Meeting Date: 12 March 2020

EXTENDED RESERVE ARRANGEMENTS

SECURITY AND RELIABILITY COUNCIL

Over the past five years New Zealand's power system has seen a reduction in the number of high inertia generating plant (large thermal generating units) and an increase in low inertia, renewable generators such as wind farms. As the New Zealand economy moves towards greater de-carbonisation, the ability of the grid to withstand a sudden, significant loss of supply will likely diminish. Automatic under-frequency load shedding (AUFLS) plays a critical role in preventing cascade failure in such a situation. It is therefore essential that the scheme is flexible and reliable now, and in the future. The Authority is working with the system operator and AUFLS providers to increase the diversity and granularity of the scheme with a view to improving the security and reliability of the power system.

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Executive Summary

The 2-block AUFLS scheme

In its letter to the Authority Chief Executive of the 17 July 2019 (Appendix A), the system operator has confirmed that the current 2-block scheme:

- is fit for purpose
- has appropriate mitigations in place to manage any potential deficiencies (assuming that distributors have appropriately armed relays).

The system operator's previous concerns regarding under- and over-provision of AUFLS have largely been addressed following post-event analysis of both the 2011 Huntly station and 2013 HVDC AUFLS events. Additionally, process and tool improvements implemented since 2010 give the system operator confidence that the current 2-block scheme is fit for purpose for managing the power system risks of today.

Drivers for change

However, over the past five years New Zealand's power system has seen a reduction in the number of high inertia generating plant (large thermal generating units) and an increase in low inertia, renewable generators such as wind farms. As the New Zealand economy moves towards greater de-carbonisation, the ability of the grid to withstand a sudden, significant loss of supply will likely diminish. AUFLS plays a critical role in preventing cascade failure in such a situation. It is therefore essential that the scheme is flexible and reliable now and in the future through continued monitoring and enhancement.

4-block AUFLS implementation

In 2012, the extended reserve project was started with the primary goal of implementing an efficient procurement scheme for AUFLS provision, combined with a move from a two block scheme (16 per cent of load in each block) to a four block scheme (two blocks of 10 per cent and two blocks of 6 per cent). Technical issues encountered during the implementation phase of the project led to significant delays. In October 2019, the project was refocussed to deliver a technical migration to a 4-block AUFLS scheme.

The extended reserve project will deliver:

- enduring system security and resilience as the primary objective
- possible technical enhancements to further promote system reliability and resilience.

The solution will not preclude any future consideration of an efficient procurement scheme, but it will not be considered as part of this project. As a result of the refocus, the Extended Reserve Manager role has been disestablished, and AUFLS selection and arming will be decentralised.

The 2 to 4-block migration will be implemented as a managed common obligation scheme. This allows the system operator and AUFLS providers to work together to migrate physical relay settings in a secure fashion. Individual provider obligations may be varied to suit individual capabilities whilst maintaining island-wide provision levels.

1. Background

1.1 Automatic under-frequency load shedding (AUFLS) is the "last resort" mechanism by which large blocks of load are disconnected to avoid system collapse due to a failure of a source of supply greater than can be covered solely by other mechanisms i.e. an extended contingent event (ECE). Sections 1 and 2 of a Transpower video is available to explain what AUFLS is and how it works.[1]

1.2 AUFLS-like schemes are a common feature of power systems around the world. Agenda item #11 highlights the Great Britain equivalent named Low Frequency Demand Disconnection (LFDD).

1.3 AUFLS relays are currently configured in two blocks of 16 per cent of load, which are armed to trip at specific frequencies. Hence, this "2-block" scheme is intended to disconnect up to 32 per cent of load to avoid a system collapse in which power would be lost to 100 per cent of load.

1.4 This 2-block scheme currently operates across the whole of New Zealand. The South Island scheme is provided by the grid owner, and the North Island scheme is provided under a common mandate in the Electricity Industry Participation Code 2010 (Code) which obliges all distributors and direct consumers to arm 32 per cent of their offtake as AUFLS.

System operator review

1.5 In 2010, the system operator conducted a technical review that found the current AUFLS scheme posed a significant risk of tripping more AUFLS load than required. Tripping too much AUFLS load risks system frequency 'overcorrecting' after an AUFLS event which could potentially result in too high a system frequency which would cause generators to disconnect and result in system collapse.

