Meeting Date: 25 February 2021

SYSTEM OPERATOR MANAGEMENT OF SHORT-TERM SYSTEM RISK

SECURITY AND RELIABILITY COUNCIL

The system operator has provided information on its management of short-term system, specifically focussing on ancillary services and credible event reviews. Also provided is an independent review of the system operator's paper.

Note: This paper has been prepared for the purpose of Security and Reliability Council. Content should not be interpreted as representing the views or policy of the Electricity Authority.

The system operator has provided a paper on management of short-term risk

1.1.1 As part of the Security and Reliability Council's (SRC) forward work programme, the SRC requested a paper from the system operator on its management of short-term system risk (attached as Appendix A).

1.1.2 The system operator manages a range of short-term risks with this paper focussing on ancillary services and credible event reviews. The initial part of the paper focus on an overview of what the key concepts are, with section 4 providing the high-level processes used when managing short-term system risk.

1.1.3 Section 5 provides information about their processes being fit for purpose for the future. Some key points include:

a) the system operator role should enable the benefits of any new technology to be rolled out onto New Zealand's power system while continuing to provide a secure supply of electricity

b) increasing inverter connected technology presents new risks to power system operation as synchronous generation is displaced and the system behaviour becomes more dynamic. Risks being looked at now include; reducing inertia, distributed energy resource common modes of failure, and reduced system stability

c) the system operator is:

i. in the process of enhancing its reserve management tool, bringing the modelling methods and assumptions used in the tool's calculation engine closer to physical reality

ii. working with the Authority to 1) enable the full reserve capability of batteries, and 2) develop a new technology integration roadmap

iii. continuing to scan for, and assess, emerging credible events associated with the increase of new technology.

An independent review has been undertaken

2.1.1 In addition to the system operator's paper, the Authority has commissioned Strata Energy Consulting to provide an independent review of the system operator's paper. The independent review has been undertaken to provide assurance to the SRC that the system operator's explanations are technically correct and complete (attached as Appendix B).

2.1.2 The independent review seeks to answer the following questions:

a) How well does the material communicate to the intended audience?

b) Are there any significant gaps?

c) Are the system operator's views of future needs reasonable?

2.1.3 The independent review cited several areas where there were opportunities for further development of technical concepts. The secretariat will work through the comments provided, along with any advice from the SRC, with the system operator to evolve future papers.

2.1.4 The independent review also states that while there were no significant gaps in the material presented, the material was drafted as a high-level introduction to a range of complex topics. The review recommends the SRC consider requesting clearer explanations of short-term risk management focused on risk management that tie in with the SRC's role.

Questions for SRC

3.1.1 The SRC may wish to consider the following questions:

Q1	**What advice does the SRC have on the construction and style of the risk management paper that can be used to ensure future papers serve the needs of the SRC?**
Q2	**What further information, if any, does the SRC wish to have provided to it by the secretariat?**
Q3	**What advice, if any, does the SRC wish to provide to the Authority?**

Appendices

4.1.1 Appendix A: System operator's paper on management of short-term system risk.

4.1.2 Appendix B: Independent review of system operator paper on managing short-term system risk.

Appendix A System operator’s paper on management of short-term system risk

SYSTEM OPERATOR MANAGEMENT OF SHORT-TERM SYSTEM RISK

For the Security and Reliability Council

Transpower New Zealand Limited

February 2021

Keeping the energy flowing




TRANSPOWER

Transpower New Zealand Limited The National Grid

Contents

1 Introduction 3
2 Key concepts 4
2.1 Balancing supply and demand 4
2.2 Frequency 4
3 Planning for the unplanned 5
3.1 Unplanned Events 5
3.2 Ancillary Services 5
4 Reliability vs Efficiency 7
4.1 Credible Event Review 7
4.2 Purchasing only what we need to 8
4.3 Competitive procurement process 8
4.4 Shedding load when economic 9
5 Ensuring our processes are fit-for-purpose for the future 10
5.1 New technology 10
5.1.1 Reducing inertia 10
5.1.2 Distributed energy resource common modes of failure 11
5.1.3 Reduced system stability 12
5.2 Improvements and Future Work 12

1 INTRODUCTION

The Security and Reliability Council requested Transpower, as system operator, to provide papers on items that are listed in their dashboard of risk controls.

This paper looks at the role of:

- Ancillary Services (ID 4)
- Credible Event Review process (ID 11)

in the management of short-term risk (i.e. risk the system operator manages in real time). The paper considers how the system operator mitigates risk by identifying the likely events on the system; and how it determines what is economical to plan for ahead of time and when additional resource should be procured.

This paper is pitched at a high-level, using easily understood terminology rather than deeply technical explanations. More detailed information is available on the system operators' website[1].

[1] Ancillary services: https://www.transpower.co.nz/system-operator/electricity-market

Event categorisation: https://www.transpower.co.nz/system-operator/operational-information/event-categorisation

2 KEY CONCEPTS

2.1 BALANCING SUPPLY AND DEMAND

Electricity is an energy source with a unique supply chain. Supply and demand are physically connected across a live network of powerlines including transmission and distribution. To maintain operation, supply from electricity generators must match demand at all times.

Figure 1

In extreme cases, failure to match supply and demand results in the power system becoming unstable, leading to cascade failure and ending in widespread blackouts – in a worst case in New Zealand, this would mean the loss of an entire island. Restoring power can span hours or days with a significant economic impact.

