Emergency Underfrequency Response in South Australia

Expression of Interest

27/7/2022 – Version 1.0

SA Power Networks

Empowering South Australia

Contents

Document Control

Version	Date	Author	Notes
v0.9	27/05/2022		Draft issued for external distribution
v1.0	27/07/2022		Final issued for external distribution

Definitions & Abbreviations

AEMO	Australian Energy Market Operator
DPV	Distributed solar photovoltaic (PV) generation
EOI	Expression of Interest
ESOO	Electricity Statement of Opportunities
EUFR	Emergency Underfrequency Response
FY	Financial year
NEM	National Electricity Market
NER	National Electricity Rules
RFP	Request for Proposal
TBC	To be confirmed
UFLS	Underfrequency load shedding
VPP	Virtual Power Plant
Service enablement	During times of service enablement, the EUFR service provider is prepared to respond to a contingency event with the agreed technical characteristics.
Service activation	The triggering of response from an EUFR service provider following a contingency event

1. Introduction

1.1 Purpose

This expression of interest provides the details required for potential Emergency Under Frequency Response (EUFR) providers to tender their capabilities in contributing to the resolution of the Under Frequency Load Shedding (UFLS) deficit in South Australia. This EOI will inform the understanding of the response achievable and indicative costs allowing the refinement of service specifications. Credible parties can also be identified to participate in a request for proposal.

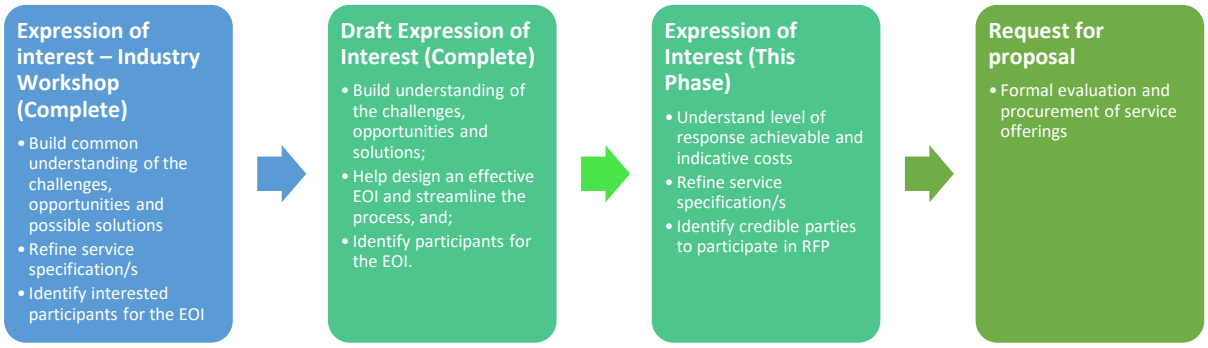
1.2 Procurement Process

Following the initial industry engagement and information phase, SA Power Networks (SAPN) has commenced this tender process that may result in the procurement of services to meet UFLS shortfalls, where considered technically and economically feasible. While the size of the shortfall could be up to 500MW, a smaller amount may be procured if there are alternative cost competitive options available or if delivery of that amount is technically or economically infeasible.

Recognising the substantial pace of change in the South Australian power system, ongoing analysis and refinement of the understanding of the power system operating under these novel conditions, and anticipated market developments (such as the imminent introduction of a Fast Frequency Response market ancillary service1) the intention is to initially procure services under a 12-month contract, and then review to determine suitable ongoing arrangements. The UFLS shortfall is anticipated to persist post commissioning of Project EnergyConnect.

This service is proposed to be procured through a staged process as shown below. This Expression of Interest (EOI) has been produced to:

- Understand level of response achievable and indicative costs;
- Refine service specification; and
- Identify credible parties to participate in an Request for Proposals (RFP).



[1] AEMC, Fast frequency response market ancillary service, https://www.aemc.gov.au/rule-changes/fast-frequency-response-market-ancillary-service

The subsequent stage of the process will involve parties responding an Request for Proposal (RFP). Indicative dates are shown below.

Phase 1 – Industry Workshop	
Stakeholder consultation on concept (this document)	18 January 2022
Industry Workshop	10 February 2022
Responses to consultation due	24 February 2022
Phase 2 – Expression of Interest	
Draft Expression of Interest circulation	27th May 2022
Draft Expression of Interest feedback due	27th June 2022
Expression of Interest publication	29th July 2022
Expression of interest responses due	12th September 2022
Phase 3 – Request for Proposal	
Request for proposal publication	Q4 2022
Contract negotiation with successful respondents	Q4 2022
Initial services enabled	Q4 2022
Phase 4 – Review of requirements	
Calculation of UFLS requirements	Q4 2023
Renewal of annual service procurement process	Q4 2023

1.2.1 Submission Details

All EUFR Expression of Interest submissions detailing the proposed resources and pricing information must be submitted to SA Power Networks only via email to networkservices@sapowernetworks.com.au. Please note the email size needs to be less than 10MB.

Closing Date: 5:00 pm ACST, 12th September 2022

SA Power Networks is not obliged to accept any response in any other manner (but reserves its right to do so, entirely at its discretion).

SA Power Networks is not obliged to consider a response received after the Closing Date although SA Power Networks reserves the right to do so at its discretion.

1.2.2 Communication

All communication (including any request for additional information) concerning this EUFR Expression of Interest must be made in writing via email to networkservices@sapowernetworks.com.au, addressed to the following persons:

- **Commercial:** Karl Garda (0447 554 342)
- **Technical:** Alexander Ward (0439 397 914)

All reasonable endeavours will be made to respond to enquiries in writing within 24 hours from receipt of email.

Please note that answers to clarification questions will be shared with all tendering parties. Should you wish to keep your question confidential, you must mark the question as so.

1.3 Context

1.3.1 AEMO advice to SAPN

Background

The UFLS scheme forms a key part of South Australia's emergency under-frequency response and contributes to the overall emergency under-frequency response of the NEM. UFLS is relied on as a last resort 'safety net' mechanism to prevent frequency collapse following rare, but severe, non-credible power system disturbances. As the system frequency falls below 49 Hz, the UFLS scheme disconnects customer supply by opening distribution circuit breakers at zone substations, with the intended effect of immediately reducing load on the network. Reducing network load aids the arrest, stabilisation and recovery of frequency following underfrequency events.

In recent years, growth of behind the meter devices such as distributed PV (DPV) has significantly reduced the amount of net load in the South Australian UFLS scheme. In some periods, the total amount of load available to be shed in the scheme has been measured as low as -110 MW, meaning that the entire scheme is now operating in reverse in some periods. That is, disconnection of feeders may serve to shed further generation rather than load, exacerbating the frequency decline rather than alleviating it.

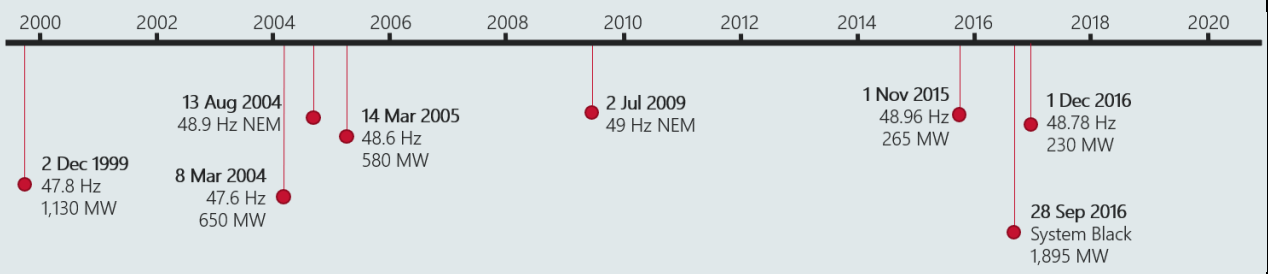
The erosion of this 'safety net' mechanism places the South Australian network at risk under both system normal and islanded conditions. It also reduces the relative contribution of the South Australian UFLS scheme to NEM-wide UFLS, placing more stress on UFLS in other states.

A number of measures are being implemented to increase net load on the UFLS scheme, such as adding more feeders into the scheme, and implementing 'dynamic arming', where UFLS relays are dynamically disarmed when the feeders they are on are operating in reverse flow.[2] .Dynamic arming prevents the UFLS scheme from exacerbating contingencies; however, this may only restore net UFLS load to 150 MW to 200 MW in periods of high DPV generation. According to the National Electricity Rules (NER), appropriate reserves should be available to arrest the impacts of a range of significant multiple contingency events affecting up to 60% of the total power system load (NER clause 4.3.1(k)). Estimates based on this 60% measure and based on non-credible contingencies observed in the past suggest that UFLS load in South Australia should be in the range of 800 MW to 1,200 MW. Though 60% of power system load may not be required in all circumstances for UFLS to operate adequately, analysis by AEMO shows there are times where not meeting this requirement would result in UFLS failure, particularly during periods of high DPV and moderate demand. Thus, further actions are required to restore emergency underfrequency response capability in South Australia to adequate levels and bring the state's contribution to NEM-wide UFLS back in alignment with other states.

Incidence of UFLS triggering events

The UFLS scheme is only triggered in extreme non-credible contingency events that cause the frequency in SA to drop below 49 Hz. Historically, these events are rare and have only occurred on average every ~3 years with UFLS being triggered 8 times in South Australia since 1999 as shown in Figure 1. Although events are rare, the consequences of inadequate UFLS can be severe potentially resulting in a system black and disconnection of all customer load.

