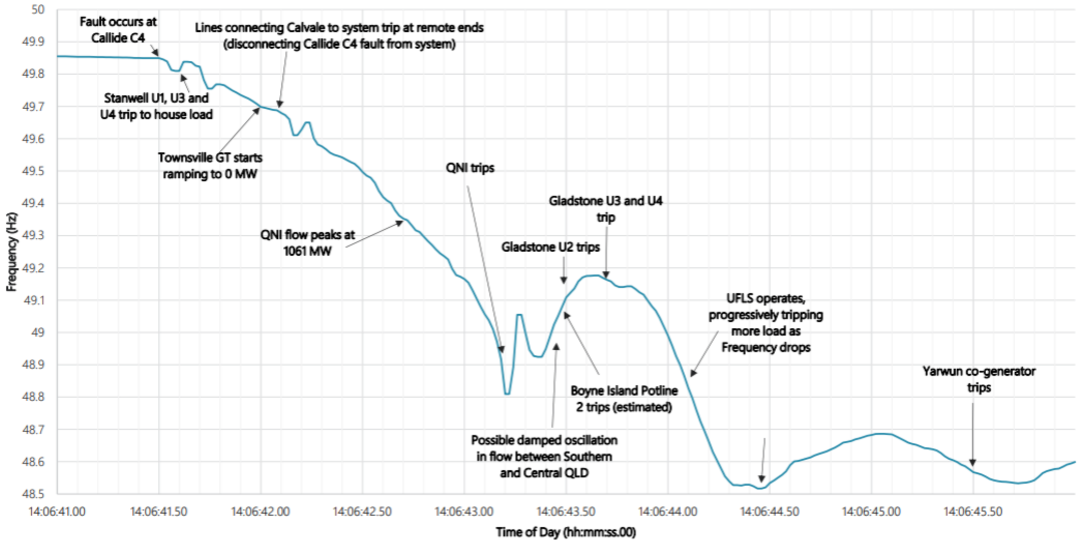
[16] AEMO, Under Frequency Load Shedding: Exploring dynamic arming options for adapting to distributed PV, Victorian case studies, October 2023.

[17] AEMO, Trip of multiple generators and lines in Central Queensland and associated under-frequency load shedding on 25 May 2021, 2021, Figure 1.

FIGURE 2 SYSTEM FREQUENCY AND MAJOR EVENTS DURING INCIDENT



UFLS technology acted as intended to arrest a rapid decline in frequency. Without UFLS, it is likely that blackouts would have been experienced, potentially across all of Queensland.

The Queensland example highlights the critical role of the UFLS scheme in maintaining resilience and reliability of the power system. However, this contingency event relied on UFLS at 11kV and 22kV distribution levels – which is more comprehensive than the current approach in Victoria.

The Queensland incident report recommended that AEMO review the operation of UFLS in greater detail to confirm that individual UFLS load blocks operated as expected and assess whether the UFLS scheme remains effective as inertia falls and distributed generation grows. This is directly applicable in Victoria and to our network, where the net load available for shedding has significantly decreased due to the penetration of distributed PV.

4. Assessment of credible options

Several options were considered to increase the amount of load available under the UFLS scheme in Victoria.

Our proposed options vary around the voltage level that UFLS capabilities that would be installed at and the speed that these capabilities would be achieved.

Our options have regard to AEMO's recommendations for improving the effectiveness and capability of the UFLS scheme in Victoria.

A summary of each option is described below in table 2 below.

TABLE 2 OPTIONS SUMMARY ($M, 2026)

OPTION	UFLS OPERATION LEVEL	UFLS PROTECTION LEVEL	TIMING	CAPEX REQUIREMENT (2026–31)
Maintain status quo	66kV, low	Low	N/A	0
Implement UFLS at zone substations, new relay installation	11kV and 22kV, high	High	Complete by 2036	22.3
Implement UFLS at zone substations, rely on existing relays	11kV and 22kV	Medium	Complete by 2036	7.4
Implement UFLS at the AMI meter level	240V	Low (not credible)	Not feasible	-

A summary of the costs and benefits of each option are provided below.