Ensuring supply meets demand at any given second is the role of the system operator. We do this by firstly determining demand – a combination of bid quantities from large, unpredictable loads and a forecast of demand of the more predicable load, such as residential load. Based on the overall demand at any time we then then dispatch supply in accordance with generators' offers of supply. Dispatch takes place from our control room every five minutes.

2.2 FREQUENCY

Frequency provides an indication of the supply demand balance. When the New Zealand power system is balanced, the power system frequency is 50 Hz. If frequency drops lower than 50 Hz it indicates a need for more supply (or less demand); if frequency is greater than 50 Hz it indicates a need for less supply (or more demand).

When frequency deviates too far from 50 Hz, load and generators start to disconnect in a controlled way to prevent damaging their equipment. Without intervention by the system operator, this may lead to cascade failure.

The cause of a frequency deviation could range from a natural disaster impacting demand, or a mechanical failure of an electricity asset resulting in an instant change in supply.

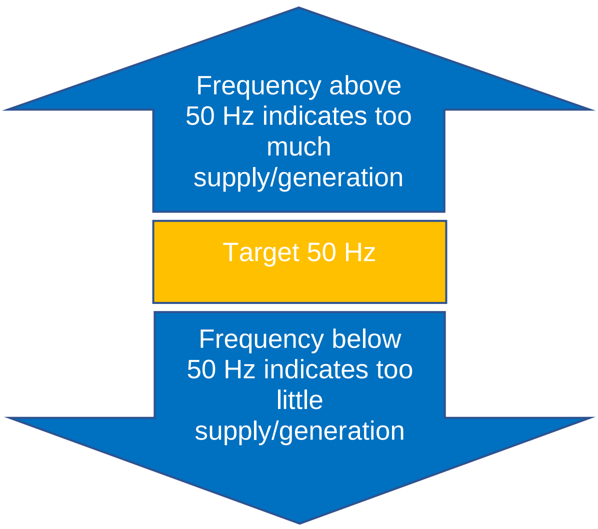

Figure 2

3 PLANNING FOR THE UNPLANNED

3.1 UNPLANNED EVENTS

An unexpected incident that results in a loss of power on the power system is referred to as an unplanned event. The system operator refers to those events created by asset failure that could cause cascade failure as credible events.

There are three categories of credible event. Each category provides for options that can be used to mitigate the risks associated with the credible event (for example, ancillary services).

How we categorise credible events is included in section 4.1 of this report; this process is known as the Credible Event Review.

3.2 ANCILLARY SERVICES

When frequency deviates unexpectedly, such as when an unplanned event occurs, reserve products kick in automatically to help stabilise or restore frequency in a controlled way. Much of this is done through the procurement of ancillary services that activate at varying degrees of frequency. The system operator is responsible for procuring ancillary services on behalf of industry, which it does via individual performance contracts with participants. The terms and conditions of the procurement are set out in the Procurement Plan (a document incorporated into the Code by reference and reviewed every two years). Some services are fixed price and quantity procurement (e.g. over frequency reserve and black start), while others are procured through a market (e.g. frequency keeping and instantaneous reserve). Because of the market aspect, ancillary services costs can vary from month-to-month depending on market conditions – in 2020, the monthly costs varied between $978k and $1.79 million.

The services currently procured are:

Frequency keeping: This product responds to small changes in frequency and is provided from selected generators to manage fluctuations in frequency second by second in between each five-minute dispatch.

Over Frequency Reserve: This product is generation that turns off instantly if frequency gets too high.

Instantaneous (Under Frequency) Reserve: This product is demand that cuts off, or generation that ramps up very quickly, if frequency drops too low.

Black Start: This is generation that is designated to restart the power system in the event that the power system has collapsed.

We ensure the ancillary services perform as expected by regular testing against the performance standards and technical requirements outlined in the contracts. For greater detail of each of the ancillary service products refer to our *website*.

In addition, we rely on Code-mandated **Automatic Under Frequency Load Shedding (AUFLS).** This is up to 32 per cent of either island's demand that cuts off automatically if frequency drops too low. It is effectively the last layer of defence to avoid cascade failure.

Each of these products activates based on frequency, as illustrated at a high level below in Figure 3. A more detailed diagram can be found on our *website*.