Figure 1 Historical UFLS Events in South Australia



Additional context can be found in Appendix A

1.4 Amount of Service Required

In order to reduce the risk of widespread outages in South Australia as a result of rare, severe power system disturbances, AEMO, SA Power Networks and ElectraNet are collaborating to procure additional emergency underfrequency response (EUFR) of up to 500 MW commencing in 2022. This quantity of 500 MW is based on AEMO's current assessment of the operational envelope where AEMO has reasonable confidence that the UFLS scheme can function effectively. This is subject to change based on further studies of system conditions and performance, including the impact of new standards such as AS/NZS 4777.2:2020 and the primary frequency response rule change.

Periods of high requirement for this service are expected to coincide with periods of high DPV generation and low load. However, this is subject to change based on further AEMO analysis, which may indicate that the highest risk periods are moderate load periods which may have a higher likelihood of severe power system disturbances. Further details on the types of periods where UFLS shortfalls occur are provided in Appendix A.

1.5 Types of Service Required

This tender is seeking expressions of interest from any providers that can deliver an increased under-frequency response, in very rare emergency conditions (less than once per year), over and above their existing obligations (including obligations under the National Electricity Rules, Australian Standards, regulated schemes and contracts and other existing requirements).

The EUFR service can be either a reduction in load, an increase in generation, or both. This could take the form of either:

- A switched service where the full response is provided at once (often by disconnecting loads), activated at a configurable frequency between 49Hz and 47Hz. Any generation at load sites will need to remain connected to the power system.
- A proportional (i.e., droop) response, where the response is dynamic and continuously adjusts proportionally to the size of frequency deviation.

Categories of response have been defined based on the feedback received from the industry workshop and are described in section 1.5.2. EUFR procured in this EOI is intended to replicate both the fast-acting arrest of frequency decline and assistance in longer term frequency recovery that the current UFLS scheme provides. EUFR also needs to be sustained in a similar manner to UFLS to allow sufficient time for re-configuration of the network and central dispatch following a large frequency disturbance. The type and timing of the response is informed by the capabilities of plant in each category.

It is expected that EUFR will be activated very rarely. Although historical events are not a reliable indicator of future occurrences, frequency excursions below 49 Hz have typically occurred less than once per year.

[2] AEMO (May 2021) South Australian Under Frequency Load Shedding – Dynamic Arming, https://aemo.com.au/-/media/files/initiatives/der/2021/south-australian-ufls-dynamic-arming.pdf?la=en&hash=C82E09BBF2A112ED014F3436A18D836C

1.5.1 Reservation of Headroom

Provision of EUFR does **not** require reservation of headroom. EUFR providers can freely participate in the NEM energy and FCAS markets, FFR markets, and other frequency services with the same capacity offered to provide EUFR. Given the very rare occurrence of severe under-frequency events that require EUFR, this tender is seeking providers that can efficiently provide an increased under-frequency response under these very rare circumstances. The objective is to materially reduce the likelihood of a cascading failure for a rare non-credible contingency event, eliminating the risk entirely is unlikely to be cost-effective or possible. This is different to the objectives of other types of frequency control used to manage smaller and more common credible contingency events, where the National Electricity Rules prescribe required outcomes, and reservation of headroom is therefore required.

This tender process therefore requests that potential providers outline the additional response they can provide (beyond existing requirements), and the statistical likelihood of that additional response being available at times of UFLS shortfall.

1.5.2 Potential EUFR providers

Two types of desired response have been identified:

- **Rapid EUFR** – Under-frequency response delivered within 200-500ms
- **Slow EUFR** – Under-frequency response delivered within 10 minutes and sustained until frequency is recovered and normal dispatch resumes (may be up to 60 minutes)

Rapid EUFR aims to assist in the fast arrest of frequency decline following a large loss of generation capacity. Slow EUFR then assists in relief for energy limited plant to sustain the response until the power system is stabilised, and assists in recovering frequency back within normal operating bands. The combination of services aims to sustain the under-frequency response for a long enough period to allow to allow management options to be put in place to account for the initial loss of capacity.

Providers are encouraged to simultaneously offer both Rapid EUFR and Slow EUFR, if they meet the eligibility criteria for both categories.

It is anticipated that each of these services could be delivered by a range of different types of technologies, including large inverter-based resources, virtual power plants, and loads. Separate specifications for each of these categories have been developed, tailored to the unique characteristics of each technology type. In all cases, the response provided must be **additional** to any mandatory frequency response delivered at present. Table 1 summarises the different specification categories, which are outlined in detail in the following sections of this document.

Any providers that have the ability to deliver services that do not fit within these categories, but that could assist with frequency arrest or recovery in rare, severe under-frequency events, should also respond to this EOI with details of the service offering, for discussion.

Table 1 Categories of EUFR response

Service	Providers	Eligibility	Example possible actions delivered	Section
Rapid EUFR	Large inverter connected generators (registered NEM market participants)	• Under-frequency response within 200-500ms, and • Response is additional to any present mandatory requirements	• Deliver PFR when dispatched at or below 0 MW; or • Deliver PFR when exempt from mandatory PFR; or • Utilise short term overload capability; or • Solar farms changing control schemes to enable PFR when pre-curtailed to 0MW • Provide additional frequency response in some way beyond present requirements	2
Rapid EUFR	Virtual Power Plants (non-registered aggregated distributed inverter connected resources, generally subject to AS/NZS4777.2:2020)	• Under-frequency response within 200-500ms, and • Response is additional to any present mandatory requirements, and • Located on feeders with dynamic UFLS arming implemented, and • Must meet AS/NZS4777.2:2020	• Provide a frequency response faster than required under AS/NZS4777.2:2020; or • Utilise short term overload capability or additional reserves not usually accessed; or • Provide a frequency response additional to any current requirements	3

Rapid/ Slow EUFR	Large loads (>3MW)
	
	Or
	
	Load aggregators
	
	Or
	
	Metering Coordinators
		• Direct connect customers (on a dedicated SAPN feeder) must have on-site generation.
		• Aggregated load sites (managed by load aggregators or metering coordinators) must be located on feeders with dynamic UFLS arming implemented.
		• Load reduction response must be additional to any present mandatory requirements
			• Provide rapid demand reduction (200-500ms)
			• Where sites have local generation:
			  ○ Implement arrangements to disconnect/reduce load whilst maintaining generation online (preferred); or
			  ○ Implement arrangements to only disconnect site when site is a net load; or
			• Metering coordinators or load aggregators:
			  ○ Disconnect/reduce load at sites whilst keeping any local generation at the
				4

			site connected (preferred), or ○ Selectively disconnect sites that are net loads.	
Slow EUFR	Fast-start generators	• Can synchronise and deliver capacity within 10min • Unit is not typically generating in most periods • Must have PFR enabled	• Fast Start Generators implementing control settings to automatically synchronise, ramp up, and deliver capacity to the market within 10 minutes in response to local under-frequency.	5
Slow EUFR	Frequency Recovery Mode - Any generating resources delivering proportional frequency control (frequency droop)	• Must be delivering proportional frequency control (frequency droop)	• Implement settings to automatically change setpoint in response to local frequency • Implement other changes to control settings to assist frequency stabilisation and recovery	6

2. Rapid EUFR: Large Inverter Connected Generators

If capable, tenderers in this category should additionally tender in the Inverter based resources frequency recovery mode category.

2.1 Quantity of response

This tender process is seeking up to 500 MW of rapid EUFR, from various sources. Quantities are subject to cost, performance of units and estimated benefit to power system frequency outcomes.

2.2 Eligibility

This category is intended for large inverter connected generators (typically NEM registered market participants) who can activate an under-frequency response within 200 – 500 ms. Resources that do not meet the timing requirements may be eligible to tender in the Slow EUFR category of this document.

EUFR must be additional to participants existing mandatory obligations. This includes Primary Frequency Response (PFR) as per AEMOs IPFRR[3] and any other response required by the National Electricity Rules, applicable standards, contracts and obligations. An example of a suitable additional response would be a generating unit that has not received a dispatch instruction to generate a volume greater than zero (and therefore has no PFR requirement) and provides a fast increase of generation in response to an under-frequency condition.

Required:

Provide details of eligibility including the proposed response mechanism and how it is additional to the tenderers existing obligations and contracts.

2.3 Availability

Tenderers must indicate their probabilistic expected percentage active power and energy availability over a one-year period (2022-23) as per Table 3. Each line represents an active power/ energy availability pair and the percentage expected availability is broken down into low, moderate, and high South Australian (SA) operational demand periods[4]. Table 2 demonstrates the proportion of periods expected to experience a UFLS shortfall in each Operational demand range.

Table 2 UFLS shortfall periods by operational demand range in South Australia

	When SA Operational Demand < 600 MW	When SA Operational Demand 600 - 1200 MW	When SA Operational Demand > 1200 MW
Percentage of periods where UFLS shortfall is expected	99%	73%	9%

[3] Interim Primary Frequency Response Requirements, https://aemo.com.au/-/media/files/initiatives/primary-frequency-response/2020/interim-pfrr.pdf?la=en

[4] Operational demand has a strong correlation with available UFLS load.

EUFR availability can be determined independently from FCAS and ElectraNet inertia support services. This means capacity reserved for FCAS and inertia support services can count towards a tenderer's EUFR availability, where it is additional to mandatory obligations.

Required:

Availability estimates for a full year (2022-23) in a format consistent with Table 3 and details of the proposed method by which EUFR availability can be determined in real time.

For clarity, the example in Table 3 can be interpreted as follows: This resource has **at least** 80 MW and 200 MWh of active power and energy available in 50% of periods when SA operational demand is less than 600 MW, 40% of periods when SA operational demand is between 600-1200 MW, and 30% of periods when SA operational demand exceeds 1,200 MW.