4.1 Option one: maintain status-quo

Maintaining the status-quo provides no increase of load available to the UFLS scheme in Victoria. This option leads to the ongoing deterioration of UFLS performance in Victoria and leads to an outcome where, if UFLS is required to operate, in the worst case a system black event impacting significant parts of the Victorian network and potentially the broader NEM. This will have significant economic and reputational impact and potentially impact long term investment in Victoria.

4.2 Option two: implement UFLS at zone substations – new relay installation

This option includes the installation of independent new relays on the medium voltage (MV) feeder breakers in our zone substations, while using existing functionality available in feeder management relays.

The new MV relays would detect the frequency and direction of power flow and direct feeders to sequentially trip in response to increasingly severe frequency declines. This prioritisation ensures that no more load is shed than necessary to arrest a frequency decline and minimises customer impacts.

The net load on MV feeders would be monitored for reverse power overload. Relays that detect reverse power overload would not be tripped. This would improve the effectiveness of the UFLS scheme and reduce the amount of customer load that would need to be shed during a contingency event.

The preset frequency value will vary for every feeder as part of the solution design and will typically be in the range from 49.0 to 47.0 hertz. In some cases a delay of up to 60 seconds could be added at the request of AEMO.

Under this option, UFLS relays on MV feeders would be rolled out comprehensively across our network across the 2026–31 and 2031–36 regulatory periods. Half of the works would be completed through the 2026–31 regulatory period, targeting zone substations with high levels of renewable generation and connected CER. The rest of the program would be completed in 2031–36.

The costs to implement this option are summarised in table 3 below.

TABLE 3 OPTION TWO: REQUIRED EXPENDITURE ($M, 2026)

PROJECT	FY27	FY28	FY29	FY30	FY31	TOTAL
Implement UFLS at zone substations – relay installation	0.6	4.1	6.0	6.0	5.6	22.3

4.2.1 Case Studies

To determine the likely value of implementing UFLS technology at the zone substation level, we reviewed how much more effective the UFLS scheme would be at the 22kV level compared to the 66kV sub-transmission loop level.

Our analysis found that there was significant merit to moving UFLS technology to the 22kV level across our zone substations, particularly during daylight hours when solar PV generation is highest.

During daylight hours, load and generation were often found to be equal, meaning the feeder would add little to no protection under the UFLS scheme in the case of a contingency event. However, all customer loads and renewable generation on the feeder would still be tripped and lose supply. In the case of reverse power flows, existing arrangements could make a contingency event worse.

Further information about this analysis is presented in Appendix A.

4.3 Option three: implement UFLS at zone substations – rely on existing relays

This option would rely on existing feeder management relays and use software updates to convert these feeders to become UFLS-ready. This option differs from option two in that no new relays are installed.

Relays that are updated would function similarly to separate UFLS relays, and would be cheaper and quicker to implement relative to installing a new relay.

Not all feeders on our network would have underfrequency control capability through software updates, limiting the improvement in our UFLS capability and providing reduced functionality compared with option two.

This option also poses significant risks to our assets and the safety of our staff and customers in the event that the UFLS scheme is required. For example, in the case where one feeder is highly loaded and another feeder at the same zone substation has a generator connected with reverse flows through the zone substation, tripping load can cause reverse power overload at the zone substation, causing damage to assets and safety risks for our staff.

Temporary voltage distortions can also cause changes in frequency that can trip the UFLS protection of individual feeders without coordinated control at the zone substation. Relaying on existing relays would not provide coordinated control at the zone substation, creating increased outage risks for customers.

The costs to implement this option are summarised in table 4 below.

TABLE 4 OPTION THREE: REQUIRED EXPENDITURE ($M, 2026)

PROJECT	FY27	FY28	FY29	FY30	FY31	TOTAL
Implement UFLS at zone substations – rely on existing relays	0.2	1.4	2.0	2.0	1.8	7.4

The case studies discussed in section 4.2.1 above are equally applicable to option three for feeders that have underfrequency control capability.

4.4 Option four: implement UFLS at the AMI meter level

AEMO has proposed investigating the UFLS capabilities of the existing advanced metering infrastructure (AMI) fleet that is now available throughout our network.