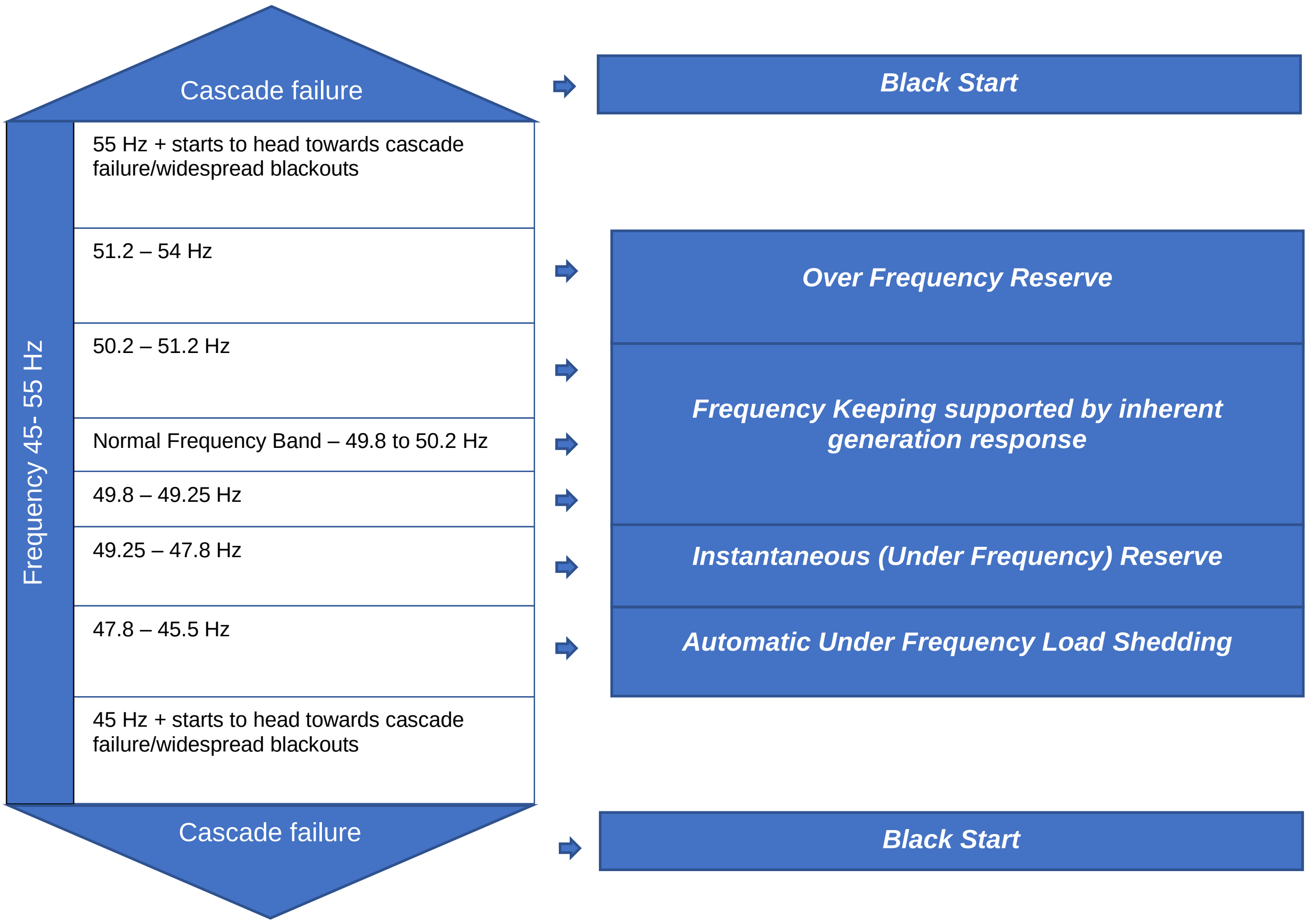
Cascade failure
Frequency 45- 55 Hz
55 Hz + starts to head towards cascade failure/widespread blackouts
51.2 – 54 Hz
50.2 – 51.2 Hz
Normal Frequency Band – 49.8 to 50.2 Hz
49.8 – 49.25 Hz
49.25 – 47.8 Hz
47.8 – 45.5 Hz
45 Hz + starts to head towards cascade failure/widespread blackouts
Cascade failure
Black Start
Over Frequency Reserve
Frequency Keeping supported by inherent generation response
Instantaneous (Under Frequency) Reserve
Automatic Under Frequency Load Shedding
Black Start

Figure 3

4 Reliability vs Efficiency

Part of the system operator's objective is to ensure reliability of supply in the most efficient way.

Ancillary services are purchased, and the costs are allocated to the market participants according to the Code. These costs are ultimately passed on to the consumer through electricity charges. The system operator endeavours to minimise cost as much as possible through its procurement mechanisms. There are several components to this.

4.1 Credible Event Review

In accordance with our *Policy Statement* the system operator must seek to manage the outcomes of events that may cause cascade failure. To achieve this the system operator cyclically reviews and classifies events that may occur on the power system and cause cascade failure using the Credible Event Review process.

The assessment process establishes the potential impact for the power system (in terms of frequency and voltage) from a credible event using a fault probability cost-based methodology.

Through this review we classify events into three categories:

Contingent Event (CE): A CE is a credible event where the impact, probability of occurrence and estimated cost and benefits of mitigation are considered to justify implementing policies that are intended to be incorporated into the scheduling and dispatch processes pre-event. This includes scheduling and dispatching sufficient instantaneous reserves and taking consideration of other control measures such as arming over frequency reserves, demand inter-trips, run-back schemes and automatic under-voltage load shedding.

Extended Contingent Event (ECE): An ECE is a credible event where the impact, probability, cost and benefits are not considered to justify the controls required to totally avoid demand shedding or maintain the same quality limits defined for contingent events. This includes a combination of AUFLS, provision of instantaneous reserves, demand shedding and taking into consideration other control measures.

Other Event: An 'Other' Event is a credible event that is considered to be uncommon and for which the impact, probability of occurrence and estimated cost and benefits do not justify implementing available controls, or for which no feasible controls exist or have been identified, other than unplanned demand shedding, AUFLS and other emergency procedures or restoration measures; or events that have no impact or where no pre or post contingent management is required.

Our methodology and the results of our assessments are published to the *Transpower website*. A summary of existing credible event classification can be found in Table 1.

