

Monitoring reliability

Measures available for reporting to the SRC to monitor reliability of electricity supply

28 July 2017

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

Contents

Executive summary	1
1 The purpose and scope of this paper	2
1.1 The purpose of this paper is to provide information about reliability of electricity supply that satisfactorily addresses two open SRC action items	2
1.2 The scope of this paper deals with backward- and forward-looking measures of reliability	2
2 Proposed reliability metrics	3
2.1 Overview of the proposed reliability metrics	3
2.2 Australian Stock Exchange (ASX) contract prices	3
2.3 Under-frequency events (UFEs)	4
2.4 Automatic under-frequency load shedding (AUFLS) events	5
2.5 Instances of scarcity pricing	5
2.6 Grid warning and excursion notices	5
2.7 Reserves dispatch at lower levels than necessary to cover the largest risk	7
2.8 Transmission outage data	8
2.9 EDB monitoring dashboard	10
2.10 Monitoring technology uptake	12
3 Proposed reliability reporting to SRC	13
3.1 Measures that are already public	13
3.2 Measures that the EA can deliver	13
4 Questions for the SRC to consider	13

Executive summary

This paper relates to the monitoring of reliability of electricity supply and addresses the following two open action items:

“Develop a plan for reporting on the performance of the supply chain (such as generation, transmission and distribution) in terms of reliability of supply” (Action item #2 as at 28 July 2017)

“The secretariat is to identify a suite of market measures that may give an indication of the perception of risks to security or reliability” (Action item #8 as at 28 July 2017)

The Security and Reliability Council (SRC) has previously indicated that it is generally satisfied with the information it receives about *security* of electricity supply, but that the breadth of information on *reliability* of electricity supply ought to be improved. Accordingly, we have prepared this paper to explain what reliability measures that the Electricity Authority (hereafter referred to in the first person) can implement given the data that we have. This includes using market-based data to calculate measures of reliability *and security*. In other words, we have interpreted action item #8 above to mean market perceptions to risks of security or reliability.

The approach we took was to look at each part of the electricity supply system in turn—generation, transmission, distribution—to determine what monitoring was being done, and what indicators we could develop with available data that would add to the picture of reliability that exists now. The paper lists these additional indicators and sets out what we can deliver to the SRC and at what frequency.

We considered actual reliability (reliability measured by the past performance of assets) and potential reliability (reliability indicators that are forward looking). As well as reliability of individual components and reliability of the system as whole, further indicators can be developed and brought to the SRC as our resources allow. Regardless of what indicators the SRC wishes to receive, we will continue to use the indicators presented in this paper to help fulfil our monitoring function.

1 The purpose and scope of this paper

1.1 The purpose of this paper is to provide information about reliability of electricity supply that satisfactorily addresses two open SRC action items

1.1.1 This purpose of this paper is to address the following two open action items for the SRC:

“Develop a plan for reporting on the performance of the supply chain (such as generation, transmission and distribution) in terms of reliability of supply” (Action item #2 as at 28 July 2017)

“The secretariat is to identify a suite of market measures that may give an indication of the perception of risks to security or reliability” (Action item #8 as at 28 July 2017)

1.1.2 We are addressing these action items by proposing a list of measures that we can report on given existing data. This list is contained in section 3 below.

1.2 The scope of this paper deals with backward- and forward-looking measures of reliability

1.2.1 In this paper, we use ‘reliability’ to refer to the propensity of equipment or services to fail to function as intended.

1.2.2 Reliability can be backward-looking in the sense that it uses data of failures that have occurred in the past. But it can also be forward-looking in the sense that the past reliability performance can be indicate future reliability performance. It can also be forward-looking in the sense that if a fuel supply is unreliable—hydro inflows for example—then generation may be constrained in the future. The paper presents measures that are both forward- and backward-looking. We categorise measures accordingly recognising that the distinction make not be precise in all cases.