Referring to it as a "novel solution", some AMI meters meters could be programmed to sense under-frequency conditions and be set up to interrupt the load that they supply to customers if certain underfrequency thresholds are reached

One benefit of this approach would be that it is very granular and precise amounts of load could be interrupted for each frequency level, staggering the load shedding of customers.

This option has only been conceptually documented at this stage and has not been confirmed as technically practicable or achievable.

Our assessment is that this option is not credible for a variety of reasons, including:

- the AMI meters have not been tested to demonstrate that they are capable of performing UFLS capabilities, such as stability of detection, adequate response times and consistent trip performance, which means UFLS capabilities could fail to operate during a contingency event
- the requirement for UFLS capability has not been included in the AMI specification and so individual manufacturers could not provide UFLS capability and remain compliant.
- less than 9 per cent of the existing meter fleet could have UFLS capabilities through the application of settings given to date only one manufacturer has UFLS capability
- there is only a single manufacturer with AMI meters capable of this function at this time
- there is no established testing regime for UFLS capabilities on AMI meters
- there are no standardised settings for individual meters, meaning implementation may not be reliable

- load and generation are not mandatorily separated on customers' premises, meaning full capability would likely require site rewiring, or households who are generating may be tripped.

There are several other possible disadvantages of this approach that have not yet been investigated in detail. For example if most of the load on a low voltage network was tripped off due to an underfrequency event, it is possible that remaining generation could lead to overvoltage in the network, which could damage customer installations and network equipment, or overload network assets with excessive generation flows.

The existing regulatory framework is not clear around the liability, penalties or exemptions from penalties that would arise from mal-operation of UFLS or failure of ULFS function to operate. Given we may be subject to penalties, it is paramount that we are certain that the implemented UFLS technology would function as intended. AMI UFLS capabilities have not yet demonstrated this function.

Given the significant uncertainties, lack of demonstrated capability, potential unexpected impacts and low level of UFLS protection available under this option, we consider that this option is not technically feasible.

5. Preferred option

Option two, installing independent new relays on the MV feeder breakers in our zone substations while using existing functionality available in feeder management relays is our preferred option.

This option is preferred because it meets the identified need to deliver sufficiently granular UFLS capability to ensure that the scheme functions as intended in a high-CER world and credibly arrests contingency events.

This option would improve our networks' UFLS capability to the same standards that other states across the NEM have by 2036, able to operate with adequate protections in a highly renewable and electrified future. Feeders that have the capability

While improving UFLS capability through only using software updates on feeders that have underfrequency control capability is feasible under option two, we consider this option is not preferable on its own because it would create safety risks and limit the improvement in UFLS capability to levels that would not be fit for purpose in an electrified future.

Our proposed capital expenditure over the 2026–31 regulatory period to deliver UFLS protection at za zone-substation level is shown in table 5:

TABLE 5 EXPENDITURE FORECAST FOR PREFERRED OPTION ($M 2026)

CAPITAL EXPENDITURE	FY27	FY28	FY29	FY30	FY31	TOTAL
Implement UFLS at zone substations – new relay installation	0.6	4.1	6.0	6.0	5.6	22.3

A List of UFLS clauses

TABLE 6 KEY NETWORK RESPONSIBILITIES RELATING TO UFLS

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 NSPs transmission or distribution system.
S5.1.10.1(a)	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.
S5.1.10.1a(a)	Cooperate with AEMO in the conduct of power system frequency risk reviews and provide to AEMO all information and assistance reasonably requested by AEMO in connection with power system frequency risk reviews; and provide to AEMO all information and assistance reasonably requested by AEMO for the development and review of EFCS settings schedules.
S5.1.10.2	(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.

B Case studies

To determine the likely value of implementing UFLS technology at the zone substation level, we reviewed how much more effective the UFLS scheme would be at the 22kV level compared to the 66kV sub-transmission loop level.

Our analysis found that there was significant merit to moving UFLS technology to the 22kV level across our zone substations, particularly during daylight hours when solar PV generation is highest.