1.6 Having too much AUFLS load was a direct outcome of a scheme that obliges distributors to provide a minimum 32 per cent 'at all times', but sets no maximum constraint on the amount of AUFLS provided; an obligation most easily met by arming well in excess of the 32 per cent of a distributor's or direct consumer's load.

The efficient procurement of extended reserve project

1.7 In 2012, on the basis of a recommendation by the system operator, the Authority initiated the Efficient Procurement of Extended Reserve project (extended reserve) to implement a 4-block AUFLS scheme across the North Island. The 4-block approach allowed smaller blocks and different types of blocks to be adopted (some blocks could be activated based on the level of system frequency and some could be activated based on the rate at which system frequency fell). Additionally, the Authority expanded the scope to:

a) centrally select demand units from the entire North Island network to deliver the best possible alignment between the overall network half-hour load profile and the corresponding amount of demand available to be shed through the extended reserve scheme

[1] Available from https://youtu.be/O301BqxvGHI

b) develop a methodology to prioritise, for disconnection, customers with the lowest cost of interruption

c) provide a payments mechanism to both encourage participation and to efficiently fund the distributors and direct connect consumers who would be providing AUFLS for the benefit of all

d) configure the scheme to implement it at the lowest possible net cost.

Technical issues encountered

1.8 Although an early trial of the central selection method proved successful, subsequent attempts to produce an arming scheme that satisfied the system operator's security requirements proved difficult and time consuming.

1.9 As well as issues with the data specification, investigation uncovered the selection methodology's preference for selecting larger blocks of load to arm as AUFLS. This led to a significant proportion of load being armed in the Upper North Island. Modelling by the system operator indicated the potential for voltage collapse in the North Island, should all the armed AUFLS load be disconnected during a grid event.

1.10 Following several unsuccessful iterations of the selection methodology, the process was halted, and a review of the project undertaken.

System operator update

1.11 As a part of the project review, the authority asked the system operator to confirm:

a) if the current 2-block AUFLS arrangements are fit for purpose

b) the operational and system changes they have put in place since their 2010 report

c) whether a North Island 4-block AUFLS scheme is still worth pursuing from a system security and resilience point of view.

1.12 In its 17 July 2019 reply to the Authority Chief Executive, the system operator confirmed that the current 2-block scheme:

a) is fit for purpose

b) has appropriate mitigations in place to manage any potential deficiencies (assuming that distributors have appropriately armed relays).

1.13 The system operator's previous concerns regarding under- and over-provision of AUFLS have largely been addressed following post event analysis of both the 2011 Huntly station and 2013 HVDC AUFLS events.

1.14 Additionally, process and tool improvements implemented since 2010 give the system operator confidence that the current 2-block scheme is fit for purpose for managing the power system risks of today. These improvements included:

a) increased procurement of over frequency armed (OFA) generation

b) the introduction of the online transient stability analysis tool (TSAT) to the control room improved the co-ordinator's ability to assess the impact of an ECE and mitigate it in real time.

1.15 In the system operator's view, the move to a 4-block AUFLS scheme will improve the flexibility and resilience of the AUFLS. Modelling suggested that 4 blocks provided a better match between the size of the system event and the amount of load shed.

1.16 The addition of the 'rate of change of frequency' settings would provide additional resilience should an ECE occur during periods of low system inertia, as frequency decay will occur much more quickly in a low inertia system and the standard relay settings will react too slowly to arrest the decay. With the continued investment in low inertia generation, such as wind and solar PV, and likely retirement of larger thermal units over the coming years, the North Island power system is likely to see increased periods of high HVDC transfer with little or no large thermal generation.

2. Refocussed extended reserve project

2.1 Following the project review, the Authority decided to refocus the scope of the extended reserve project. The revised scope is now to deliver:

a) enduring system security and resilience as the primary objective

b) possible technical enhancements to further promote system reliability and resilience.

2.2 The project will focus on the technical transition to a 4-block AUFLS scheme. The solution will not preclude any future consideration of an efficient procurement scheme, but it will not be considered as part of this project.