1.2.3 Reliability metrics and trends are useful if they can be used to identify areas of interest to carry out more in-depth analysis to find root causes of issues; such as issues with risk management or maintenance practices. In this sense the measures in this paper are more akin to a temperature gauge in a car—they indicate that there may be a problem without specifically identifying the problem.

1.2.4 Not all interruptions to components of the supply chain are equal. The core grid is built to N-1; so will continue to supply even if some assets trip. Reserves are purchased to cover unplanned generation outages; so the biggest unit can trip without interruption to supply. Outages on distribution networks will have the greatest impact on reliability (from a consumer’s perspective), primarily because it is not economic to build all parts of distribution networks to an N-1 standard. However, data on when reserves are used, when the system frequency drops, or when reserves are used can provide information on the reliability performance of the system as a whole. As such, they are included in the scope of this paper.

1.2.5 Action item #8 asks for market measures of perception of risks. We consider that the measures that fall into this category are measures based on forward markets. These markets have prices that are the market’s best guess of future spot prices. These prices can reflect data and perceptions which is why we are using them for action item #8. These are set out in section 2.2.

1.2.6 We exclude existing security of supply measures from the scope of this paper.

1.2.7 The SRC has indicated that it is satisfied with the level of reporting on security of supply. This reporting includes:

- a) the hydro risk curves
- b) the annual security of supply assessment
- c) the New Zealand generation balance
- d) ad hoc reviews such as the recent on upper-North Island voltage limits.

1.2.8 Consequently we do not discuss those measures in this paper.

2 Proposed reliability metrics

2.1 Overview of the proposed reliability metrics

2.1.1 To develop a monitoring plan for reliability for the SRC, we split the supply chain up into its components and assessed how we could monitor reliability with currently available data.

2.1.2 The resulting reliability metrics from this process were then categorised according as to whether they are forward- or backward-looking. This categorisation comes with the caveat that it may not be precise in all circumstances.

2.1.3 **Figure 1** below provides an overview of the results of the above assessment and categorisation process.

Figure 1: Overall framework for reliability reporting

Ref.	Proposed reliability metric	Backward looking	Forward looking	Relevant supply chain component(s) ¹
2.2	ASX contract prices		✓	F, G, T
2.3	Under-frequency events	✓		G, T
2.4	AUFLS events	✓		G, T
2.5	Scarcity pricing	✓		G, T
2.6	Grid warning and excursion notices	✓		G, T
2.7	Sub-optimal reserve dispatched	✓		G, T
2.8	Transmission outage data	✓		T
2.9	EDB monitoring dashboards	✓	✓	D
2.10	Monitoring of technology uptake	✓	✓	D

2.1.4 The remainder of this section details the nine proposed reliability metrics.

2.2 Australian Stock Exchange (ASX) contract prices

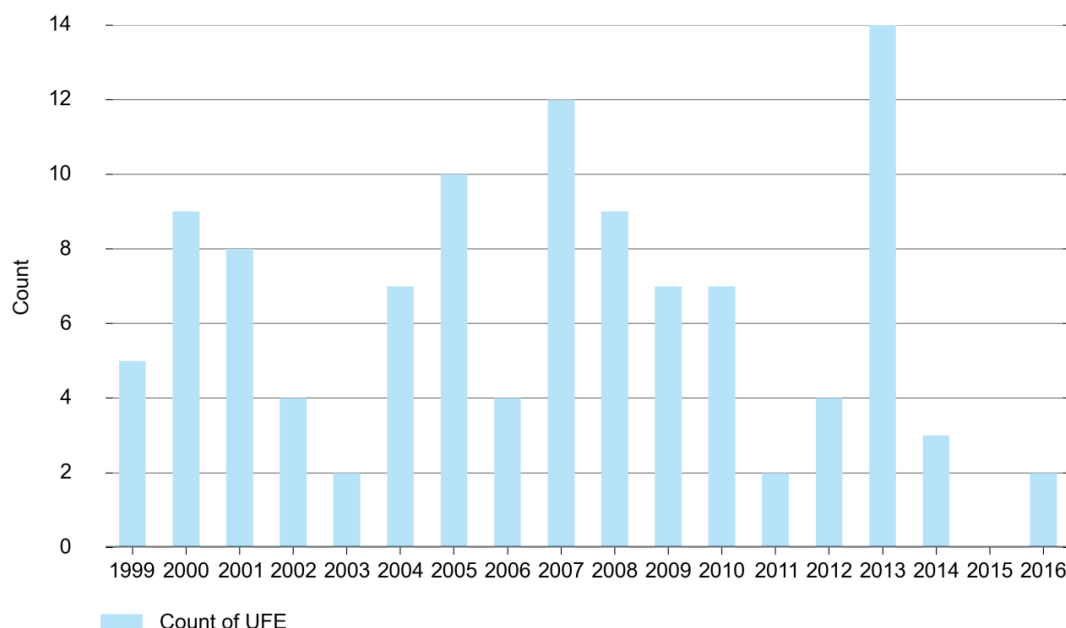
2.2.1 ASX operate a platform for trading of New Zealand electricity contracts.