Table 3 Example Forecast EUFR availability per active power/ energy combination

Active Power Available (MW)	Energy Available (MWh)	Expected Availability (%)		
		When SA Operational Demand < 600 MW	When SA Operational Demand 600 - 1200 MW	When SA Operational Demand > 1200 MW
80	*200*	*50*	*40*	*30*
80	*100*	*70*	*60*	*40*
….	*….*	*….*	*….*	*….*
50	*100*	*95*	*90*	*80*

2.4 Enablement

Tenderers can either have their EUFR capability enabled:

a) At all times (preferred); or
b) On receipt of communication in periods where UFLS availability is low;

Tenderers do not need to reserve headroom during these periods. If enablement is prevented by hardware, system or communication faults, planned maintenance, or other circumstances preventing enablement, no penalties will be applied. However, it is expected that indicated availability percentages will be met in aggregate over the year. Availability payments will be scaled based on actual availability delivered during low UFLS periods.

Required:

Tenderers must indicate their proposed method of EUFR enablement and where applicable, any requirements of communication to indicate enablement. Details of any circumstances where the tenderer anticipates they will not have the ability to be enabled for EUFR should be provided.

2.5 Activation

Activation of EUFR from large inverter connected generators must be automatic based on local frequency measurement. Response can either be proportional and/or switched in nature.

- A proportional response is a dynamic response where the service is provided proportionally in relation to the size of frequency deviation continuously. The response should align with any PFR requirements such as deadbands and droop settings where applicable and a tenderers response can also be consistent with contingency FCAS settings. Response must be delivered at minimum starting from 49 Hz (or higher) and the full capability must be delivered before frequency drops below 48 Hz.
- Switched responses are where the full service is provided once frequency drops below a configurable threshold setting.

Tenderers are required to abide by any existing rules or generator connections obligations that apply to them, including droop and deadband restrictions.

Required:

Details of the proposed nature of response including, where applicable, droop settings, relevant frequency deadbands and frequency setting capability.

2.6 Speed of response

Tenderers need to be able to provide their full response within 200-500 ms of frequency falling below the nominated threshold.

Required:

Details of the activation speed capability of the respondent in response to under frequency including timing from detection to delivery of full EUFR capability.

2.7 Ceasing response

Units must make best endeavours to sustain their response until:

a) transitioned to frequency recovery mode if delivering the response type in section 6; or
b) been requested by SAPN or directed by AEMO

Upon ceasing response units should return to normal market participation making best endeavours to ramp gradually (e.g. linearly) over a period of at least five minutes to prevent a fast withdrawal of power.

Required:

Details of tenderer's proposed method to cease EUFR response including capability to respond to the above conditions and timing of response withdrawal.

2.8 Pricing and settlement

The proposed pricing structure includes three components:

a) **Availability Price:** a price paid per MWh of available response during periods of low UFLS availability throughout the year; and

b) **Activation compensation:** an amount paid to recover costs if the energy price does not cover the costs of operation when EUFR is activated ('make whole' payment). It should incorporate a minimum price required per MWh of response delivered where the compensation would cover the difference from the energy market price. An example method can be found in Appendix B.
c) **Commissioning Price:** a payment to recover the cost associated with setup and commissioning of the response.

Payments will be in addition to normal market settlements for the energy delivered.

Tenderers can propose a different pricing structure to that indicated.

As mentioned in Section 1.2, the intention is to initially procure services under a 12-month contract, and then review to determine suitable ongoing arrangements.

Required:

Proposed availability price, activation compensation and commissioning price as per the above structure or details and pricing where an alternative pricing structure is proposed.

2.9 Verification

2.9.1 Performance

Tenderers should provide details on how the proposed capabilities will be demonstrated during the tendering process to meet the requirements (e.g. testing results).

Required:

Tenderers must provide details on how they will demonstrate their proposed EUFR capabilities, including data and test results that will be provided during tender process to verify plant response.

2.9.2 Availability

Actual EUFR availability will be assessed quarterly for settlement payments. Availability data may also be used in real time to inform power system security assessments and various real-time interventions.

Tenderers must provide visibility of their available capacity for EUFR by either:

a) Specifying a method to indicate availability using existing systems; or
b) By other means if existing systems are not sufficient

It is preferred that availability data is provided in real-time, if possible.

Required:

Details on how tenderers will provide data on availability, and if this will be available in real time.

2.9.3 Post Event

Following a non-credible contingency event, participants must provide details on how they have responded. Methods can be in alignment with AEMO's Market Ancillary Services Specifications for Fast Raise Services[5] where applicable. Failure to deliver a contracted EUFR response consistent with indicated capability may affect the price paid.

Required:

Details on how respondents will demonstrate their response following a contingency event including any metering capabilities.

[5] Section 3.7 at https://aemo.com.au/-/media/files/stakeholder_consultation/consultations/nem-consultations/2020/primary-freq-resp-norm-op-conditions/market-ancillary-services-specification---v60.pdf?la=en&hash=4E46BE456C8D1DEAF12D0FF922DE4DBA

3. Rapid EUFR: Virtual Power Plants

This section covers emergency underfrequency response that can be provided by inverter based Virtual Power Plants (VPPs).

3.1 Quantity of response

This tender process is seeking up to 500 MW of rapid EUFR, from various sources. Quantities are subject to cost, performance of units and estimated benefit to power system frequency outcomes.

3.2 Eligibility

VPPs include **non-registered** NEM market participants, with inverter connected assets generally subject to AS/NZS 4777.2:2020. These can be single or multiple sites that contain generation or storage actively providing EUFR.

A minimum VPP aggregate size of 3MW is proposed for tenderers. There is no minimum size of individual VPP resources. VPPs consisting solely of loads, or those with passive generation not equipped to provide EUFR, should refer to Section 0.

VPPs for EUFR are only eligible in sites supplied by distribution network feeders equipped with 'dynamic arming,' where UFLS relays are dynamically disarmed when feeders are operating in reverse flow. Approximately 30% of distribution feeders and 50% of loads are included in the dynamic arming UFLS scheme. **Tenderers must submit a list of NMIs for proposed sites to SAPN, for a pre-feasibility check** to confirm which sites are on network feeders equipped with dynamic arming, and therefore eligible to deliver EUFR[6].

All distributed inverter-based resources delivering EUFR must be compliant with AS/NZS4777.2:2020. Evidence of correct installation to this standard must be provided.

Participation in the provision of EUFR services must be **additional to existing mandatory obligations, including the under-frequency response specified in AS/NZS 4777.2:2020**. This standard requires that inverters decrease charging to zero when frequency reaches 49Hz, and increase power output to maximum when frequency reaches 48Hz, with response commencing within 1 second, and completed within 10 seconds. EUFR offered must be additional to these obligations. For example, this could include demonstration of additional capacity reserves not typically utilised (understanding that EUFR events are very rare, occurring less than once per year), or demonstration of faster response times than required in the standard.

Required:

Tenderers must submit a NMI list of proposed sites to SA Power Networks via email to networkservices@sapowernetworks.com.au for the pre-feasibility check. Please allow up to 2 business days for a response from SAPN.

[6] If the VPP is partially located on eligible feeders, availability payments will be made for the eligible proportion.

If deemed eligible, tenderers must:

- specify proposed response mechanism, detailing how the response is additional to existing mandatory obligations and contracts, including requirements in AS/NZS 4777.2:2020; and
- confirmation that all distributed resources involved are commissioned correctly to AS/NZS 4777.2:2020 (providing quantitative evidence of correct installation)

3.3 Availability

Tenderers must indicate their probabilistic expected percentage active power and energy availability over a one-year period (2022-23) as per Table 5. Each line represents an active power/ energy availability pair and the percentage expected availability is broken down into low, moderate, and high South Australian (SA) operational demand periods[7]. Table 4 demonstrates the proportion of periods expected to experience a UFLS shortfall in each Operational demand range.

Table 4 UFLS shortfall periods by operational demand range in South Australia

	When SA Operational Demand < 600 MW	When SA Operational Demand 600 - 1200 MW	When SA Operational Demand > 1200 MW
Percentage of periods where UFLS shortfall is expected	99%	73%	9%

EUFR availability can be determined independently from FCAS. This means capacity reserved for FCAS can also count towards a tenderer's EUFR availability, where it is additional to mandatory obligations.

Required:

Availability estimates for a full year (2022-23) in a format consistent with Table 5 and details of the proposed method by which EUFR availability can be determined in real time.

For clarity, the example in Table 5 can be interpreted as follows: This resource has **at least** 80 MW and 200 MWh of active power and energy available in 50% of periods when SA operational demand is less than 600 MW, 40% of periods when SA operational demand is between 600-1200 MW, and 30% of periods when SA operational demand exceeds 1,200 MW.

Table 5 Example Forecast EUFR availability per active power/ energy combination

Active Power Available (MW)	Energy Available (MWh)	Expected Availability (%)		
		When SA Operational Demand < 600 MW	When SA Operational Demand 600 - 1200 MW	When SA Operational Demand > 1200 MW
80	*200*	*50*	*40*	*30*
80	*100*	*70*	*60*	*40*
….	*….*	*….*	*….*	*….*
….	*….*	*….*	*….*	*….*
50	*100*	*95*	*90*	*80*

[7] Operational demand has a strong correlation with available UFLS load.

3.4 Enablement

Tenderers are required to have their EUFR capability enabled at all times unless this is prevented by:

- hardware, system or communication faults;
- planned maintenance;
- other circumstances preventing enablement.