Project design and engagement

2.3 The project is to be structured around three co-ordinated work streams:

a) technical assurance

b) policy implementation

c) stakeholder engagement.

2.4 Each work stream will involve significant cross-agency collaboration. The Authority project team will work closely with the system operator staff to ensure that project is progressed in a way that works towards the common goal of enhancing system reliability and flexibility. External stakeholders will be actively included in the progression of both the technical and policy development work streams.

2.5 Whilst the project structure describes three distinct work streams, each work stream will need to be closely integrated. Results of the technical work stream will inform the policy development and vice versa. Around this, the stakeholder engagement work stream will be critical to ensuring that AUFLS providers and wider industry stakeholders are included in key decision-making processes.

3. Next steps

3.1 The Authority announced the project refocus in October 2019 and invited participants to arrange meetings with project staff to discuss the changes. Four providers responded and meetings were held with the Major Electricity Users Group, Wellington Electricity, Northpower and Horizon Networks.

3.2 The system operator published a draft data specification for AUFLS provision data in February 2020 and invited comment from providers. Powerco, Vector and Energy Market Services responded. The Authority followed up with Vector on their general comments regarding the refocused project direction. A written follow up to all participants will be released via Market Brief in March 2020.

3.3 The system operator is currently preparing a proposal for their technical investigation work. If approved, this phase will start in July 2020. In parallel, the Authority will engage with industry and the system operator to develop the required Code amendments to support the transition to, and continued provision of, the 4-block AUFLS scheme.

3.4 Future enhancements to the 4-block scheme will be considered once the North Island providers have been fully transitioned from the 2-block scheme.

4. Questions for the SRC to consider

4.1 The SRC may wish to consider the following questions.

Q1. Given the system operator's advice has been qualified with an assumption about the appropriate arming of AUFLS relays by distributors, is the SRC satisfied this is a sound assumption?

Q2. What further information, if any, does the SRC wish to have provided to it by the secretariat? For example, information about whether armed AUFLS relays would disconnect hospitals and water treatment facilities like happened in the event reported on in agenda item #11?

Q3. What advice, if any, does the SRC wish to provide to the Authority?

5. Appendices

5.1 The following is attached as Appendix A: 17 July 2019 system operator letter to the Chief Executive of the Authority.

Appendix A: 17 July 2019 system operator letter

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17 July 2019

James Stevenson-Wallace
Chief Executive
Electricity Authority
PO Box 10041
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Automatic under-frequency load shedding (AUFLS) security performance and ongoing improvement

Dear James

This letter addresses the three points Andy Doube raised in our discussion regarding AUFLS and extended reserves on 28 June 2019. My response is based on the information currently available to the system operator. Importantly it does not include any new analysis at this stage to reconfirm the capability or case for a 4-block AUFLS scheme.

Confirm if the current New Zealand 2-block AUFLS arrangements are fit for purpose

Under the Code the system operator has the accountability to define credible system events, identify and implement the appropriate controls for such events, in order to achieve the principal performance objectives (the PPOs).

The purpose of AUFLS is to act as a control in response to an extended contingent event (ECE). An ECE is a credible event where the most efficient way to achieve the system reliability required is to rely on automated load shedding, in addition to other controls such as frequency reserves.

In the credible event framework, the main ECE risk being managed is the simultaneous loss of both HVDC poles. From time to time other events may be treated as an ECE, for example instantaneous tripping of multiple generating units due to a temporary identified single point of failure.

The system operator is confident, from a system security perspective, that the present 2-block AUFLS scheme in both the North and South Islands, along with the other controls we have in place (the reserve management tool (RMT), real-time monitoring tools, instantaneous reserves and over frequency arming), are robust and able to manage an ECE, provided asset owners are meeting their AUFLS obligations.

The initial 2010 AUFLS investigation came to the same conclusion. It added the caveat that the overall 2-block scheme design did not provide confidence that it would be effective for large events, not currently defined as an ECE. For instance the full loss of Huntly power station, which was then capable of 1,400 MW total output[1]. Through our regular credible event reviews since 2010, we have not yet identified

[1] The total maximum continuous output at Huntly station is now 1,047 MW following the decommissioning of one Rankine unit and only two other Rankine units able to run simultaneously.