2.2.2 These forward markets provide information about future supply conditions. In this sense market prices are forward-looking and reflect all available information about factors that affect supply. For example, thermal closure announcements in 2015 and Tiwai decisions have previously been

¹ F=Fuel, G=Generation, T=Transmission, D=Distribution

reflected in the forward curve on the ASX. The forward curve is shown on our Electricity Market Information (EMI) website — www.emi.ea.govt.nz/r/neoo2.

- 2.2.3 However, prices also reflect the perceptions that traders have about future prices. For example, prices in June 2017 started to reflect the possibility of high prices in July. These prices, in part, reflect expectations of future South Island rainfall. These are likely to be based on perceptions as there is no analytical way to predict weather that far in advance. Consequently, these perceptions are reflected in market prices.
- 2.2.4 We anticipate that two cap products will be listed on the ASX later this year:
- a) an 'energy' cap with a strike price of \$130 per megawatt hour (MWh)
 - b) a 'capacity' cap with a strike price of \$300/MWh
- 2.2.5 Caps provide additional information about forward price expectations. A cap only pays out if spot prices go above the relevant strike price. Hence, caps provide information about how many high-priced trading periods are likely to occur. The higher the cap price, the greater the chance that high prices will occur. This gives additional information about potential security issues, for example:
- a) Low prices on both cap products implies the market has no energy or capacity concerns.
 - b) Low prices on the \$130/MWh strike price cap and high prices on the \$300/MWh strike price cap implies the market has no energy issues but forecasts many short-lived capacity issues.
 - c) High prices on the \$130/MWh strike price cap and low prices on the \$300/MWh strike price cap implies the market perceives high energy risks (such as a 'dry year') but has no capacity concerns.
 - d) High prices on both cap products implies the market perceives high energy and capacity risks.
- 2.2.6 Once caps are being traded with enough liquidity to generate reliable data, we will look at what measures might be derived from them. We imagine that price changes and relative price changes will be good indicators of hydro risk.
- 2.3 Under-frequency events (UFEs)**
- 2.3.1 A UFE occurs when the system frequency falls below 49.25Hz. While these do not directly impact system reliability, tracking the frequency of UFEs provides information on the direction of incidence and enables further enquiries.
- 2.3.2 The system operator tracks the numbers of these events. UFEs can be caused by transmission tripping and disconnecting a generator or by a fault in the generator itself.
- 2.3.3 **Figure 2** shows the count of annual UFEs. These numbers are at least in part driven by how much new equipment is being commissioned.