During daylight hours, load and generation were often found to be equal, meaning the feeder would add little to no protection under the UFLS scheme in the case of a contingency event. However, all customer loads and renewable generation on the feeder would still be tripped and lose supply. In the case of reverse power flows, existing arrangements could make a contingency event worse.

An example zone substation is the Swan Hill (SHL) 66kV loop, which includes the Swan Hill zone substation, the Cohuna zone substation and a 50 MW solar farm connection.

We extracted 30 minute SCADA data from January 2023 for the Swan Hill (SHL) 66kV loop to determine how much additional UFLS load would be available if UFLS was implemented at the 22 kV level.

The charts below compare the total 66 kV loop load with the simultaneous 22 kV load at Swan Hill. We have assumed that reverse flow blocking of UFLS at 66 kV has been implemented prior to this project.

Figure 2 below demonstrates that the UFLS scheme would be more impactful when loads on the 66kV loop are close to zero, when the load and generation on the loop are roughly equal.

FIGURE 3 SWAN HILL (SHL) LOOP ADDITIONAL LOAD @22KV (BY TOTAL LOAD)

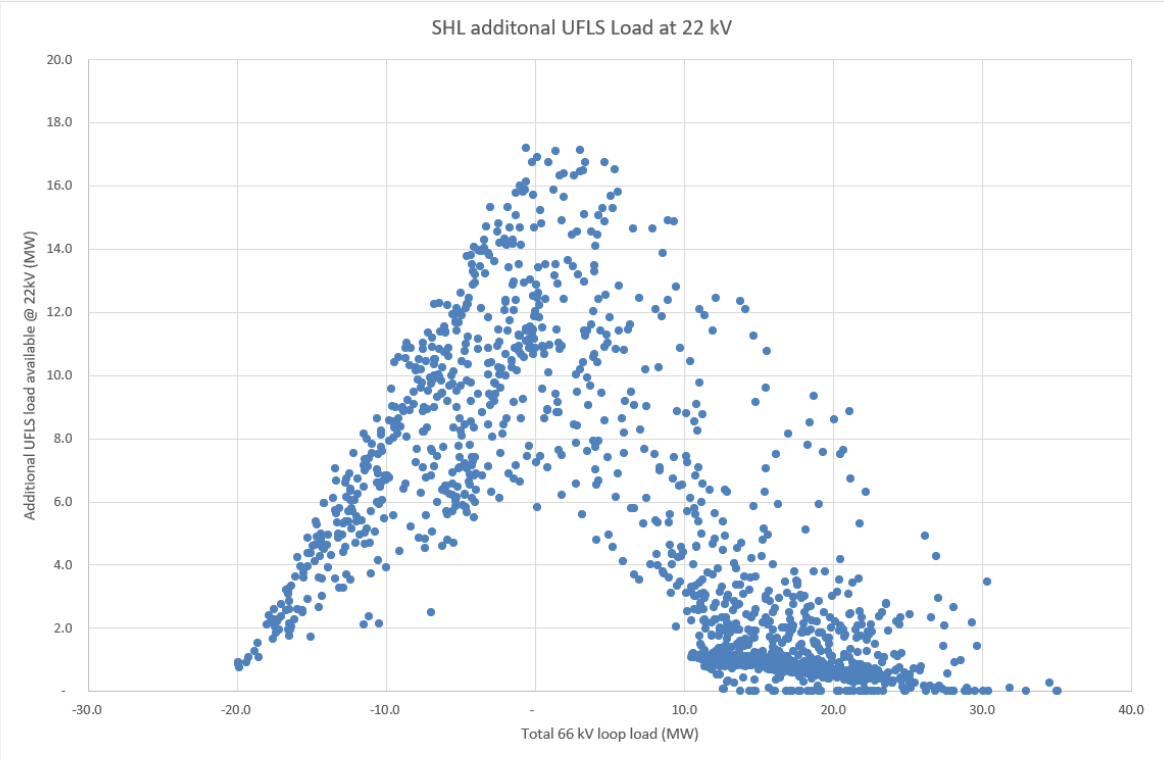


Figure 3 below demonstrates shows that the largest benefits to switching UFLS from 66 kV to 22 kV would be during daylight hours when renewable generation is highest.