Tenderers do not need to reserve headroom during these periods. However, it is expected that indicated availability percentages will be met in aggregate over the year. Availability payments will be scaled based on actual availability delivered during low UFLS periods.

Required:

Details of any circumstances where the tenderer anticipates they will not have the ability to be enabled for EUFR.

3.5 Activation

Activation of EUFR must be automatic based on local frequency measurement. Response can either be proportional and/or switched in nature.

- A proportional response is a dynamic response where the service is provided proportionally in relation to the size of frequency deviation continuously. The response should align with any existing requirements such as deadbands and droop settings where applicable and a tenderers response can also be consistent with contingency FCAS settings. Response must be delivered at minimum starting from 49 Hz (or higher) and the full capability must be delivered before frequency drops below 48 Hz.
- Switched responses are where the full service is provided once frequency drops below a configurable threshold setting.

Tenderers are required to abide by any existing rules or generator connections obligations that apply to them, including droop and deadband restrictions.

Required:

Details of the proposed nature of response including, where applicable, droop settings, relevant frequency deadbands and frequency setting capability.

3.6 Speed of response

Tenderers need to be able to provide their full response within 200-500 ms of frequency falling below the nominated threshold.

Required:

Tenderers must provide details of their activation speed capability in response to under frequency including timing from detection to delivery of full EUFR capability

3.7 Ceasing response

Units must make best endeavours to sustain their response until:

a) transitioned to frequency recovery mode if delivering the response type in section 6; or
b) been requested by SAPN or directed by AEMO

Upon ceasing response units should return to normal market participation making best endeavours to ramp gradually (e.g. linearly) over a period of at least five minutes to prevent a fast withdrawal of power.

Tenderers must have the capability to achieve **both** of the following:

- Return to normal operation within 15 minutes of receiving the instruction from SAPN; and
- Automatically return to normal operation within 90 minutes of the initial event in the absence of power and/or communications at the relevant site(s).

Required:

Tenderers must provide details of proposed method to cease EUFR, and demonstrate capability to meet the conditions outlined above as well as timing of return to normal market operation.

3.8 Pricing and settlement

The pricing structure will include three components:

a) **Availability price**: a price paid per MWh of available response during periods of low UFLS availability throughout the year; and
b) **Activation compensation:** an amount paid to recover costs if the energy price does not cover the costs of operation when EUFR is activated ('make whole' payment). It should incorporate a minimum price required per MWh of response delivered where the compensation would cover the difference from the energy market price. An example method can be found in Appendix B.
c) **Commissioning Price:** a payment to recover the cost associated with setup and commissioning of the response.

Tenderers can propose a different pricing structure to that indicated.

As mentioned in Section 1.2, the intention is to initially procure services under a 12-month contract, and then review to determine suitable ongoing arrangements.

Required:

Proposed availability price, activation compensation and commissioning price as per the above structure or details and pricing where an alternative pricing structure is proposed.

3.9 Verification

3.9.1 Performance

Tenderers should provide details on how the proposed capabilities will be demonstrated during the tendering process to meet the requirements (e.g. testing results). Type testing may be considered an appropriate means of performance verification where appropriate.

Required:

Tenderers must provide details on how they will demonstrate their proposed EUFR capabilities, including data and test results that will be provided during tender process to verify plant response.

3.9.2 Availability

Actual EUFR availability will be assessed quarterly for settlement payments. Availability data may also be used in real time to inform power system security assessments and various real-time interventions.

Tenderers must provide visibility of their available capacity for EUFR by either:

a) Specifying a method to indicate availability using existing systems; or
b) By other means if existing systems are not sufficient

It is preferred that availability data is provided in real-time, if possible or a suitable estimate of likely available capacity is provided for use in real time decision making.

It is the intention that the method make best use of existing metering capability and estimation methods to keep costs as low as possible.

Required:

Details on how tenderers will provide data on availability, and if this will be available in real time.

3.9.3 Post Event

Following a non-credible contingency event, tenderers must provide details on how they have responded. Methods can be in alignment with AEMO's Market Ancillary Services Specifications for Fast Raise Services[8] where applicable, however, the requirements for EUFR are less onerous. Tenderers

[8] Section 3.7 at https://aemo.com.au/-/media/files/stakeholder_consultation/consultations/nem-consultations/2020/primary-freq-resp-norm-op-conditions/market-ancillary-services-specification---v60.pdf?la=en&hash=4E46BE456C8D1DEAF12D0FF922DE4DBA

should aim to use the lowest cost method to indicate timing and quantity of response. Where appropriate, approximation methods based on existing metering may be acceptable.

For example, a tenderer may propose to use bench testing or type testing to prove performance in combination with approximation of response by metering a subset of units or using a lower sampling rate for measurements.

Failure to deliver a contracted EUFR response consistent with indicated capability may affect the price paid.

Required:

Details on how respondents will demonstrate their response following a contingency event including the data that will be provided for verification, and any metering capabilities.

4. Rapid/ Slow EUFR: Loads

This section covers emergency underfrequency response via load reduction.

4.1 Quantity of response

This tender process is seeking up to 500 MW of rapid EUFR from various sources. It is anticipated that less quantity of slow EUFR in this category will be required. Quantities are subject to cost, performance of units and estimated benefit to power system frequency outcomes.

4.2 Eligibility

Load reduction can be provided by customers and/or market participants, with either dedicated or shared connections to the distribution or transmission network, who can offer automated reduction of load based on a local frequency measurement, in rare disturbances (occurring less than once per year).

The response must result in a net reduction of load. For sites with both load and generation, it is preferred that customer load is disconnected while leaving any generating unit operating and connected to the power system. Where this is not possible, the site must be dynamically armed whereby the disconnection only occurs if the site is in a net load condition.

Load disconnection for EUFR is only eligible under one of two conditions:

1. **Sites supplied by distribution network feeders equipped with 'dynamic arming,' where UFLS relays are dynamically disarmed when feeders are operating in reverse flow; or**
2. **Customers with a dedicated supply and behind the meter generation able to independently trip loads, leaving generation connected.**

Approximately 30% of distribution feeders and 50% of loads are included in the dynamic arming UFLS scheme. For loads that don't meet condition 2, **Tenderers must submit a list of NMIs for proposed sites to SAPN, for a pre-feasibility check** to confirm which sites are on network feeders equipped with dynamic arming, and therefore eligible to deliver EUFR[9]. SAPN will then determine whether the proposed sites

[9] If the VPP is partially located on eligible feeders, availability payments will be made for the eligible proportion.

are on feeders equipped with dynamic arming and assess eligibility. Tenderers will be advised of this outcome, with only eligible sites able to proceed.

Eligibility of generation sites with a zero export agreement will be assessed on a case by case basis.

Participation in the provision of EUFR services must be additional to existing mandatory obligations and existing contributions to the UFLS. Tenderers who are market customers and required under the NER[10] to have UFLS capability are not eligible to participate unless they can provide response in addition to existing obligations and contributions. Solutions will need to operate in conjunction with, complement and augment the response of the existing UFLS scheme.

A minimum load response aggregate size of 3MW is proposed for tenderers. An aggregation service or agent can be used to summate loads of multiple customers at geographically dispersed locations. This minimum block size is negotiable.

Required:

Tenderers must submit a NMI list of proposed sites to SA Power Networks via email to networkservices@sapowernetworks.com.au for the pre-feasibility check. Please allow up to 2 business days for a response from SAPN.

If deemed eligible, tenderers must specify proposed response mechanism, detailing how the response is additional to existing mandatory obligations and contracts.

4.3 Availability

Tenderers must indicate their probabilistic expected percentage load reduction availability over a one-year period (2022-23) as per Table 7. The percentage expected availability is broken down into low, moderate, and high South Australian (SA) operational demand periods[11]. Table 6 demonstrates the proportion of periods expected to experience a UFLS shortfall in each Operational demand range.

Table 6 UFLS shortfall periods by operational demand range in South Australia

	When SA Operational Demand < 600 MW	When SA Operational Demand 600 - 1200 MW	When SA Operational Demand > 1200 MW
Percentage of periods where UFLS shortfall is expected	99%	73%	9%

EUFR availability can be determined independently from FCAS. This means capacity reserved for FCAS can also count towards a tenderer's EUFR availability, where it is additional to mandatory obligations.

[10] Section 4.3.5 at https://www.aemc.gov.au/sites/default/files/content//NER-v105-Chapter-04.PDF
[11] Operational demand has a strong correlation with available UFLS load.

Required:

Availability estimates for a full year (2022-23) in a format consistent with Table 7 and the proposed method by which EUFR availability can be determined in real time.

For clarity, the example in Table 7 can be interpreted as follows: This resource has **at least** 80 MW of active power available in 50% of periods when SA operational demand is less than 600 MW, 40% of periods when SA operational demand is between 600-1200 MW, and 30% of periods when SA operational demand exceeds 1,200 MW.

Table 7 Example Forecast EUFR availability per active power

Load reduction Available (MW)	Expected Availability (%)		
	When SA Operational Demand < 600 MW	When SA Operational Demand 600 - 1200 MW	When SA Operational Demand > 1200 MW
80	*50*	*40*	*30*
….	….	….	….
….	….	….	….
50	*95*	*90*	*80*

4.4 Enablement

Tenderers are required to have their EUFR capability enabled at all times unless this is prevented by:

- hardware, system or communication faults;
- planned maintenance;
- other circumstances preventing enablement.

Required:

Details of any circumstances where the tenderer anticipates they will not have the ability to be enabled for EUFR.