Figure 2: Count of under frequency events

2.4 Automatic under-frequency load shedding (AUFLS) events

- 2.4.1 AUFLS and other large reliability issues are already subjects of reviews. For example, we conducted a review of the 2013 AUFLS trip caused by a Transpower test of Pole 3 of the high-voltage direct current (HVDC) link. We are doing an enquiry into the 2 March 2017 South Island AUFLS trip and subsequent reconnection of two South Island electrical islands.
- 2.4.2 These large events could be caused by transmission or generation issues. The SRC has already, and is expected to do so in the future, receive reviews of AUFLS events.

2.5 Instances of scarcity pricing

- 2.5.1 If an electricity supply emergency causes forced power cuts (typically referred to as emergency load shedding) in one or both islands, the system operator notifies the pricing manager, triggering the scarcity pricing regime. The regime is intended to provide increased certainty of spot electricity prices during these emergency situations, as spot prices can be significantly affected by the forced reduction in electricity demand. This ensures that last resort plant can operate profitably as during these times when such plant is critical, it is important that that market price is high enough to cause it to be dispatched, and that it receives a return that is not set artificially low by involuntary demand response.
- 2.5.2 In a scarcity pricing situation, the scarcity pricing regime sets a \$10,000/MWh price floor and a \$20,000/MWh price cap for the island generation weighted average spot price (GWAP) in the trading periods affected by the emergency.
- 2.5.3 To date there have not being any scarcity pricing events. It is likely that should such an event occur, it would be the subject of a market performance review similar to an AUFLS review.

2.6 Grid warning and excursion notices

- 2.6.1 Grid warning notices come from the system operator because of a range of events, some local and some island- or country-wide. We will track the island- and country-wide notices over time.

These tend to be sent when there are insufficient energy offers to cover forecast demand. We can also track grid emergency notices which follow grid warning notices if the response from asset owners is not adequate. Tracking the number and type of notice provides information on participant behaviour and other issues like fuel delivery, and may highlight trends in to enable further enquiries.

- 2.6.2 Excursion notices are sent by the system operator when voltage or frequency measures exceed stated limits. **Figure 4** shows the annual count of voltage and frequency notices. Tracking excursion notices is another source of data indicating the state of transmission and generation equipment that could raise questions and spark more in-depth investigation.