Table 1 - Credible Event Classifications

ID	Identified Event	Existing Classification
1	Single transmission circuit failure	CE
2	Generator unit failure	CE
3	HVDC single pole failure	CE
4	Reactive injection and reactive equipment failure	CE
5	HVDC bipole failure	ECE
6	Interconnecting transformer failure	Varies[2] – CE, ECE, Other
7	Busbar connected to the core grid failure (thermal, voltage)	Varies[2] – CE, ECE, Other
7	Both transmission circuits of a double circuit line failure	Other / CE[3]
8	Multiple transmission circuits failure	Other
9	Multiple generating units failing	Other
10	Busbars connected to the core grid failure (frequency)	Varies – ECE, Other[4]

4.2 PURCHASING ONLY WHAT WE NEED TO

We use a specialised software programme, called the Reserve Management Tool (RMT), to model the possible unplanned events on the power system and calculate the amount of reserves required to mitigate the event. This helps to ensure we optimise the amount of reserves we procure for any given half hour.

4.3 COMPETITIVE PROCUREMENT PROCESS

Black Start and Over Frequency Reserve are procured through a competitive tender process, while Instantaneous Reserve and Frequency Keeping are procured through a competitive market on a half hourly basis. AUFLS is a mandated service provided by network companies in the North Island and the grid owner in the South Island. AUFLS providers are not compensated for this service, but when it is used its cost is estimated at $20,000/MWh, the Code-mandated value of unserved energy.

[2] Refer to the interconnecting transformer and core grid busbar classifications published here on the Transpower website: https://www.transpower.co.nz/system-operator/operational-information/event-categorisation

[3] The loss of both transmission circuits of a double circuit line can be managed as a contingent event where the system operator has determined there is a high level of likelihood of occurrence (based on historical information) or the system operator has been advised there is a high level of likelihood of occurrence due to a temporary change to environmental or system conditions

[4] The loss of any busbar on the core grid is managed as an 'Other' event, except the Manapouri busbar which is classified as an extended contingent event for frequency.

4.4 SHEDDING LOAD WHEN ECONOMIC

RMT factors into its calculations if shedding load is the economic option when determining how much reserves are to be procured in any given half hour.

While using AUFLS to cover an event costs $20,000/MWh in unserved energy, the cost is only incurred when the load is lost. On the other hand, by using Instantaneous Reserve to cover an event, the cost per MWh is much lower but since this is incurred every trading period, this could result in an overall higher cost.

5 Ensuring our processes are fit-for-purpose for the future

5.1 New technology

The price and capability of batteries, solar and wind generation are improving at exponential rates, increasing their presence on power systems around the world.

Because these new technologies generate clean energy their uptake is often supported by government policy and subsidies as part of decarbonisation strategies. No subsidies currently exist in New Zealand for any type of generation. This is partly because our fleet is already 75 - 85 per cent renewable. This has led to a slower uptake of these technologies in New Zealand compared to other countries. However, these technologies are still growing steadily in New Zealand and their penetration is a matter of 'when' not 'if'.

Global uptake of new technologies is also being supported by greater automation and smart management of solar and batteries at the household level, enabling households to optimise their power usage.

Our role as the system operator is to enable the benefits of any new technology to be rolled out onto New Zealand's power system while continuing to provide a secure supply of electricity.

Increasing inverter connected technology presents new risks to power system operation as synchronous generation is displaced and the system behaviour becomes more dynamic. Some of these risks we are thinking about now include; reducing inertia, distributed energy resource common modes of failure and reduced system stability.

5.1.1 Reducing inertia

Inertia is the momentum of the power system. Like a vehicle on the road, the greater the momentum the more time it takes to stop; the lower the momentum the quicker it stops. 'Synchronous' spinning generator units provide inertia as an inherent generation response when they produce electricity. This generation includes thermal, hydro and geothermal generator units[5]. The more inertia a power system has, the more stable the frequency is to unexpected events, making it more reliable.

Because wind, solar and batteries are connected to the power system by inverters, they provide little or no inertia when they produce power. As their uptake increases, we can expect the power system to carry less inertia, becoming less stable when the unexpected happens.

Our current studies do not expect inertia to become an issue in the near future, however we will continue to study and monitor inertia levels to identify any emerging risk. If it does become a risk, engineering solutions exist to mitigate it (e.g. batteries can tailor their output to provide 'synthetic inertia[6]' or synchronised condensers can be built on the transmission network).

[5] Note, some early generation wind turbines provide some inertia due to how they are coupled to the power system.

[6] National Grid ESO outline new approach to stability services. National Grid ESO has introduced contracts to procure 12.5 GVA seconds of inertia, the equivalent of the inertia provided by approximately 5 coal fired power stations. It is estimated that the new approach will save consumers up to £128 million over the six-year period, reducing the costs currently associated with managing system balancing and stability, with the reduced carbon emissions a significant step towards the ESO's ambition of being able to operate the GB electricity system carbon free by 2025.

Unlike the current situation, these engineering solutions are not provided as an inherent generation response as a result of producing electricity. They must be tailored or built to provide inertia. Hence inertia would become a specific service with a quantity, measurement, and payment method all needing to be designed, as summarised in Figure 4.

