Heywood UFLS constraints

October 2020

AEMO is updating and expanding existing network constraints to keep power flows across the Heywood interconnector within limits that should allow the under frequency load shedding (UFLS) scheme in South Australia to operate effectively if needed. UFLS is an important last resort "safety net" protecting South Australian consumers from black system events when severe contingencies occur, such as the separation of South Australia from Victoria at the Heywood interconnector. UFLS capability has been significantly reduced by the growth in distributed PV, and the constraint changes are part of a suite of measures to restore this capability and mitigate risks. The improved constraint set is designed to dynamically reduce imports into South Australia at times when the UFLS is known to be inadequate. This will reduce the risk of cascading failure and a black system if a separation event occurs.

What's the issue with UFLS?

Under frequency load shedding (UFLS) is one of South Australia's emergency frequency control services (EFCS), designed as the 'last line of defence' to manage large contingency events (including separation events) through the controlled disconnection of load. Under frequency relays in the network detect when the power system frequency falls to very low levels (49 Hz or below) and automatically disconnect load circuits within less than a second in an attempt to rebalance the system. This is designed to rapidly stabilise the power system following severe contingencies, avoiding cascading failure to a black system. System operators can then take actions as necessary to restore the system to a secure state and reconnect load.

AEMO's studies have found that the growth of distributed PV has made South Australia's UFLS much less likely to stop an uncontrolled frequency decline. Distributed PV generation reduces the net load on UFLS circuits, meaning less net load is shed when the UFLS activates and the scheme is therefore less effective. As PV generation grows further, some circuits move into reverse flows. When this happens, the action of UFLS relays to trip load circuits will exacerbate an under-frequency event, rather than helping to correct the disturbance. AEMO's analysis of the UFLS in South Australia has shown periods with as little as 100 MW of UFLS load in 2019. Periods with less than 0 MW of UFLS load are anticipated in spring 2020, with more than half the UFLS trip frequency bands in reverse flows at certain times.

Distributed PV itself also demonstrates under-frequency disconnection behaviour, which further exacerbates severe under-frequency events by disconnecting distributed PV earlier than the UFLS stages[1].

South Australia relies on UFLS to arrest frequency declines caused by significant non-credible events, such as the simultaneous trip of both Heywood interconnector circuits when it is importing into South Australia. Based on future dispatch projections, AEMO's analysis indicates that if there were a double circuit loss of the Heywood interconnector, South Australia would be at risk of cascading failure around 2-4% of the time[2].

By reducing flows into South Australia on the Heywood interconnector to levels that can be effectively managed by the expected capability of the UFLS scheme, the risk of cascading failure is minimised if a separation event occurs.

AEMO is also working with SA Power Networks (SAPN), ElectraNet and the South Australian Government to implement a suite of additional, complementary actions to address these risks:

- Adding new loads to the UFLS and optimising the distribution of loads on the UFLS. This boosts the effectiveness of the UFLS scheme.

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[1] AEMO's studies show that approximately 10-15% of distributed PV generation in South Australia trips before any UFLS load is disconnected. For further information, refer to: AEMO, *Response of existing PV inverters to frequency disturbances*, April 2016, at https://aemo.com.au/-/media/Files/PDF/Response-of-Existing-PVInverters-to-Frequency-Disturbances-V20.pdf.

[2] Analysis based on the forecast period prior to the installation of the synchronous condensers at Davenport and Robertstown.

- Introducing more sophisticated UFLS relays that dynamically disarm a circuit when it is in reverse flow.
- Improving compliance of distributed PV inverters with performance standards, so that they are less likely to disconnect in under-frequency events.
- Reviewing UFLS arrangements under the National Electricity Rules (NER), to allow for a wider range of more innovative strategies for providing emergency frequency response.

Further background and details can be found in the 2020 Power System Frequency Risk Review (PSFRR)[3]. This fact sheet provides details on the first stage of implementation of the constraints on Heywood imports.

South Australian Regulations

AEMO will update and extend the constraint set originally introduced to meet the requirements of the limits advice provided to AEMO by ElectraNet under regulation 88A of the *Electricity (General) Regulations 2012 (SA)*. This advice requires that AEMO keep the rate of change of frequency (RoCoF) in South Australia below 3 Hz/s for the non-credible trip of both Heywood interconnector circuits.

The existing constraint set limits Heywood flows to maintain instantaneous RoCoF upon separation to 3Hz/s or less. The increased likelihood of cascading failure due to ineffective UFLS operation means the current formulation may no longer meet ElectraNet's limits advice under the regulation in all periods, because RoCoF will exceed 3 Hz/s once cascading failure starts to occur.

AEMO is also preparing a request to the Reliability Panel to declare the separation of South Australia under certain conditions as a protected event. This will formalise mitigative actions under the NER, and account for a wider range of possible separation pathways.