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or classified any ECE risks with a greater system impact than an HVDC bipole tripping at 1,200 MW transfer[2].

We have some minor concerns over the impact of asset owner over-provision of AUFLS, given the present scheme only specifies a minimum amount of load per block. However the successful performance of AUFLS during events in 2011 (Huntly station separation of 874 MW) and 2013 (HVDC 892 MW runback), which each triggered the first block of North Island AUFLS, provide some assurance that obligations are being met. They also provide confidence that the scheme is robust enough to accommodate some under-provision and over-provision of AUFLS by asset owners.

The 2011 Huntly station separation AUFLS event and more recent 2017 South Island splitting AUFLS event were 'other' events. As such they were not considered credible at the time, and were not being treated as ECE risks. Both events highlight the benefit of having AUFLS as a backstop for mitigating high impact/low probability events, where under the credible event framework, the cost and benefit of relying on other available controls to avoid the loss of all or part of the power system in one island, is not justifiable.

Confirm changes that the system operator has made since it raised an issue with the North Island 2-block AUFLS arrangement in 2010. Has the system operator put in place management activities to further enhance the current AUFLS arrangements?

The largest credible ECE being securely covered by instantaneous reserves and AUFLS still remains a HVDC bipole tripping. Since 2010, we have continued to improve the tools we are using in real-time to predict the system response to an ECE.

Since December 2011, we have had North Island over frequency arming (OFA) contracts in place to mitigate over-frequency caused by the loss of the HVDC bipole during high southwards transfer. This OFA is also available to be used to mitigate any "frequency overshoot" resulting from excess load being shed by AUFLS operation. This excess load shedding may be due to either the block size being larger than required for the event or due to asset owners over-provision of AUFLS.

In 2016 we introduced the transient stability assessment tool (TSAT) online into the control room. This has provided our co-ordinators with an improved ability to assess how the power system will respond to an ECE. TSAT alerts co-ordinators to arm sufficient OFA generators, or in rare occasions to redispatch the HVDC transfer, to mitigate any potential frequency overshoot due to AUFLS tripping excess load.

Does the system operator think a North Island 4-block AUFLS scheme is still worth pursuing from a system security and resilience point of view?

In 2013 we published an AUFLS scheme design technical summary which compared the existing North Island scheme with alternatives. The report concluded a 4-block scheme (10%, 10%, 6%, and 6%) using a 'rate of frequency change' rely on the fourth block had the best overall technical performance, estimated at $11m/year benefit over the 2-block scheme.

Our view is still that there is an opportunity to improve the flexibility and resilience of AUFLS by providing a 4-block North Island scheme. In our studies 4-blocks provided a better match between the amount of load shed and the size of system event. Avoiding excess load being shed would reduce consumer impact

[2] HVDC maximum capability of 1,200 MW includes headroom for frequency modulation and reserve sharing, limiting maximum energy transfer. Refer to our HVDC utilisation reports available here for typical transfer levels: https://www.transpower.co.nz/system-operator/market-insights

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and overall interruption cost for an ECE or 'other' event. This 4-block scheme would minimise any 'frequency overshoot' which could result in increased OFA event charges.

Added resilience would be further enhanced through a proposed 'rate of frequency change' facility for one of the four blocks. This is a useful mitigation for events resulting in rapid frequency decline during periods of low system inertia in the North Island.

This low system inertia condition is likely to occur more frequently in the future when there is high HVDC north flow and low or no thermal generation in the North Island. It will also occur as additional new inverter connected generation, such as wind or solar, displaces synchronous generation.

Approach to working with the Authority to ensure a fit for purpose AUFLS arrangement

I appreciate the opportunity to provide this assurance and update to the Authority. The system operator takes its obligation to ensure the successful management of credible events in meeting the Code mandated PPOs very seriously. Given the criticality of this control for both credible ECEs and mitigating 'other' events, we are committed to working with the Authority in addressing any technical concerns from the work on Extended Reserves project with the current 2-block scheme, or importantly future AUFLS arrangements based on a 4-block scheme. If necessary this includes reconsidering the case for, and nature of, future AUFLS block requirements to account for the changes since the original need was identified.

Regards,

John Clarke

GM Operations