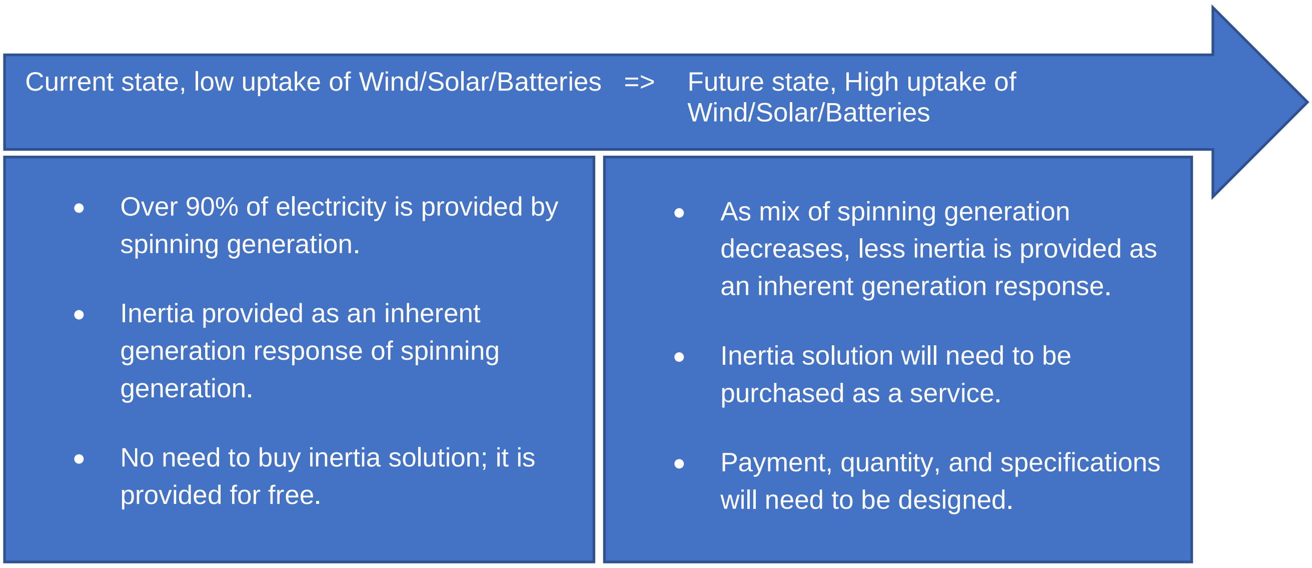

Figure 4

5.1.2 Distributed energy resource common modes of failure

Our current power system is made up of a combination of different types of generation, with the majority of energy supplied by large thermal, hydro, geothermal and wind generators. The system operator models how each of these generators will react to changes in frequency, voltage, and other power system conditions. Our tools then indicate the amount of reserve required to cover various events on the power system over and above any free response contributed by connected generation.

As distributed energy resources such as household solar and battery uptake increases, the number of these new technology devices on the system will grow exponentially. Looking to Australia provides a clear example of this, since 2011 there have been over two million rooftop solar installations, 89,000 in October 2020 alone.

Each distributed energy resource is connected to the network via an inverter with individual settings indicating how it responds to deviations in frequency, or other changes in system conditions like voltage. The inverter will respond by disconnecting the house from the grid to protect the solar panels or battery from potential damage. While many of these settings are changeable at any point in time, they come with factory default settings that are not often changed at installation.

Consider if all these inverters connected distributed energy resources, or a large proportion of them respond, in a negative or unexpected way to a particular system condition, then this could present a risk to the secure operation of the power system. It may even be possible that these devices could be targeted by a cyber-attack due to their readily configurable nature. These types of aggregated behaviour are what we refer to as a common mode of failure risk. This type of risk has presented itself in Australia in recent years during the South Australian blackout event, where subsequent to the initiating event a large percentage of residential solar unexpectantly disconnected further aggravating the situation. Similarly, in the United Kingdom the system operator accounts for the negative response from some residential solar when determining its security measures.

As uptake accelerates, we will need visibility and confidence in standards governing these types of distributed energy resources to enable the system operator to manage the potential aggregated risk they pose to the secure operation of the power system.

5.1.3 Reduced system stability

As mentioned earlier with the increase in inverter connected assets displacing existing synchronous generation system behavior will become more dynamic, with the potential for greater instability risks to arise during system events further aggravating the situation. While not an immediate threat in New Zealand we are seeing other countries such as Australia grapple with this issue after the fact, constraining new generation while they act to reform and modify their grid codes and connection standards. We want to ensure we do not end up in the same position in New Zealand, so have started to investigate and plan for how we will ensure system instability does not become an issue for our power system.

5.2 Improvements and Future Work

Since upgrades to the HVDC controls in 2013, the system operator has made significant reductions in the amount of reserves it needs to operate the power system in a reliable way.

1. Creating a National Market for Instantaneous Reserve. This reduced the amount of reserves required by approximately up to 220 MW per trading period and 120 MW on average.
2. Increased the self-cover capability of the HVDC. This enabled 150 MW more northward energy transfer for the same amount of reserve.

We currently have a project underway to enhance our reserve management tool, bringing the modelling methods and assumptions used in the tool's calculation engine closer to physical reality. These enhancements should deliver further reductions to the amount of reserves needed.

We are also working with the Authority to enable the full reserve capability batteries can offer.

Over the last two years we have continued to strengthen the probabilistic and economic analysis used in the credible event review process, ensuring we are mitigating credible events in the most cost-effective way for New Zealand. Furthermore, as mentioned in section 5.1, we will also continue to scan for and assess emerging credible events associated with the increase of new technology.

Our attention has now shifted towards working with the Authority to develop a new technology integration roadmap. This will outline the changes required to policy framework, market design, and operations. This is needed for New Zealand to capture the opportunities of new technology and mitigate any risks they may introduce.

Appendix B Independent review of system operator paper on managing short-term system risk

Review of a system operator paper on managing short-term system risk

Report for

the Security and Reliability Council

Strata Energy Consulting Limited

17 February 2021

This report has been prepared to assist and provide advice to the Security and Reliability Council (the SRC) via the Electricity Authority (the Authority) in its role as SRC secretariat.