Figure 3: Voltage excursion notices

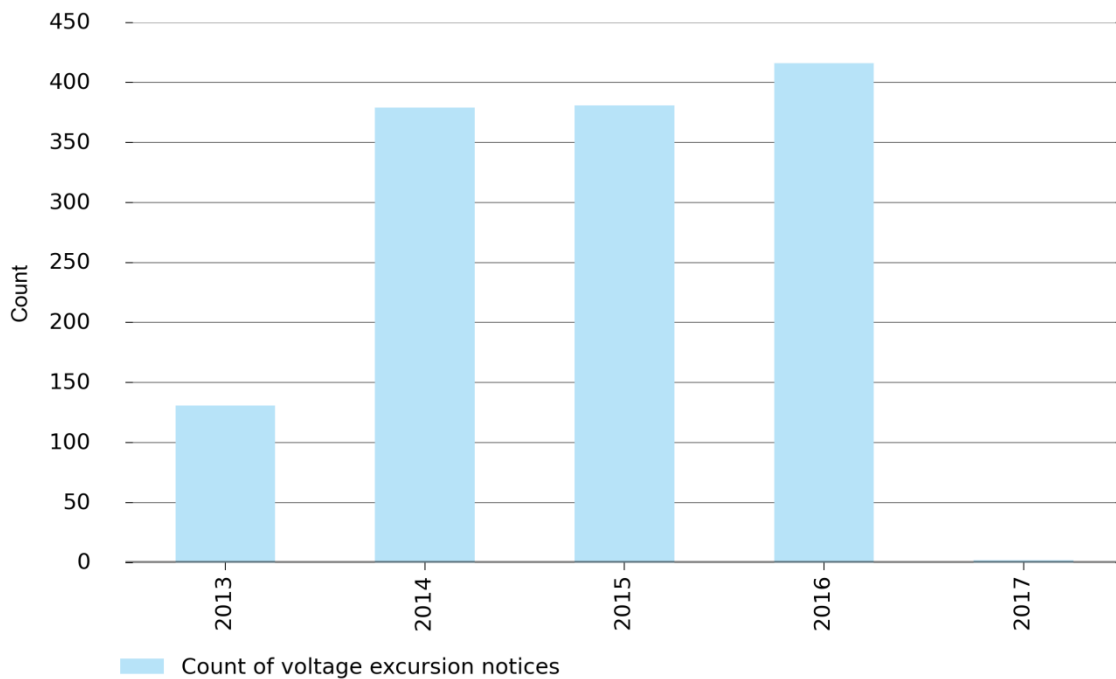
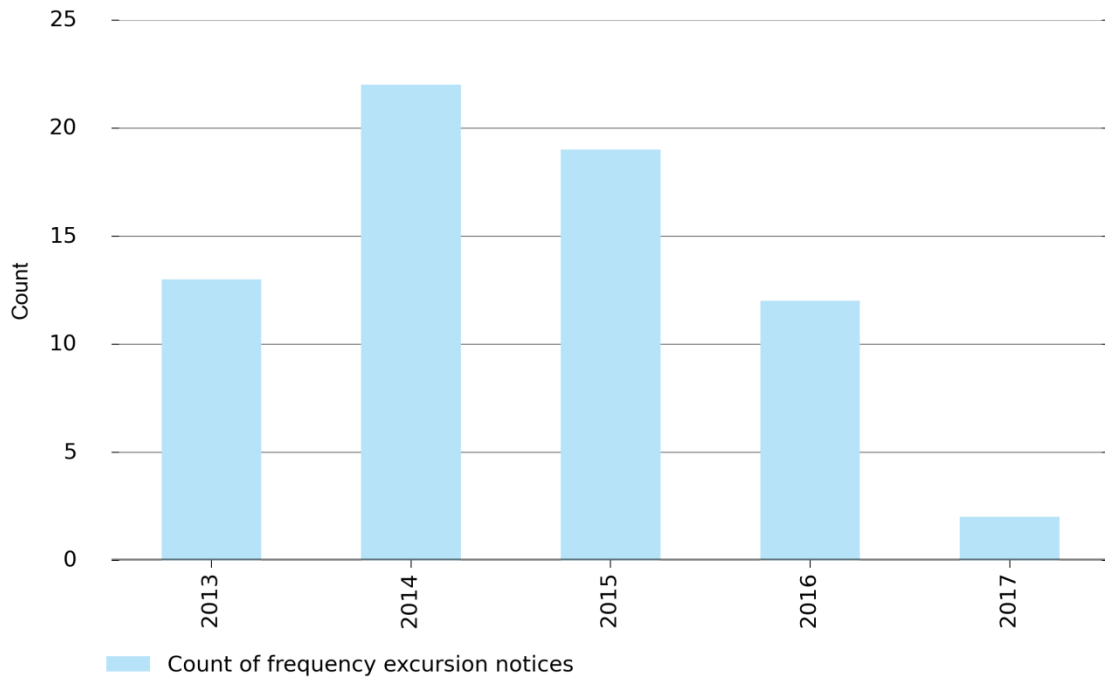
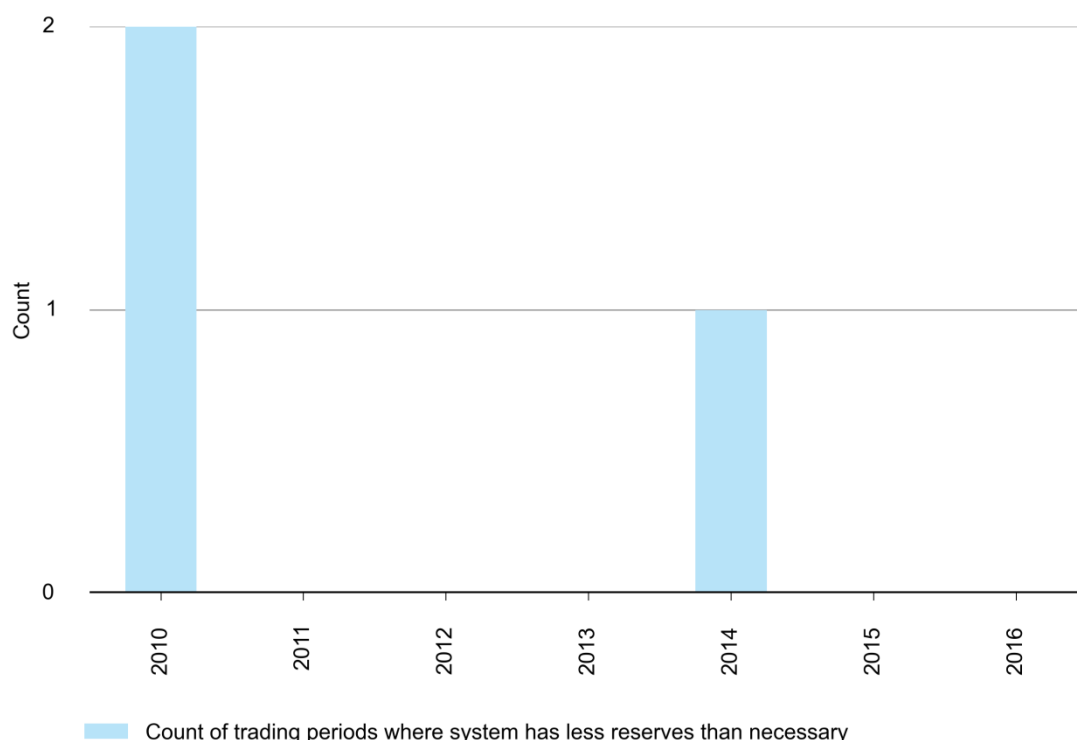