FIGURE 4 SWAN HILL (SHL) LOOP ADDITIONAL LOAD @22KV (BY TIME)

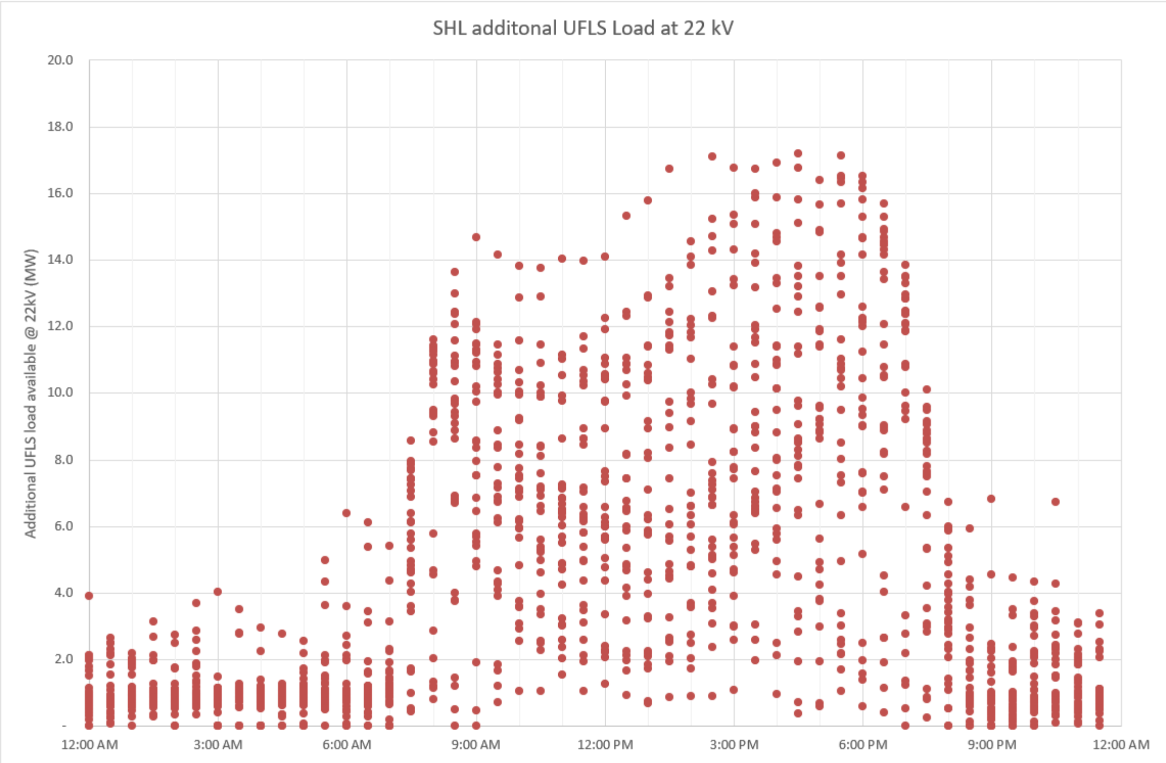
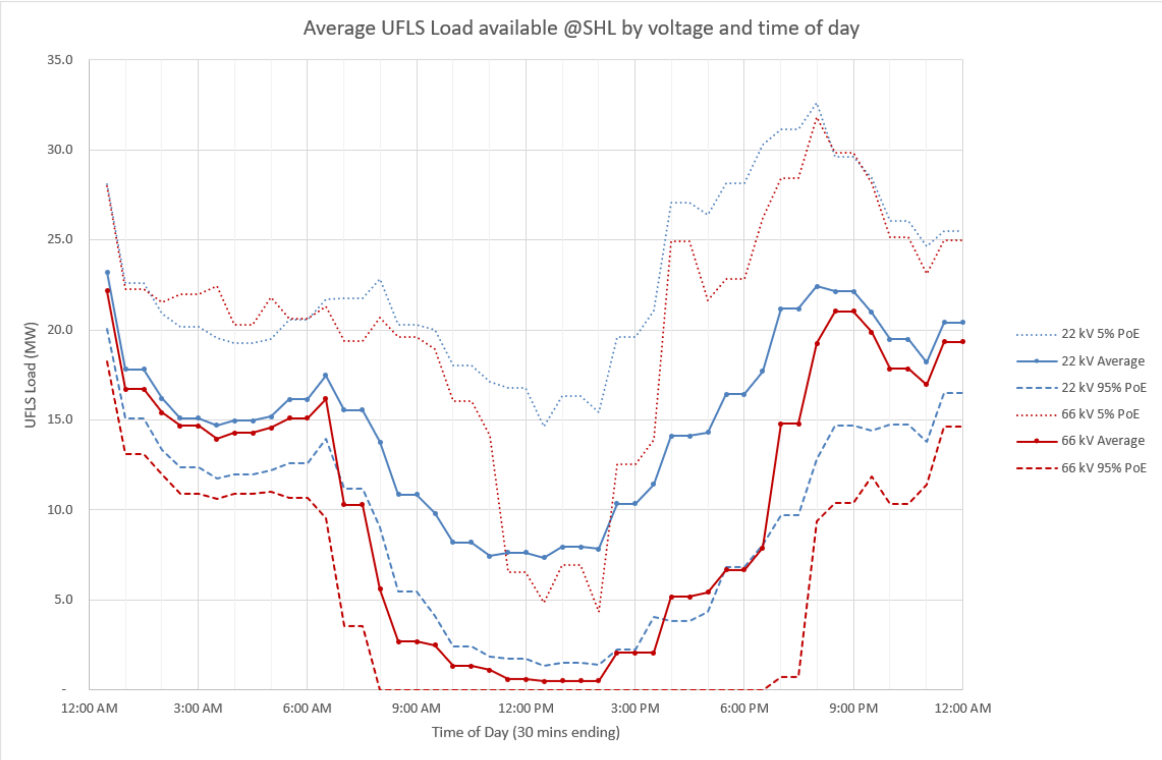