4.5 Activation

Activation of EUFR from loads must be automatic based on local frequency measurement. Response **must be switched** where the full service is provided once frequency drops below a configurable threshold setting between 49Hz and 48Hz.

Required:

Tenderers must demonstrate that they can deliver a switched response as outlined above and detail, where applicable relevant frequency setting capability.

4.6 Speed of response

Tenderers must be able to meet the timing requirements for Rapid (preferred[12]) or Slow EUFR:

- Rapid: must be able to disconnect loads within 200-500ms of detection of frequency event and remain disconnected until advised by SAPN.
- Slow: must be able to disconnect loads within 10 minutes (less preferred) of detection of frequency event and remain disconnected until advised by SAPN

The duration of disconnection will be dependent on the contingency event that has occurred and the system conditions following the contingency. It is expected that this process could take up to 60 minutes.

Required:

Tenderers must provide details of their activation speed capability in response to under frequency including timing from detection to delivery of full EUFR capability. Faster response is preferred

4.7 Ceasing response

The tenderer shall ensure a sustained EUFR response (i.e. loads remain disconnected) until:

a) It is instructed by SAPN following confirmation that system has returned to a stable operating condition and loads can be reconnected, or
b) Automatically reconnect[13] disconnected customer load 90 minutes after the initial event, in the absence of power and/or communications at the relevant site(s).

Tenderers must have the capability to achieve **both** of the following:

- Effectively reconnect disconnected customer load remotely within 15 minutes of receiving the instruction from SAPN; and
- Automatically reconnect disconnected customer load within 90 minutes of the initial event in the absence of power and/or communications at the relevant site(s).

Required:

Tenderers must demonstrate capability to meet the conditions outlined above.

4.8 Pricing and settlement

The pricing structure will include three components:

a) **Availability price**: a price paid per MWh of available response[14] during periods of low UFLS availability throughout the year; and
b) **Activation price:** a price on activation per MWh of EUFR delivered for cost recovery; and
c) **Commissioning Price:** a payment to recover the cost associated with setup and commissioning of the response.

[12] The timing requirements for Rapid EUFR are sufficient to help arrest frequency decline immediately following a large contingency and are therefore preferred over slow EUFR
[13] Reconnection is synonymous with a resumption of normal operations e.g. flexible loads responding to the market
[14] Quantity of net load reduction available

Tenderers can propose a different pricing structure to that indicated.

As mentioned in Section 1.2, the intention is to initially procure services under a 12-month contract, and then review to determine suitable ongoing arrangements. Where the majority of the costs are capital costs to setup, contracts exceeding 12-months may be considered.

Required:

Tenderers must provide an availability price, activation price and commissioning price as per the above structure, or details and pricing where an alternative structure is proposed.

4.9 Verification

4.9.1 Performance

Tenderers must provide details on how the proposed capabilities will be demonstrated to meet the requirements of this Expression of Interest. SA Power Networks may request testing to be undertaken and witnessed if insufficient evidence is provided to demonstrate the capabilities. Type testing may be considered an appropriate means of performance verification where appropriate.

Required:

Tenderers must provide details on how they will demonstrate their proposed EUFR capabilities.

4.9.2 Availability

Actual EUFR availability will be assessed quarterly for settlement payments. Availability data may also be used in real time to inform power system security assessments and various real-time interventions.

Tenderers must provide visibility of their available capacity for EUFR by either:

a) Specifying a method to indicate availability using existing systems; or
b) By other means if existing systems are not sufficient

It is preferred that availability data is provided in real-time, if possible, or a suitable estimate of likely available capacity is provided for use in real time decision making.

It is the intention that the method make best use of existing metering capability and estimation methods to keep costs as low as possible.

Required:

Details on how tenderers will provide data on availability, and if this will be available in real time.

4.9.3 Post Event

Following a contingency event, tenderers must provide details on how they have responded. Methods can be in alignment with AEMO's Market Ancillary Services Specifications for Fast Raise Services[15] where applicable, however, the requirements for EUFR are less onerous. Tenderers should aim to use the lowest cost method to indicate timing and quantity of response. Where appropriate, approximation methods based on existing metering may be acceptable.

For example, a tenderer may propose to use bench testing or type testing to prove performance in combination with approximation of response by metering a subset of units or using a lower sampling rate for measurements.

Failure to deliver a contracted EUFR response in line with indicated capability may affect the price paid.

Required:

Details on how respondents will demonstrate their response following a contingency event including the data that will be provided for verification, and any metering capabilities.

[15] Section 3.7 at https://aemo.com.au/-/media/files/stakeholder_consultation/consultations/nem-consultations/2020/primary-freq-resp-norm-op-conditions/market-ancillary-services-specification---v60.pdf?la=en&hash=4E46BE456C8D1DEAF12D0FF922DE4DBA

5. Slow EUFR: Fast Start Generators

5.1 Quantity of response

This tender process is seeking between 100 MW and 200 MW of total response[16] from fast start generators that can synchronise and deliver an increase in active power delivery in the 10 min following a separation event. Quantities are subject to cost, performance of units and estimated benefit to power system frequency outcomes.

5.2 Eligibility

Tenderers capable of providing slow EUFR in this category include NEM market participants with fast start units capable of synchronising and reaching their minimum stable loading within 10 minutes and are not typically generating in most periods.

Units must have PFR implemented as per AEMOs IPFRR[17] (this is important to minimise risks of excessive service delivery leading to over-frequency).

EUFR procured in this category complements the response of rapid EUFR providers that cannot sustain their response for sufficient timeframes and also assists with frequency recovery.

Provision of EUFR must not impact a unit's capability at meeting their current obligations or contracted services including System Restart Ancillary Services (SRAS).

Required:

Details on how the tenderer meets the eligibility, including time to synchronise and reach minimum stable loading, ramping profiles up to maximum stable loading, and details of PFR/ proportional frequency control settings implemented.

5.3 Availability

Tenderers must indicate their expected percentage availability over a one-year period (2022-23). This should indicate the amount of capacity that is not dispatched in the market, and is available to start and ramp up within 10 minutes based on automatic detection of the trigger signal.

Tenderers can indicate a probabilistic availability in tranches. Example: at least 20 MW for 90% of year; at least 30 MW for 70% of year; and at least 50 MW for 10% of year.

EUFR availability can be determined independently from FCAS and ElectraNet inertia support services. This means capacity reserved for FCAS and inertia support services can count towards a tenderer's availability.

[16] Response is limited due to management of over frequency risk following frequency recovery.
[17] Interim Primary Frequency Response Requirements, https://aemo.com.au/-/media/files/initiatives/primary-frequency-response/2020/interim-pfrr.pdf?la=en

Required:

Availability estimates for a full year (2022-23) in a format consistent with Table 8, and the proposed method by which EUFR availability can be assessed in real time.

Table 8 Example Forecast EUFR availability

Active Power Available (MW)	Expected Periods Available (%)
20	*90%*
30	*70%*
50	*10%*
….	….

5.4 Enablement

Tenderers are required to have this capability enabled at all times for the full capacity available at the time, unless this is prevented by:

- hardware, system or communication faults;
- planned maintenance;
- other circumstances preventing enablement.

There is no requirement to reserve headroom, although it is expected that aggregate annual availability will be consistent with estimates provided during the tender process.

Required:

Details of any circumstances where the tenderer anticipates they will not have the ability to be enabled for EUFR.

5.5 Activation

Activation of Slow EUFR must be automatic based on local frequency measurement and preferably in conjunction with a signal indicating SA is islanded. The proposed activation will comprise of three conditions, with the slow EUFR response triggered when all of conditions 1, 2 and 3:

1. Condition 1: an initial trigger when frequency falls below 49.5 Hz; and
2. Condition 2: a second trigger if frequency is still below 49.5 Hz at an intentional time delay following the initial trigger[18] as demonstrated in Figure 2; and
3. Condition 3: receipt of a SCADA logic signal indicating that South Australia is islanded[19]

To prevent an over frequency condition caused by excessive generation coming online at once, the intentional delay will be staggered for different units, likely in the range from 10 – 180s. An additional time delay may also be included to assist with coordination where required. The time settings will be determined based on unit specific capability and coordination with other procured EUFR services.

[18] The trigger settings reflect the delayed UFLS functionality they aim to replicate. It assists in relief of energy limited response and longer-term recovery of frequency important to prevent additional loss of generation.
[19] Signal could take 30 s plus to update following the islanding event, may consist of two individual signals indicating different separation locations in which case the condition would be the receipt of A or B signal.