This report relies on information provided to Strata Energy Consulting (Strata) by the SRC secretariat and other parties. Strata disclaims liability for any errors or omissions, for the validity of information provided to Strata by other parties, for the use of any information in this report by any party other than the SRC and for the use of this report for any purpose other than the intended purpose.

In particular, this report is not intended to be used to support business cases or business investment decisions. Strata's opinions in this report include considerations of materiality to the requirements of the SRC and opinions stated or inferred in this report should be read in relation to this over-arching purpose.

Strata Energy Consulting Limited (Strata) specialises in providing services relating to the energy industry. The Company, which was established in 2003, provides advice to clients through its own resources and through a network of Associate organisations. Strata has completed work on a wide range of topics for clients in the energy sector both in New Zealand and overseas.

This report was prepared by:

Clive Bull, Director, Strata Energy Consulting

For further information, please contact:

Strata Energy Consulting Limited

PO Box 25157

Wellington 6140

New Zealand

Phone:	+64 4 890 5293
Email:	clive.bull@strataenergy.co.nz
Web:	http://www.strataenergy.co.nz

Prepared by:	Clive Bull
Date:	17/02/2021 9:43 PM
Version:	FINAL

Contents

1 Introduction 5
1.1 The report reviews a system operator paper on short term risk 5
1.2 The subject matter covers two short-term risks 5
2 Our initial comments are about effective communication 6
3 Stepping through the paper's sections 7
3.1 Key concepts include supply and demand balance and system frequency 7
3.2 Ancillary services provide risk mitigations to manage short-term system risk 7
3.3 The credible event review process seeks to balance risk and cost 8
3.4 New technologies provide challenges and opportunities 9
4 Our summary of feedback on the paper 12

1 Introduction

1.1 The report reviews a system operator paper on short term risk

1 The Electricity Authority (the Authority), in its role as secretariat for the Security and Reliability Council (SRC), engaged Strata to review a paper developed by the system operator titled *System Operator Management of Short-term System Risk* and dated February 2012.

2 The SRC regularly receives papers from the system operator with procedural and technical detail provided. Strata understands that SRC members may not be experts on the detailed operational and procedural functions of the system operator, and may not have the technical expertise to determine whether the system operator papers provide full transparency.

3 Accordingly, the purpose of this review is to provide assurance to the SRC that the system operator's explanations are technically correct and complete and that there are no evident gaps in the system operator's approach to short-term system risk management. As the subject matter of the system operator's paper includes a final section covering the system operator's views of possible future developments, we provide additional perspectives on that section.

4 The key outcome from the system operator's paper, assisted by our review, is to enable informed discussion amongst SRC members on the addressed risks.

1.2 The subject matter covers two short-term risks

5 The system operator manages a range of risks related to short-term (real time) electricity supply security and reliability. The risks described in the system operator's paper are:

(a) Ancillary services (SRC risk rating = 12)

(b) Credible event reviews (SRC risk rating = 10)

6 These risks are included in the SRC's dashboard of risk controls and have been assigned a relatively high risk rating. The dashboard has been built from a bottom up risk analysis, and seeks to ensure that the SRC is looking at the right things.

7 The system operator's paper is structured in four relatively succinct sections:

(a) an overview of key concepts (section 2)

(b) how the system operator procures ancillary services to mitigate short-term system risk (section 3)

(c) the credible event review process and how the system operator seeks to balance security outcomes and cost (section 4)

(d) the future – what is changing and what developments might be needed to remain fit for purpose (section 5).

8 Our review seeks to answer the following questions:

(a) How well does the material communicate to the intended audience?

(b) Are there any significant gaps?

(c) Are the system operator's views of future needs reasonable?

9 Our review does not attempt to polish the system operator's explanations, where we consider these to be difficult to understand without pre-existing knowledge or relevant industry expertise. The SRC may consider that further engagement with the system operator would aid a better understanding of some of the topics covered.

2 Our initial comments are about effective communication

10 Managing short-term system risk is a broad and technical topic. The system operator's 8-page paper covers its topics in the style of an executive summary. The paper briefly introduces technical subject matter and, in some places, provides weblinks to relevant pages on the system operator's website for additional information. We recommend that SRC members follow one or more of these links from an electronic version of the paper to get a sense of the style and depth of the content provided on the system operator's website, which may also aid further understanding. Regarding the topics covered in the paper, the system operator's website provides well written and relatively straightforward explanations and includes links to relevant documents.

11 A significant challenge for a paper like this is to pitch the descriptions at a level appropriate for the target audience. Many of the SRC members have longstanding careers in the industry. For these members, the subject matter may serve to provide a refresher of some of the detail, or, at a minimum, a launch point for SRC discussions. On the other hand, we think relative newcomers may find even this paper's attempt to pitch at a high-level somewhat daunting in several areas; many of the concepts rapidly fall into a very 'deep wells'.

12 Overall, we consider that a single paper is not the best communications medium in all cases, particularly for developing or improving understanding of key technical concepts. Section 2 of the paper, which introduces key technical concepts, is a good example of this.

13 We suggest better understandings of technical concepts to audiences at Council level might be better achieved by augmenting well-edited, de-jargoned text

alongside professionally designed graphics. Such introductory written material could fit with tutorials conducted on-site in the system operator's premises, outside of the SRC's normal meeting cycle if necessary. The system operator has access to technical experts who possess top-rate communications skills; we feel this would be time well spent in pitching technical concepts at an audience-specific level, and answering questions as they arise.