Development of the constraint

AEMO assessed UFLS performance in South Australia using a modelled representation of the South Australian network. The model used half-hourly UFLS load data from SAPN and ElectraNet, and the contingency event modelled was the double-circuit loss of the Heywood interconnector. Hundreds of thousands of simulations were performed across a range of future dispatch projections, including the 2020 Electricity Statement of Opportunities (ESOO)[4] Central scenario and other possible dispatch scenarios that could eventuate.

UFLS was defined to be inadequate (a 'fail' condition) if RoCoF exceeded 3Hz/s, or the minimum frequency was below 47.6 Hz. These criteria identify periods where cascading failure to a black system is very likely. AEMO also identified 'high risk' periods where RoCoF exceeded 2Hz/s, or the minimum frequency was below 48 Hz. These 'risk' periods show an increasing risk of complications and adverse outcomes and should be avoided if possible.

Regression analysis was applied to the simulation results to develop a constraint which defines an import limit for the Heywood interconnector based on UFLS load, distributed PV generation, power system inertia and the availability of Fast Active Power Response (FAPR)[5]. The constraint will adjust dynamically in real-time based on these factors, constraining flows into South Australia only when required.

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[3] AEMO (July 2020), *2020 Power System Frequency Risk Review – Stage 1*, Appendix A1. Available at: https://aemo.com.au/en/consultations/current-and-closed-consultations/2020-psfrr-consultation.

[4] AEMO, *NEM Electricity Statement of Opportunities*, September 2020, available at: https://aemo.com.au/-/media/files/electricity/nem/planning_and_forecasting/nem_esoo/2020/2020-electricity-statement-of-opportunities.pdf?la=en.

[5] Fast active power response (FAPR), a sub-second active power response, was found to provide significant assistance in arresting a frequency decline. For example, with 150 MW of FAPR in South Australia, all cases with Heywood imports below 150 MW met the acceptance criteria. FAPR can be delivered by inverter connected resources such as utility-scale

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As the Heywood UFLS constraint requires real-time estimates of UFLS load and DPV generation, AEMO's Energy Management System (EMS) feed has been updated to receive this information, including a new SCADA feed established from SAPN and ElectraNet.

Constraint formulation

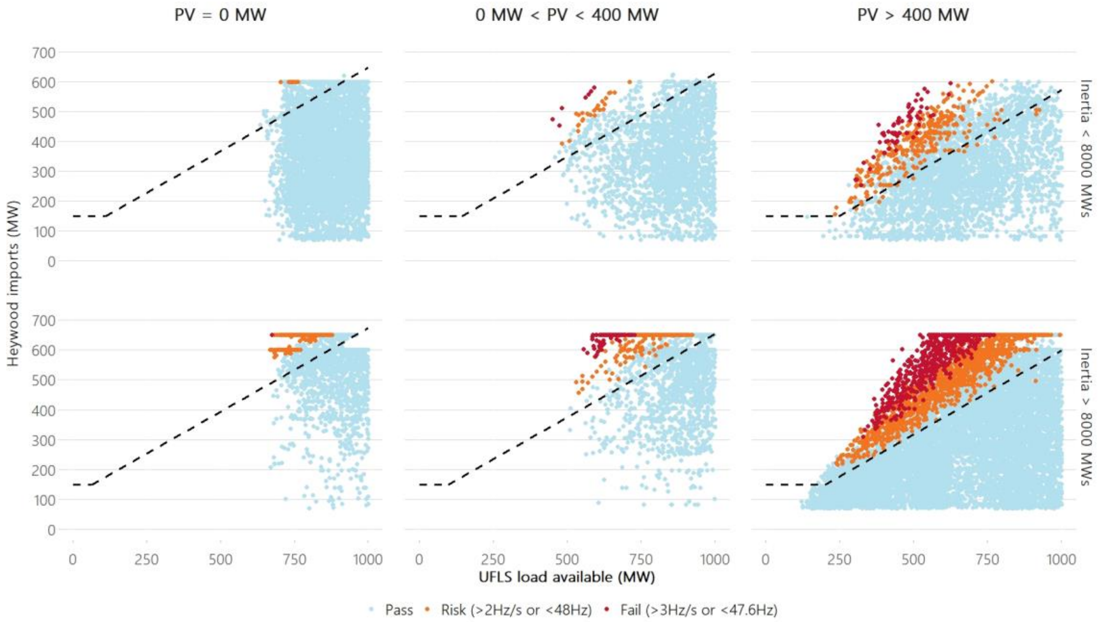
When the total UFLS load in South Australia is less than 1,000 MW, the following constraint will be applied[6]:

VIC to SA flows on the Heywood Interconnector will be limited to the maximum of:

- *Available FAPR*
- *-50.7 + 1.3*Inertia - 0.1*Distributed PV generation + 0.6*(UFLS load – 30) + 0.3*FAPR – 25*
- *0*

A visual representation of the constraint is provided in Figure 1. Each dot represents a simulation of a dispatch interval with various levels of Heywood imports and UFLS load, with each of the six panels showing different levels of distributed PV generation and power system inertia. Blue dots represent simulations that met all acceptance criteria, red dots represent simulations that are very likely to lead to cascading failure, and orange dots represent 'risk' conditions. A representation of the constraint is illustrated by the dashed black line. Heywood imports will be limited to this level, adjusting based on real time conditions.