Figure 4: Frequency excursion notices

2.7 Reserves dispatch at lower levels than necessary to cover the largest risk

- 2.7.1 Reserves are required to cover the largest risk in the system, usually a large generator or the HVDC. The system operator dispatches reserves to minimise cost, but may have to dispatch fewer reserves than optimal after an event or due to insufficient generation offers. Tracking the instances that the system is running with less than ideal amount of reserves, while not directly affecting system reliability, may highlight trends that enable further enquiries to be made.
- 2.7.2 We measure of the number of trading periods that the power system is run with less than the required quantity of reserves—this data is shown in **Figure 5**.
- 2.7.3 After an event, the system operator is temporarily blind to how much interruptible load (IL) has tripped. As IL provides a large portion of high quality reserves, this is a problem at a time when the system operator is trying to recover the power system. In the past the system operator used to set the reserve adjustment factors zero after an event, which effectively removes the reserve market. The current approach is to create a fictitious reserve provider.
- 2.7.4 The reason for these approaches is to help the system operator recover the power system after an event when IL has tripped and the system operator does not know how much is available until participants reoffer. However, in both cases the power system is being run at less than the optimal amount of reserves, and the reserve market is at least partially compromised if not removed entirely—undermining the incentives to build peaking generation or IL at a time when this sort of plant is most valuable.