14 As a technical communications paper to a less familiar audience, the early sections of the paper in particular feel rushed and unpolished. In pitching material at a high-level, we think these sections may raise more questions than they answer, particularly for SRC members with less industry context. The website links are helpful but there is scope for a more comprehensive introductory piece that graphically ties the 'deep wells' together.

15 All sections of the paper would benefit from a good technical edit and a tightly edited glossary. The paper's use of terms should also align with the same terms used on the system operator's website. The website hosts a comprehensive glossary, found at https://www.transpower.co.nz/resources/glossary. As an example of the need to ensure terminology consistency, '*cascade failure*' is a paper term not included in the website glossary.

3 Stepping through the paper's sections

16 This section provides our section-specific review of the system operator's paper.

17 While there are no significant gaps in the material presented, the paper in many places falls short of an effective communication about risk management.

3.1 Key concepts include supply and demand balance and system frequency

18 The paper commences with a one-page introduction to some basic power system concepts. Relevant to the subject matter, these concepts include how power systems have to balance supply and demand in real time and how supply and demand imbalances are reflected in the system frequency. This is a critical starting point for the subjects covered in the balance of the paper.

19 The section seeks to address the right key technical concepts but, in its brevity and use of jargon, may present a struggle for non-technical audiences.

3.2 Ancillary services provide risk mitigations to manage short-term system risk

20 This section sets out to explain what an unplanned event is and how different types of unplanned events are categorised as credible events. It goes on to explain the role of ancillary services to mitigate the risk of a cascade failure.

21 The section essentially provides the components of the short-term system risk mitigation *framework* managed by the system operator in real time. The framework has developed over many years and has evolved significantly with the introduction of the wholesale electricity market in the 1990s along with the introduction of market mechanisms to procure some of the ancillary services. Evolution of the framework is a trend that will continue into the foreseeable future, but more on that in the paper's section 5.

22 While no ancillary service categories are missing or strictly incorrect, the section glosses over some important steps that would aid a better understanding with non-technical audiences and help to tie the components back to risk management and the SRC's risk matrix in particular.

3.3 The credible event review process seeks to balance risk and cost

23 The introduction to section 4 highlights an important principle related to system security: it is not possible to mitigate all risks and it becomes increasingly costly to mitigate increasingly improbable risks. There's a balance to be struck between the benefits of mitigating possible but rare events and the cost of procuring ancillary services to cover those events. Benefits and costs are ultimately borne by grid users and consumers alike.

24 Whereas the previous section introduced the system operator's ancillary services toolkit, the credible event review process systematically decides how much of each service to deploy.

25 A positive feature of the credible event review process is its transparency: the system operator publishes its assessments on its website. The paper's Table 1 helpfully sets out the unplanned events currently classified through the credible event review process.

26 As explained in footnote 3, the process is also sufficiently flexible to incorporate the impact of localised, environmental and/or temporary circumstances. This appropriately allows the system operator to take operating experience and rapidly changing circumstances into account within the event classification process.

27 Development and deployment of computer-based tools has enabled significant improvement in formalising processes and assuring decision-making repeatability and transparency. The Reserve Management Tool, briefly introduced in sections 4.2 and 4.4, is an example of this.

3.4 New technologies provide challenges and opportunities

3.4.1 Nothing ever stands still

28 Whereas sections 2–4 covered current risk mitigations on the grid as it exists today, section 5 introduces the climate change and new technology-driven changes electricity grids are confronting globally and how these trends might emanate in the New Zealand context.

29 Overall, section 5 provides a good overview of the system operator's view about how ancillary services will need to evolve over time. The system operator is appropriately concerned with managing system security and reliability with lessening proportions of 'free' inertia. Free inertia arises from a physical property of synchronous machines (generation units) that have historically populated the developing grid.

30 Significantly but not highlighted, geothermal developments and smaller local hydro developments continue to deploy new synchronous machines, which in turn provides additional inertia. Current examples include the Ngawha expansion in Northland and Contact Energy's recent confirmation of the Tauhara development near Taupo. As the paper notes, some wind power developments can also provide additional inertia.

31 At this point, the paper lacks balance – certainly there is a trend towards more inverter-connected, inertia-less generation sources but there are also significant new generation developments that bring new synchronous machines online, along with their 'free' inertia. A graphic representation of the relative technology capacities and their impact on system inertia under a couple of development scenarios, would help convey a sense of the relative magnitudes here, and hence the underlying risk profile.

32 Transpower has produced some useful future scenario work in its Te Mauri Hiko publication series and in other reports published in the Resources section of its website (eg, https://www.transpower.co.nz/resources/distributed-energy-resources-der-report). Linking aspects of section 5 of the paper with published online resources would assist in gaining a cohesive view of possible futures.

3.4.2 Again, a grounding in basic concepts assists overall understanding

33 The foundational technical concepts at this point are:

(a) how a low inertia system leads to an increasingly less stable frequency

(b) how frequency is 'global' (ie, in simple terms, 'the same') across a synchronous electricity network, from the largest remote generation grid-connected at 220,000 volts to the 230 volt power sockets in your grid-connected house.

34 The opening paragraph of section 5.1.1 seeks to explain the basic physics.

35 As inverters are central to the trend driving lower grid inertia, the paper should have explained what an inverter actually is, what it does and how optional inverter (and battery) capabilities may be used to provide ancillary services.

3.4.3 The global context is important as New Zealand follows others in some relevant aspects

36 The paper provides views of the pace of change globally. While many countries are following a similar de-carbonisation path, each country's context is different in important ways.