Figure 1 Visual representation of the Heywood UFLS constraint



The constraint illustrated by the black dashed lines is indicative, and shown for conditions of 150 MW FAPR, with 7,000 MWs of inertia (top panels), 9,000 MWs inertia (bottom panels), and 0 MW PV (left panels), 200 MW PV (central panels) and 800 MW PV (right panels).

battery energy storage and solar farms, and some load resources. The constraint will adjust in real time based upon the availability of FAPR. AEMO is exploring adjustments to the NER to provide improved mechanisms for procuring these responses to assist with emergency frequency response.

[6] The unit of inertia used for the constraint is MWs/100MVA base, in alignment with AEMO's real time systems. All other constraint terms have units of MW. The constraint formulation contains two values which act as safety margins: an estimated 30 MW measurement uncertainty on the UFLS load value, and a 25 MW operating margin (consistent with Heywood operating margins used for other constraints) to allow for operational movements in Heywood flows within the dispatch interval.

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Update to the instantaneous RoCoF constraint

AEMO's analysis, alongside extensive investigation by consultants[7] and discussions with international system operators, indicates that risks of power system complications and the potential for synchronous units tripping increase for RoCoF exceeding 1 Hz/s, and escalate considerably at RoCoF levels exceeding 2Hz/s. Because of the rarity of such system conditions, there is large uncertainty regarding power system behaviour in this range.

The present constraint set limits the instantaneous RoCoF to 3Hz/s immediately following a separation event. Detailed analysis conducted now shows that if further unit tripping occurs, a cascading failure could result and RoCoF will accelerate beyond 3Hz/s as the power system fails.

Due to the risks identified at RoCoF levels in the 2-3 Hz/s range, the existing constraint will therefore be updated to reduce the **instantaneous** RoCoF limit for imports into South Australia from 3Hz/s to 2Hz/s. This is necessary to provide reasonable confidence that cascading failure will be avoided in the event of a non-credible separation, and RoCoF can ultimately be kept below 3Hz/s to meet the South Australian limits advised under regulation 88A of the *Electricity (General) Regulations 2012 (SA)*.

The amendment to the instantaneous RoCoF limit will only apply to periods where the Heywood interconnector is importing into South Australia. The limit for exports across Heywood from South Australia into Victoria will remain unchanged at 3Hz/s. AEMO is undertaking further analysis at present to examine risks associated with export conditions.

Constraint impacts

Historical analysis shows that the updated and expanded constraint set would have bound 1.7% of the time in calendar year 2019. Based on the 2020 ESOO Central forecast, the constraints are projected to bind 6-7% of the time in 2020-21[8], due to a projected increase in the number of periods of energy import into South Australia. It is intended that these constraints will be replaced in 2021 with a new formulation under the proposed protected event.

These constraints primarily bind in periods with low to moderate load, when price, reliability and market impacts will be low. Market studies indicate that the regression-based constraint never binds at operational demand levels exceeding 1,400 MW, and the updated RoCoF limit binds in only a handful of periods when operational demand is greater than 2,000 MW. For context, the forecast peak demand in South Australia in 2020-21 is 2,900 to 3,200 MW[9].

Next Steps

The updated and expanded constraint set will be implemented on 9 October 2020. This will provide protection against the anticipated very low load periods in Spring 2020.

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[7] GE Energy Consulting, *Final report: Advisory on Equipment Limits associated with High RoCoF*, 9 April 2017. Available at https://www.aemo.com.au/-/media/Files/Electricity/NEM/Security_and_Reliability/Reports/2017/20170904-GE-RoCoF-Advisory.

[8] Analysis based on the forecast period prior to the installation of the synchronous condensers at Davenport and Robertstown.

[9] AEMO, *2020 ESOO Central scenario*, available at https://aemo.com.au/-/media/files/electricity/nem/planning_and_forecasting/nem_esoo/2020/2020-electricity-statement-of-opportunities.pdf?la=en&hash=85DC43733822F2B03B23518229C6F1B2

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Where can I find more information?

For any further enquiries, please contact AEMO's Information and Support Hub via

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