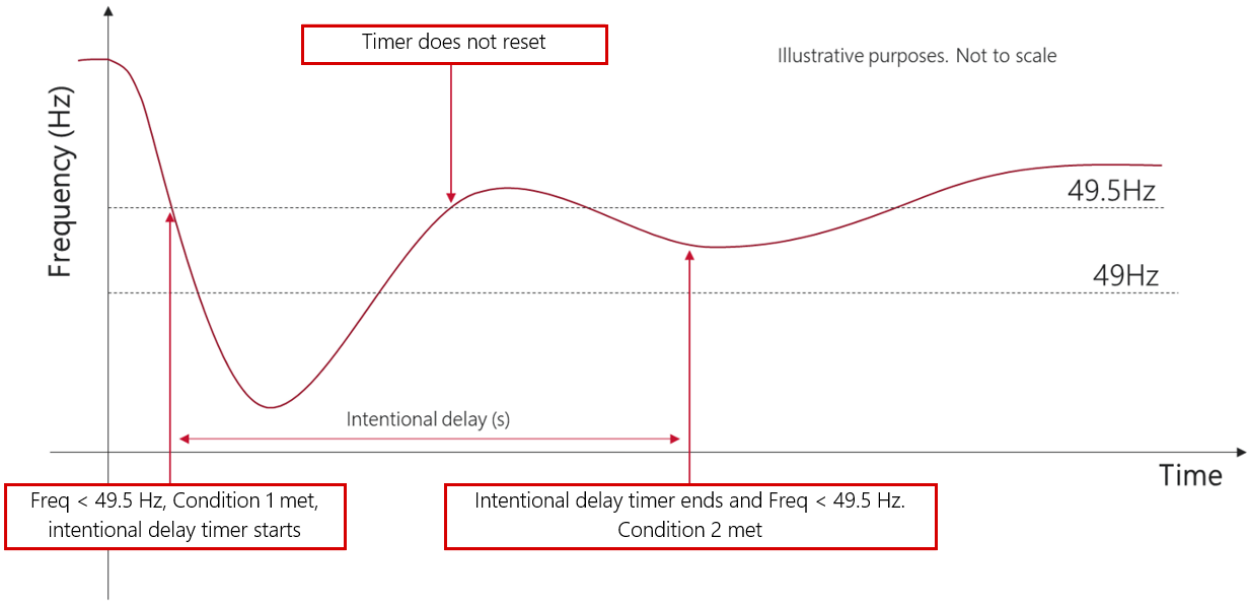


Figure 2 Diagram of proposed local frequency activation method for fast start units

Tenderers may propose an alternate activation method.

Upon activation, units must switch to local control and where required, synchronise and ramp to at least their minimum stable operating loading. Units must continue to ramp up unless local frequency falls within the units PFR deadband or the unit reaches its maximum loading, at which point the unit must hold its output and provide primary frequency response.

To ensure the unit is dispatched in successive dispatch intervals, the participant must re-bid available capacity in order to be dispatched until the EUFR service transitions to normal market operations. Preferably this function would be automatic when the unit is activated for EUFR. Where appropriate, Fast start inflexibility profile bids should be updated to reflect the units' capabilities.

Local constraints can affect the output capacity of some units and will be assessed for individual units.

Required:

- Indication that tenderers can meet the preferred activation method with details of setting capability or details of proposed alternate activation method.
- Details of how the control mechanism will be implemented
- Details of how unit bidding will be managed
- Details of any local constraints that may apply to the unit or may restrict ability to deliver this service

5.6 Speed and duration of response

Tenderers must be able to synchronise and deliver capacity to the market within 10 minutes and sustain their response until the conditions are met for response transition in section 5.7. It is expected that a response could be required for several dispatch intervals and normal market dispatch may keep units online following this.

Required:

Time to synchronise after activation (s), minimum stable loading (MW), time to reach minimum loading (s), ramp rate (MW/min) and any required plant conditions or limitations that may apply under any circumstances.

5.7 Ceasing Response

Units must make best endeavours to sustain their response until they have been requested by SAPN or directed by AEMO. Upon ceasing response units should return to normal market participation making best endeavours to ramp gradually (e.g. linearly) over a period of at least five minutes to prevent a fast withdrawal of power.

Required:

Details of tenderers capability to respond when the above condition is met and their ramping capabilities when withdrawing.

5.8 Pricing and settlement

The proposed pricing structure includes four components:

a) **Availability Price:** a price paid per MWh of available response throughout the year in periods where the Heywood interconnector is importing into South Australia (such that an under-frequency condition could arise upon non-credible separation)[20]; and
b) **Activation compensation**: a "make whole" payment, to recover cost when the energy price does not cover the cost of energy delivered while providing EUFR. It should incorporate a minimum price required per MWh of response delivered where the compensation would cover the difference from the energy market price. An example method can be found in Appendix B; and
c) **Start-up Price:** a fixed price paid per instance of EUFR response delivered where the unit is required to come online
d) **Commissioning Price:** a payment to recover the cost associated with setup and commissioning of the response.

Payments will be in addition to normal market settlements for the energy delivered.

Units providing EUFR as per their agreed method and settings will have no adverse outcomes from non-conformance to dispatch instructions. SAPN will work with AEMO and the AER to ensure a contracted

[20] Analysis by AEMO indicates that the EUFR service from fast start generators is only required during these periods. In 2021 this condition was true ~53% of the year.

response for EUFR does not result in penalty. Additionally, there will be no adverse effect on a unit's causer pays factors for the period where they are providing EUFR.

Tenderers can propose a different pricing structure to that indicated.

As mentioned in Section 1.2, the intention is to initially procure services under a 12-month contract, and then review to determine suitable ongoing arrangements.

Required:

Proposed pricing for each component of the above pricing structure, or in an alternative pricing structure if proposed

5.9 Verification

5.9.1 Performance

Participants should provide details on how the proposed capabilities will be demonstrated to meet the requirements, as part of this tender process (e.g. Test results, witnessed testing, etc).

Required:

Details on how respondents will demonstrate their proposed capabilities.

5.9.2 Availability

Tenderers must provide visibility of their available capacity in real time by either specifying a method to indicate availability:

a) using existing systems; or
b) By other means if existing systems are not sufficient

Actual EUFR availability of providers will be assessed quarterly to inform settlement payments.

Required:

Details on how respondents will provide visibility of available capacity in real time, and for assessment of availability payments.

5.9.3 Post Event

Following a contingency event, participants are to provide details on how they have responded following activation and withdrawal. Method can be in alignment with AEMO's Market Ancillary Services Specifications for Fast Raise Services[21] where applicable. Failure to deliver a contracted EUFR response in line with indicated capability may affect the price paid.

[21] Section 3.7 at https://aemo.com.au/-/media/files/stakeholder_consultation/consultations/nem-consultations/2020/primary-freq-resp-norm-op-conditions/market-ancillary-services-specification---v60.pdf?la=en&hash=4E46BE456C8D1DEAF12D0FF922DE4DBA

Required:
Details on how respondents will demonstrate their response following a contingency event including the data that will be provided, and any metering capabilities.

6. Slow EUFR: Frequency Recovery Mode

6.1 Context

AEMO modelling indicates that following a large non-credible contingency event, large quantities of fast acting proportional response is effective in arresting and stabilising frequency, but may inhibit frequency recovery[22]. As frequency recovers, fast proportional providers immediately withdraw response, which can inhibit the frequency recovery process. This means that EUFR delivered by proportional providers delivers different outcomes compared with traditional UFLS, and an additional service is required to assist frequency recovery.

This final EUFR category, termed "Frequency Recovery Mode" (FRM), is designed to provide incentives for proportional providers to assist frequency recovery, rather than inhibiting it. This could be delivered via an automatically triggered change in generation set point in response to a sustained underfrequency condition.

6.2 Quantity of Response

Participation in this category is encouraged from all providers that currently deliver a proportional frequency response (all large inverter connected resources and possibly including some VPPs and synchronous plant). This can include participants tendering to deliver Rapid EUFR, as well as proportional providers who are not delivering Rapid EUFR.

Quantities are subject to cost, performance of units and estimated benefit to power system frequency outcomes.

[22] Sustained periods outside of the NOFB increases risk of further generator disconnection.

6.3 Eligibility

This category applies to resources (typically inverter connected) that are providing a proportional under frequency response (possibly through PFR requirements, contingency FCAS or EUFR response in the large inverter connected generators or Virtual Power Plants categories).

Required:

Details on how the tenderer meets the eligibility including the speed, settings and capability of existing proportional response and capacity of plant.

6.4 Enablement

Tenderers are required to have their EUFR capability for frequency recovery mode enabled at all times unless this is prevented by hardware, system or communication faults, planned maintenance, or other circumstances preventing enablement.

Required:

Details of any circumstances where the tenderer anticipates they will not have the ability to be enabled for EUFR.

6.5 Activation

Activation of slow EUFR must be automatic based on local frequency measurement. Tenderers need to be capable of recognising a sustained local under frequency.

An example method of activation is to trigger based on the following conditions (1 and 2):

1. Condition 1: An initial trigger when frequency falls below 49.5 Hz; and
2. Condition 2: A second trigger if frequency is still below 49.5 Hz at an intentional time delay (e.g. 30 seconds) following the initial trigger[23] as demonstrated in Figure 1.

Slow EUFR is triggered when both conditions 1 and 2 are met[24].

[23] The trigger settings reflect the delayed UFLS functionality they aim to replicate. It assists in longer-term recovery of frequency important to prevent additional loss of generation.

[24] This trigger mechanism does not require an SA island condition as the frequency responsive nature manages the risk of over-frequency regardless of interconnection.