Figure 4 below directly compares the load available to be shed at SHL under the UFLS scheme at the 66kV level compared to the 22kV level.

The analysis shows that between 5 to 10 additional MW would be made available to shed under 22kV UFLS implementation compared to 66kV level UFLS implementation. Implementation at the 22kV level increasing the effectiveness of the UFLS scheme and reducing the amount of customers that would need to be shed typically by between 5 to 10 MW.

FIGURE 5 SWAN HILL (SHL) LOOP UFLS LOAD AVAILABLE @ 22 & 66 KV (BY TIME)



This analysis was replicated for the Gelong East, Drysdale and Ballarat South 66kV subtransmission loops. The findings from each of these case studies are similar to SHL.

The results of this analysis are shown below.

FIGURE 6 FIGURE 7 - GEELONG EAST AND DRYSDALE (GLE AND DDL) LOOP ADDITIONAL LOAD @22KV (BY TOTAL LOAD)

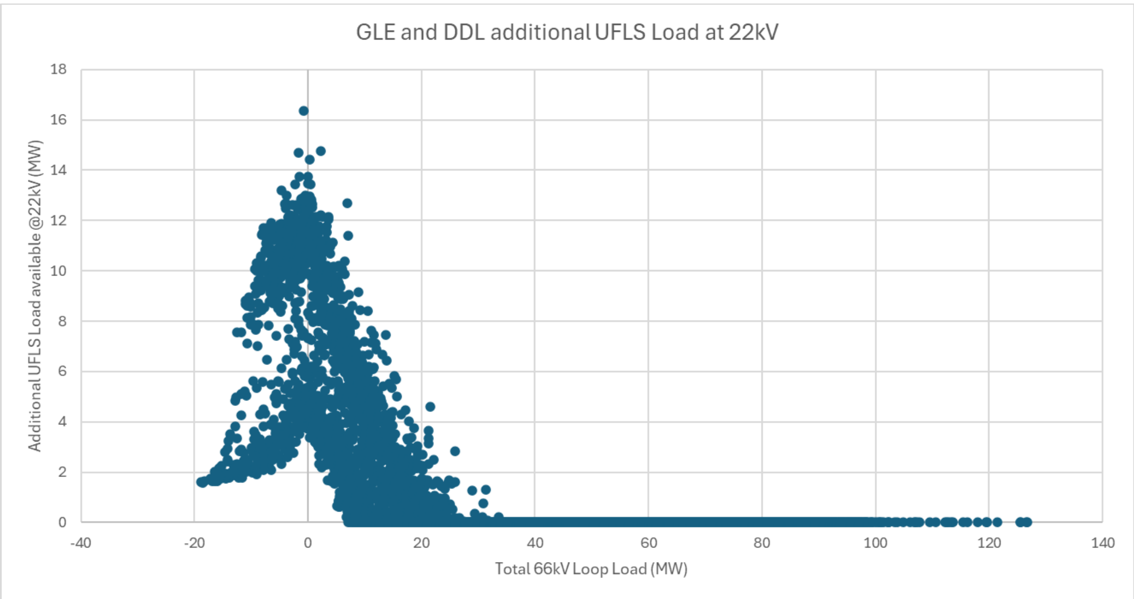


FIGURE 8 GEELONG EAST AND DRYSDALE (GLE AND DDL) LOOP ADDITIONAL LOAD @22KV (BY TIME)

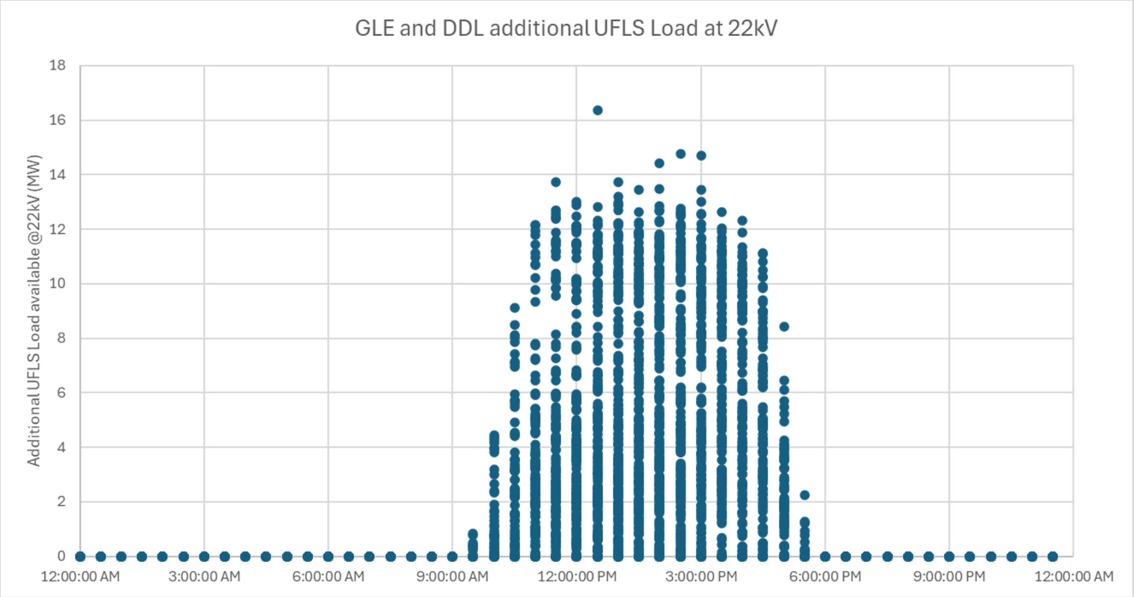


FIGURE 9 BALLARAT SOUTH (BAS) LOOP ADDITIONAL LOAD @22KV (BY TOTAL LOAD)