Figure 5: System at less than required amount of reserves

2.8 Transmission outage data

- 2.8.1 Transpower provides us two Excel files that list, in chronological order, forced outages of Transpower's assets. One file contains AC transmission outages, while the other contains unplanned HVDC system outages. Each transmission forced asset outage has a unique identifier along with a code that describes the actual equipment that was removed from service. This is called the primary outage.
- 2.8.2 Associated with each primary outage is a list of additional secondary outages that were removed as a result of the primary outage.
- 2.8.3 Forced outages are those for which the equipment was tripped or manually taken out of service within 24 hours of the fault occurring or being discovered. A circuit is deemed out of service if any circuit breaker is open. In some cases, a forced outage may be recorded against a circuit section rather than the whole circuit, in particular for three terminal circuits. A transformer is deemed out of service if either the HV or LV circuit breaker (CB) is open (an open CB on the tertiary winding is generally not considered to constitute a transformer outage). A trip—auto-reclose—trip sequence is shown as one incident (with one identifier) if the auto-reclose was unsuccessful because of a persisting fault.
- 2.8.4 If a second fault occurs or is discovered when attempting to return equipment to service, a second incident is recorded with a second identifier, e.g. failed auto-reclose because of a protection fault; or a transformer cannot be returned to service because of a CB problem.
- 2.8.5 A number of outages within a relatively short space of time will generally be recorded under one identifier if they all had the same cause, e.g. a tree causes three trippings within 10 minutes. If the

outages are caused by separate faults they will have separate identifiers, e.g. if a circuit trips for lightning 3 times in 10 minutes.

2.8.6 We have analysed this data to look at the numbers of primary and secondary outages each year since 1999, the trends in the numbers of primary and secondary faults, and the median outage duration. Examples of this data are set out below. **Figure 6** shows the numbers of primary and secondary outages since 1999. **Figure 7** shows the mean primary outage duration and the mean maximum outage duration which results from each primary outage for each year since 1999. This data has previously been published in a paper published by the Electricity Engineers' Association and provides a measure of the component reliability in the transmission network.