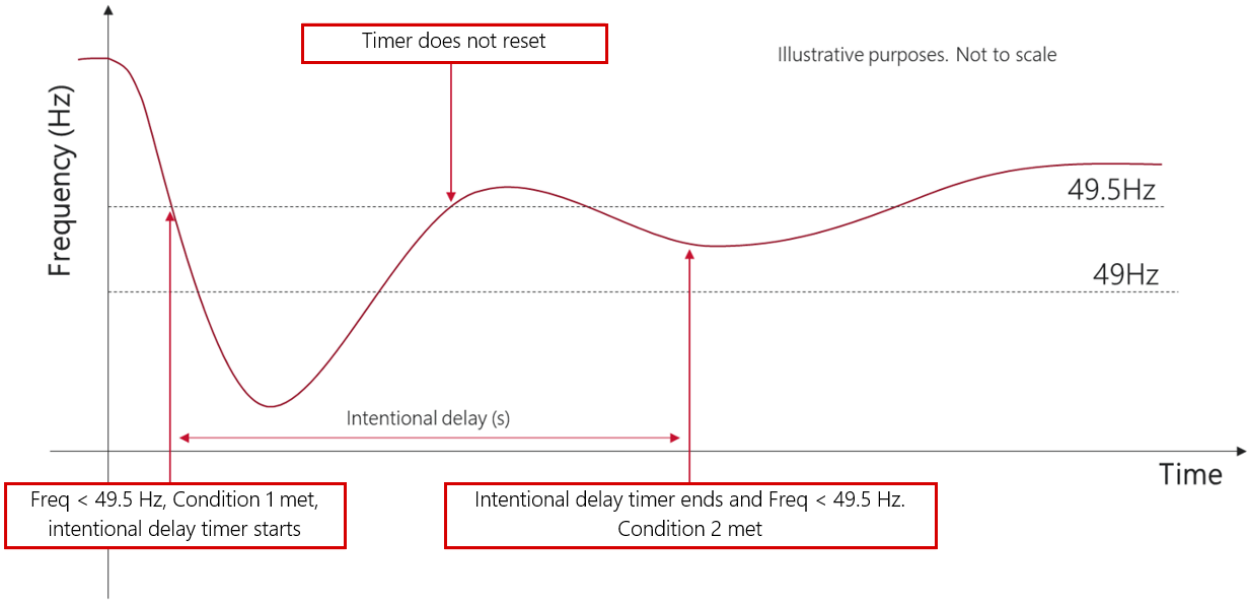


Figure 1: Diagram of local frequency activation requirement for Slow EUFR

Required:

Tenderers must detail their proposed method of activation including any relevant time setting capability.

6.6 Desired response

A possible desired response once triggered is as follows:

- Unit changes their active power setpoint, beginning to ramp active power setpoint towards available headroom
- Whilst ramping, the unit maintains proportional response to frequency (unit output is the summation of the active power setpoint plus proportional response).
- When local frequency ≥ 49.85 Hz, the unit holds its active power setpoint and provides primary frequency response where capable.

Providers must make best endeavours to set a ramp rate that allows ramping to full response over a period of 5-minutes. Ramping too quickly could exacerbate frequency recovery problems.

This response should be delivered for both under-frequency and over-frequency conditions (with the response mirrored for over-frequency).

Severe under-frequency events where this service might be required are anticipated to occur very rarely (less than once per year). In the rare scenarios where the service is activated, it is anticipated that only a small amount of energy injection is required in most cases to drive a sufficient frequency recovery[25].

Tenderers may propose an alternative response to assist frequency recovery.

[25] AEMO modelling indicates that for in 99% of SA island cases where frequency recovery is required to inject more energy into the system, less than 1 MWh of additional energy injection is required to recover frequency.

Required:

Provide details of the proposed response functionality following activation including the method, timing, capability, and any relevant settings or limitations.

6.7 Ceasing response

Units must make best endeavours to sustain their response until they have been requested by SAPN or directed by AEMO. Upon ceasing response units should return to normal market participation making best endeavours to ramp gradually (e.g. linearly) over a period of at least five minutes to prevent a fast withdrawal of power.

Required:

Details of tenderers capability to respond when the above condition is met and their ramping capabilities when withdrawing.

6.8 Pricing and settlement

The proposed pricing structure includes two components:

d) **Commissioning Price:** a payment to recover the cost associated with commissioning of the changes required; and
e) **Activation compensation:** an amount paid to recover costs if the energy price does not cover the costs of operation when FRM is activated ('make whole' payment).It should incorporate a minimum price required per MWh of response delivered where the compensation would cover the difference from the energy market price. An example method can be found in Appendix B.

Payments will be in addition to normal market settlements for the energy delivered.

Tenderers can propose a different pricing structure to that indicated.

As mentioned in Section 1.2, the intention is to initially procure services under a 12-month contract, and then review to determine suitable ongoing arrangements.

Required:

Proposed pricing for each component in the above pricing structure, or in an alternative pricing structure if proposed.

6.9 Verification

6.9.1 Performance

Tenderers should provide details on how the proposed capabilities will be demonstrated to meet the requirements of this Expression of Interest. SA Power Networks may request testing to be undertaken and witnessed if insufficient evidence is provided to demonstrate the capabilities.

Required:

Details on how tenderers will demonstrate their proposed capabilities.

6.9.2 Post Event

Following a contingency event, participants are to provide details on how they have responded following activation and withdrawal.

Required:

Details on how tenderers will demonstrate their response following a contingency event including any metering capabilities.

A. Appendix A: AEMO advice to SAPN

This Appendix provides further detail on AEMO advice to SAPN on the amount of emergency under-frequency response required, and the time periods when shortfalls tend to occur.

How much emergency under-frequency response is required?

Estimating the amount of emergency under-frequency response required to adequately reduce the risks presented by significant non-credible contingency events is complex; a power system operating almost entirely on distributed resources at times behaves very differently, and entirely new models are required to conduct this assessment thoroughly. The South Australian UFLS scheme is already critically deteriorated, so urgent remediation action is required.

To allow SAPN to commence implementation of remediation measures, AEMO has adopted a two-stage process. Initially, AEMO has estimated emergency under-frequency response shortfalls against levels where there is confidence in the performance of UFLS, and to match historical UFLS availability. In parallel, AEMO is in the process of developing alternative approaches for estimating the amount of emergency under frequency response required in the NEM and each state to produce acceptable frequency outcomes for plausible non-credible contingency events. The required amount of response indicated through this analysis could be less than determined by the preliminary estimate.

Preliminary estimate

The National Electricity Rules (NER) indicate that appropriate reserves should be available to arrest the impacts of a range of significant multiple contingency events affecting up to 60% of the total power system load (NER clause 4.3.1(k)). AEMO has used total underlying load[26] (calculated as operational demand + DPV generation) as a measure of the actual amount of customer load in the power system at a particular time, regardless of whether it is supplied by scheduled generating units or distributed generation.

The net load in the UFLS (being the amount of load available to provide an effective UFLS response to arrest a frequency decline) can then be calculated as a percentage of total underlying customer load, for comparison with the 60% value indicated in the NER.

Estimates based on this 60% measure suggest that UFLS load in South Australia should be in the range of 800 MW to 1,200 MW.

This estimate can be complemented with other measures of the amount of emergency under-frequency response required. For example, in South Australia, multiple contingency events up to 1,000 MW have occurred, suggesting a UFLS requirement in this range. Similarly, there are constraints on the Heywood Interconnector that bind when UFLS load is too low to effectively manage a non-credible separation; to prevent binding of this constraint, approximately 1,000 MW of UFLS load is required. These constraints tend to bind during periods of high DPV generation and moderate demand.

These various metrics are summarised in Table 9, and all suggest that seeking to maintain approximately 1,000 MW of response is an appropriate initial target. Further analysis is underway to develop a more nuanced estimate of the amount of emergency under-frequency response required, especially focused on

[26] In a power system with large quantities of DPV, the operational demand (defined as total underlying customer load, net of DPV) in some periods will differ very significantly from the total underlying demand. In some periods, operational demand will soon reach zero and become negative in some NEM regions. While operational demand may reach zero, the largest plausible non-credible contingency in a region will not be zero, meaning that determining UFLS requirements as a proportion of a metric that is zero or negative cannot provide a meaningful measure of power system needs.

periods with high generation from distributed resources (where the nature of plausible non-credible contingency events may be different).

Table 9 Reference points for estimating total amount of emergency under-frequency response required in South Australia

Indicative measure	Details	Indicative UFLS requirement
60% of the total power system load (NER reference)	Calculated as 60% of underlying load in historical year 2019-20 (interquartile ranges)	800 to 1,200 MW
Plausible multiple contingency events	Observed historical multiple contingency events have caused supply-demand imbalance/UFLS activation in this range.	Up to 1,000 MW
Loss of the Heywood interconnector (based on Heywood import constraint formulation)	Sufficient UFLS load to avoid binding of the present Heywood import limit (avoiding cascading failure if separation occurs).	800 to 1,000 MW

Figure 3 below illustrates the percentage of time over which a UFLS shortfall might exist during 2023-24 under a NEM intact scenario. These projections are based on DPV increase in alignment with the 2020 Electricity Statement of Opportunities (ESOO) Central scenario. A greater increase in DPV uptake could lead to a greater shortfall. Based on the 60% metric, even with all the currently proposed measures in place (including dynamic arming of UFLS relays), AEMO modelling suggests a UFLS shortfall could still exist up to 25% of the time during 2023-24, occurring primarily during periods of high DPV generation. Therefore, AEMO has recommended that SAPN and ElectraNet explore feasible options to restore UFLS or equivalent emergency under-frequency response capability as close as possible to 60% of underlying load.

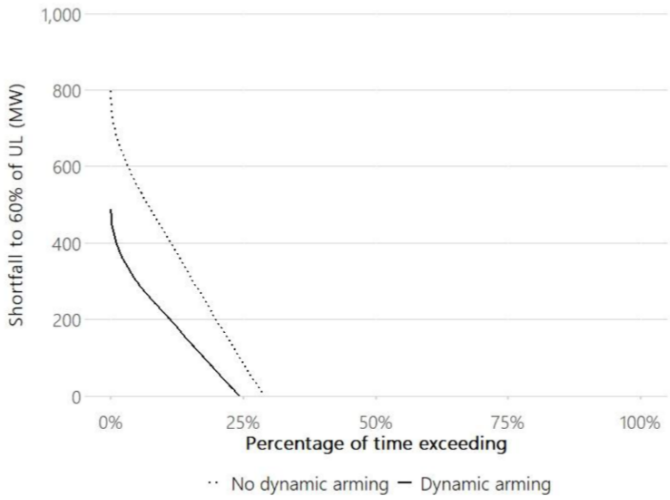


Figure 3 Shortfall to total net UFLS load in South Australia meeting 60% of underlying load (UL) (2023-24)

Further breakdown of times when a shortfall may occur by month and season is shown in Figure 4. The figure indicates that shortfall periods occur during the day throughout the year, with a particular concentration in the spring and summer months where solar generation is higher and days are longer. Large shortfalls (greater than 300MW), are rarer, and most likely to occur during midday peaks during spring and summer months.