37 For example, the challenges the grid in Australia faces are demonstrably not equivalent to the challenges New Zealand's grid faces. We have a very different starting point because of the nature of the energy sources deployed over more than a century of power generation development – that is, more hydro, geothermal and wind and less gas, coal and oil. New Zealand is very well placed to benefit from international experience, and from policy and standards development.

38 We consider the paper embellishes the urgency of local action by reference to international growth rates and headline international grid events involving widespread loss of supply to consumers. New technology devices that will '*grow exponentially'* (see section 5.1.2) requires elaboration of the underlying assumptions.

39 To be clear, significant grid events are extremely valuable to understand but the lessons provided by each event need to be translated and applied to our own context. Details matter here but striking headlines may provide inappropriate perceptions.

40 For example, the spectre of cyber security, while undeniably important, needs to be further explained in the paper, particularly as to how – and how many – inverters are cloud-connected, thereby presenting a common mode failure risk. Distributors and solar/battery installation industry experts would have valuable contributions to make to considerations of such risks.

3.4.4 The local context is important, particularly with respect to distributors

41 A gap in the paper is that it is noticeably grid-centric, focusing on things the system operator has visibility of from its central perspective. With respect to system frequency, the system operator correctly identifies inertia-less, inverter-connected energy sources, such as solar panels and batteries, as creating potential short-term risks. Distributed energy resources (DER) are, by definition, connected within distribution networks and may therefore be invisible to the system operator. At some point, short-term operational planning may require the system operator to make assumptions about the real-time levels of DER and further develop operational tools, such as the reserve management tool.

42 We consider the system operator has an important leadership role requiring active engagement with distributors, major grid users and generators. Grid exit points represent network asset ownership boundaries but should not unnecessarily inhibit operational coordination of the grid as a whole. This may tie in with considerations of the *distribution system operator* role that has been discussed amongst participants.

43 Distributors as distribution asset owners already have an important role in enabling connection of distributed generation in accordance with Part 6 of the Electricity Industry Participation Code. Amongst other things, distributor connection and operation standards define standards relating to inverters. These standards incorporate the standard AS/NZS4777.2, recent revisions of which require increasingly capable inverters to address and mitigate increasingly complex power system quality and security issues.

44 Modern, standards-compliant inverters securely installed with coordinated power quality settings applied, will mitigate risks associated with:

(a) *local voltage* management and local user hosting capacity, which are increasingly vexed issues on distributor low voltage networks (ie, the power lines and cables that connect to your house); and

(b) *global frequency* management, by ensuring that settings are applied to inverters that maximise frequency disturbance ride-through (ie, they don't trip prematurely when the frequency decreases or increases outside the normal operating zone).

45 *Distributed generation* needs to evolve into *distributed energy resources* (DER), as batteries are increasingly deployed at grid, local network and consumer levels. Grid-scale batteries have been announced by some of the large generators and rooftop solar panel installations increasingly include a battery, such as the Tesla Powerwall (https://www.tesla.com/en_nz/powerwall).

46 Batteries of all scales and connection locations will play a critical part in future short-term risk mitigation but policy development will require close coordination and consultation of all parties – the system operator, asset owners at grid and distribution level, and regulators. The paper would benefit from providing this wider context.

47 Finally, in section 5.1.3, we wonder how reduced system stability is different to the earlier discussion of the impacts of lower system inertia. If there is a difference, it begs further explanation. Ending the section with reference to Australia grappling with system instability after the fact could leave a false impression about what's actually going on.

3.4.5 Improvements and the need for future work

48 Turning finally to section 5.2, there is no doubt that ongoing review and planning is absolutely necessary, and we commend the system operator for attempting a high-level paper focused on the in-scope key risks and issues.

49 The recent improvements described in the paper represent highly valuable initiatives, brought to fruition by the system operator, participants and the Authority.

50 We understand from system operator and Authority workplans that more such initiatives are in the pipeline.

(a) The example cited of Code and ancillary services procurement plan amendments to be more technology agnostic, enabling ancillary services market participation involving larger scale batteries works on improving the *demand side*.

(b) Enhancements to the reserve management tool, bringing key parameter assumptions closer to physical reality, will further optimise procurement of ancillary services and in turn improve the *supply side*.

(c) Strengthening the underpinning economic analysis central to the credible event review process will further improve *overall efficiency*.

51 The technology integration roadmap cited in the final paragraph has industry-wide significance and importance. We recommend the SRC keeps abreast of this initiative in particular, as a guide to the timelines the roadmap will set out and details of the nature and magnitude of the risk mitigations it will seek to address.

4 Our summary of feedback on the paper

52 As it is drafted at the level of a high-level introduction to a range of technical topics, we could not identify and serious omissions in the way the system operator manages short term system risk. The paper is a summary of current ancillary services, their roles across the frequency spectrum and a future view of industry trends that will create challenges and future risks.

53 Our suggestions for improvement, particularly around delivering high quality future papers that are better aimed at SRC members possessing a wide range of pre-existing technical knowledge, are intended to be entirely constructive. We welcome feedback and debate on any of the points we raise.

54 In our view, there is a case for the SRC to request clearer explanations of short-term risk management focused on risk management that tie into the SRC's role. A formal written scope for papers – which we were not able to locate in this case – is essential.

55 A more tightly specified paper and engagement scopes will help develop an increasingly clear understanding by both parties. Papers alone may not be the best way of addressing particularly complex and technical risk management topics.

56 While current risk mitigations are critical to real time management of the interconnected grid now, future risks and opportunities require significant ongoing engagement between many interested parties, including the SRC.