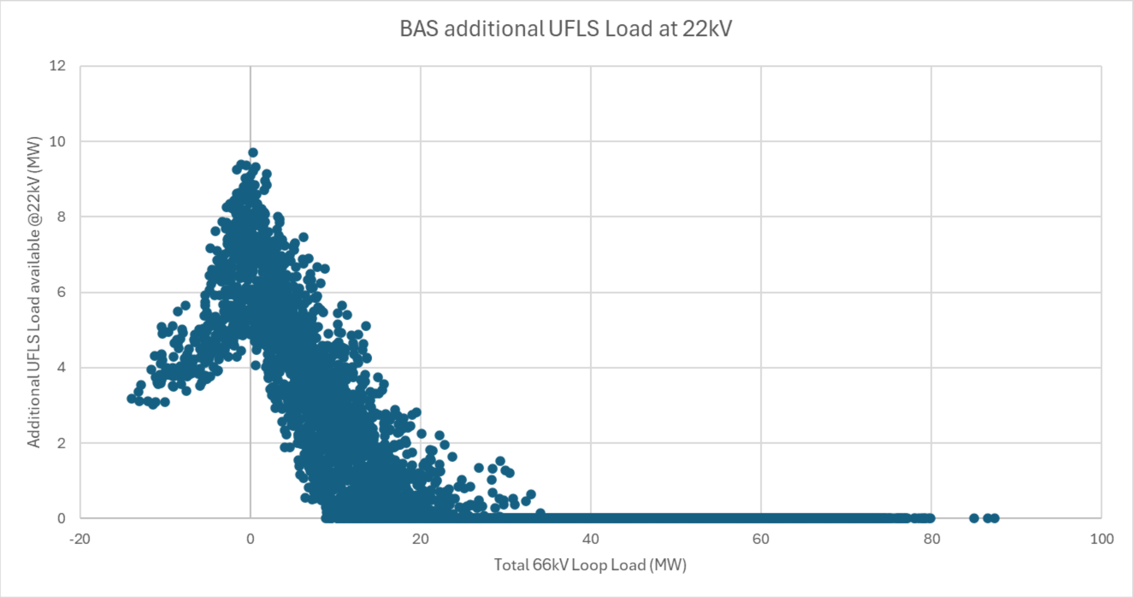
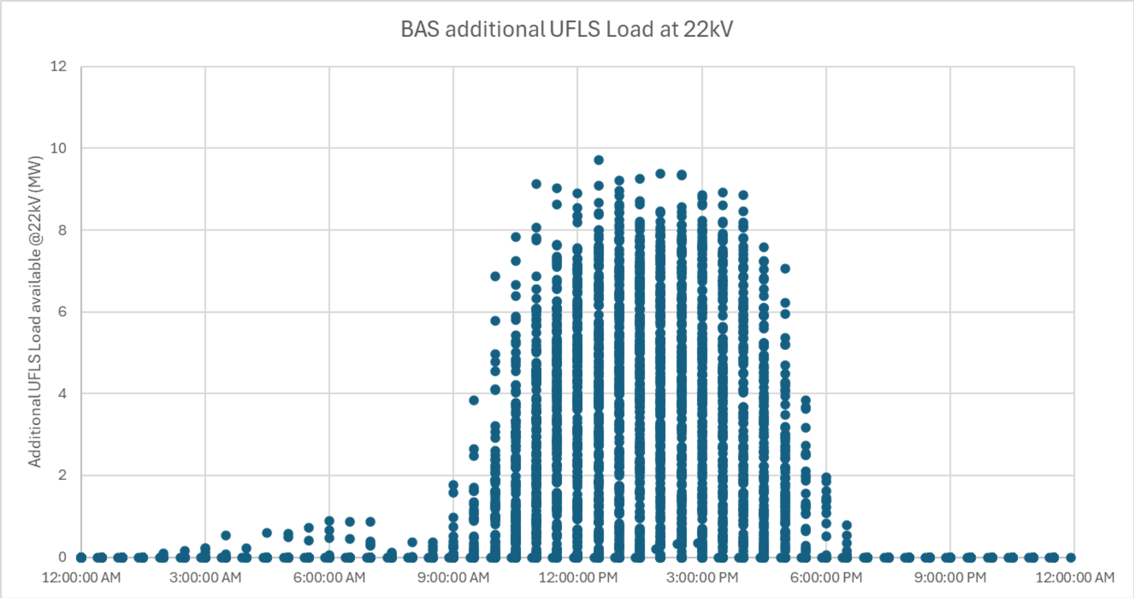


FIGURE 10 BALLARAT SOUTH (BAS) LOOP ADDITIONAL LOAD @22KV (BY TIME)



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