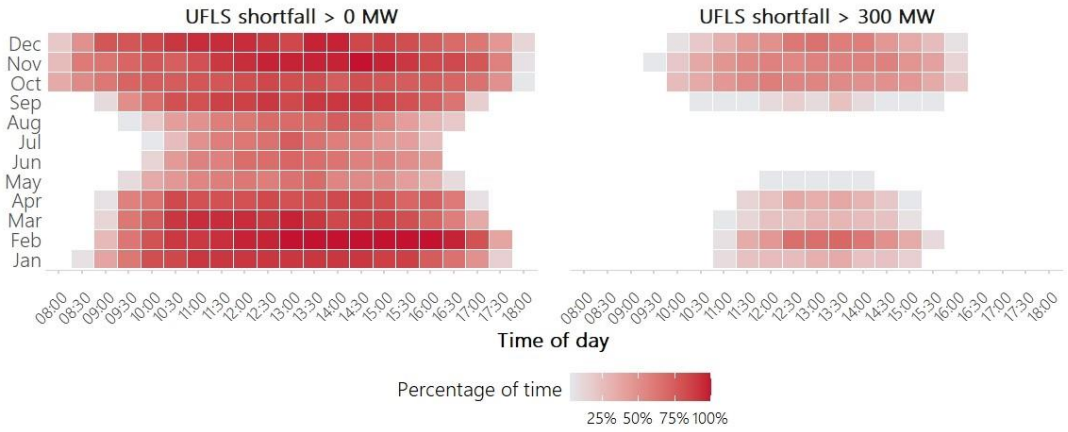


Figure 4 UFLS Shortfall by month and time of day over FYE 2024

Further background information can be found in the following AEMO reports:

Topic	Report	Section	Link
On the 60% requirement	South Australia UFLS and Dynamic Arming	2.2	https://aemo.com.au/-/media/files/initiatives/der/2021/south-australian-ufls-dynamic-arming.pdf
Decreasing UFLS levels in SA	2020 Power System Frequency Risk Review – Stage 1	A1	https://aemo.com.au/-/media/files/stakeholder_consultation/consultations/nem-consultations/2020/psfrr/stage-1/psfrr-stage-1-after-consultation.pdf?
Remediation work on SA UFLS	2020 Power System Frequency Risk Review – Stage 2	6.2	https://aemo.com.au/-/media/files/initiatives/der/2020/2020-psfrr-stage-2-final-report.pdf?

Indicative correlation to market prices

It is not possible to forecast market prices during the 2024 forecast periods, so historical data over the November 2020 – November 2021 period has been used to provide indicative correlations between market prices and UFLS shortfall requirements. It should be noted that a number of measures will be taken by 2024 to reduce the UFLS shortfall and the EUFR contract is intended to cover residual risks. Consequently, the size and expected probability of occurrence of a UFLS shortfall will reduce in future years.

Figure 5 shows the percentage of time where energy spot prices fall within a specific bin and its historical correlation to UFLS shortfall sizes. It can be observed that UFLS shortfalls are larger during lower price periods (often when price is negative). For example, over the historical period, a UFLS shortfall greater than 600 MW was present in ~31% of periods when prices were below -$100/MWh. In contrast, only 15% of periods where prices were above $200/MWh had an UFLS shortfall.

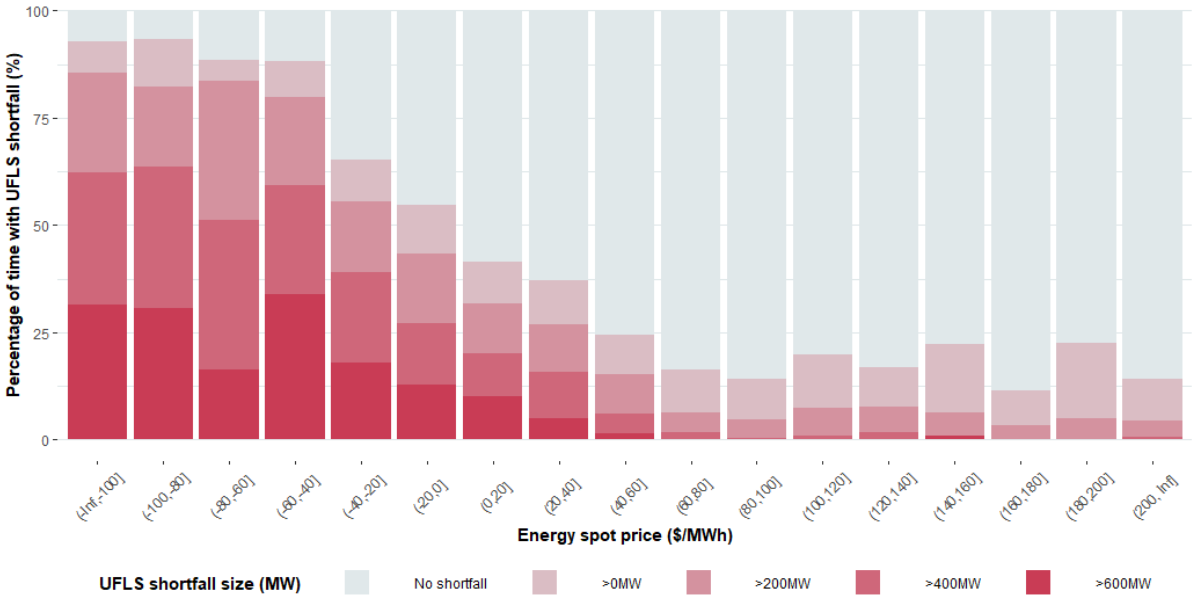


Figure 5 **Correlation of UFLS shortfall to energy spot prices over November 2020 – November 2021**

Figure 6 shows the data in Figure 5 above in reverse. It provides an indication of the market price when a UFLS shortfall was present in South Australia. It is observable that prices are relatively low during high UFLS shortfall periods (>600MW) with ~50% of this time exhibiting negative prices. Prices were also never above $100 when the UFLS shortfall was greater than 400MW.

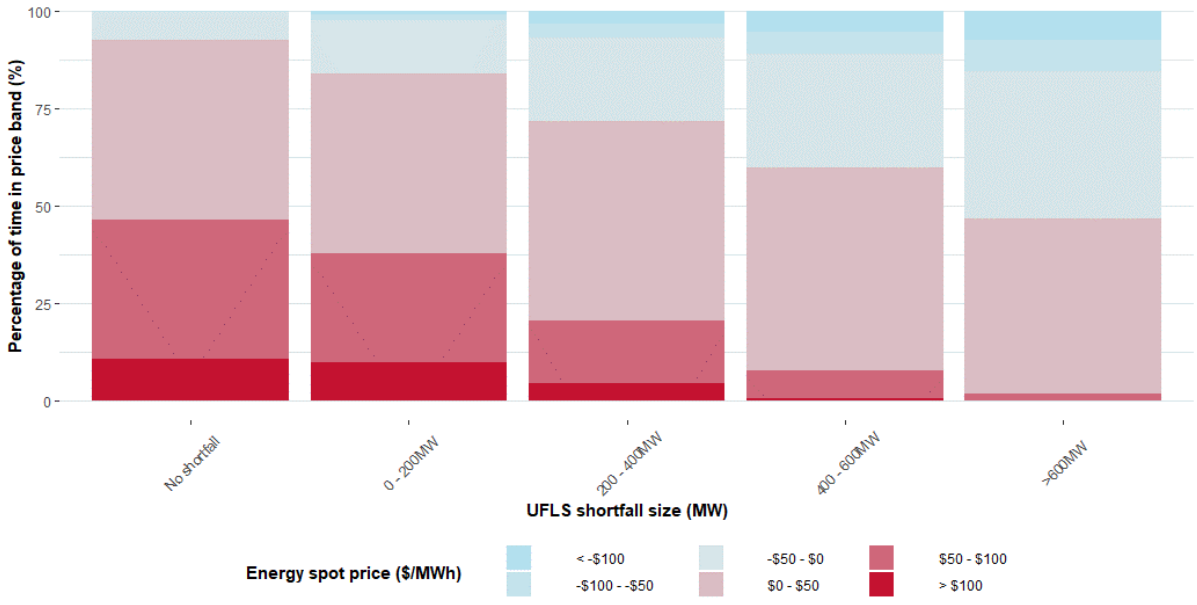


Figure 6 **Correlation of energy spot prices to UFLS shortfall over November 2020 – November 2021**

B. Appendix B: Example Activation Pricing Equation

This appendix provides an example equation that can be used to specify the activation compensation required from a tenderer.

$$MAX\left(0, \sum_{di=1}^{n} (AC - RRP_{di}) * GE_{di}\right)$$

Where:

AC – Activation Charge is the minimum required ($/MWh) for EUFR provided to cover costs associated with fuel, emissions obligations, and maintenance.

RRP – Regional Reference Price ($) for energy in the South Australia Region for each dispatch interval

GE – Generated Energy (MWh) for EUFR for each dispatch interval

di – each dispatch interval in which EUFR was provided