2.8.7 This data provides a different view of reliability to that set out in section 2.5 above.

Figure 6: Primary and secondary outage counts

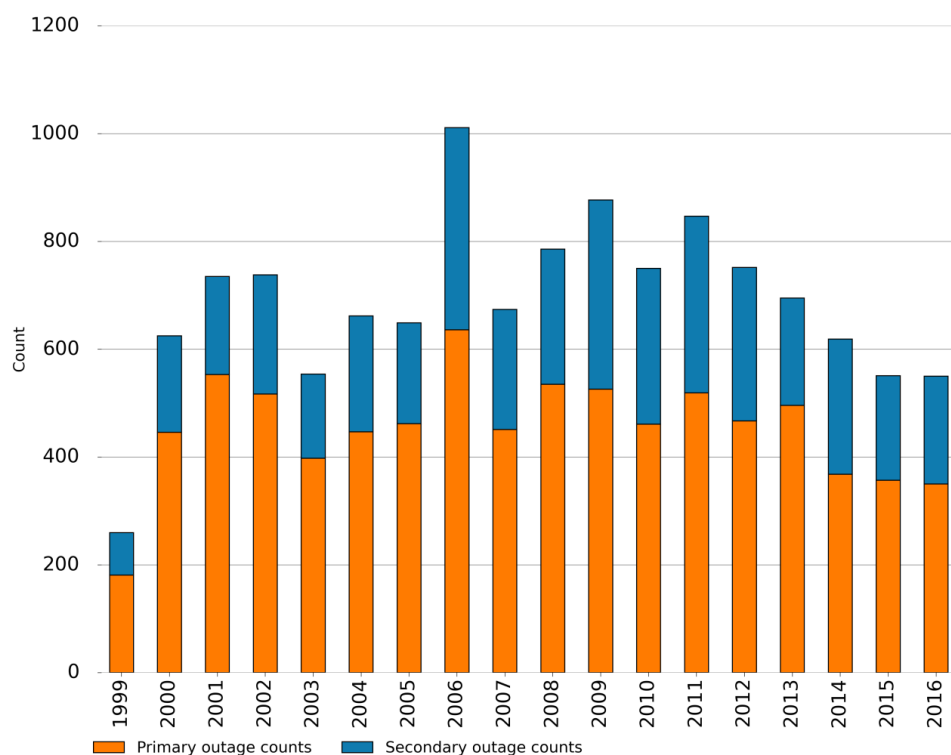


Figure 7: Primary and maximum outage duration in minutes

2.9 Electricity distribution business (EDB) monitoring dashboard

- 2.9.1 The Authority has developed a tool to analyse EDB disclosure data that is provided to the Commerce Commission. The dashboard allows monitoring over time, and comparisons between New Zealand and Australian EDBs. The dashboard's metrics are aligned with our statutory objective to promote competition, reliability and efficiency for the long-term benefit of consumers.
- 2.9.2 We will continue to develop the dashboard and determine what measures are useful enough to publish on our EMI website. In the interim, we recommend reporting the top level reliability measure: the average service availability index (ASAI) to the SRC and any further reliability measures that seem to add value at a later date. ASAI is a measure of the component reliability of distribution, as well as perceived system reliability as distribution outages affect consumers acutely and are a measure of consumer experience with the power system as a whole. It measures availability as the percentage of customer hours (number of customers multiplied by the number of hours in a year) that were actually supplied compared to what could have been supplied.
- 2.9.3 Two views of the ASAI are presented below. **Figure 8** shows ASAI for all EDBs in 2015. It shows the range of outcomes that consumers experience in terms of network reliability. **Figure 9** shows ASAI over four years from 2013 to 2016.

Figure 8: ASAI in 2015

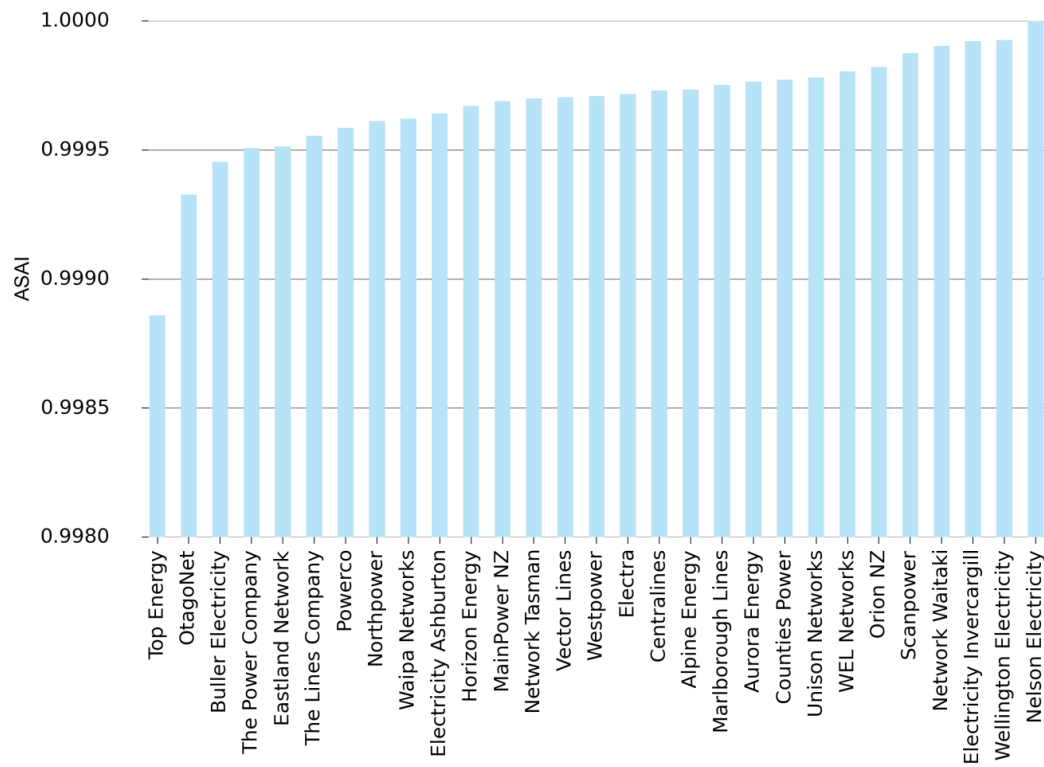
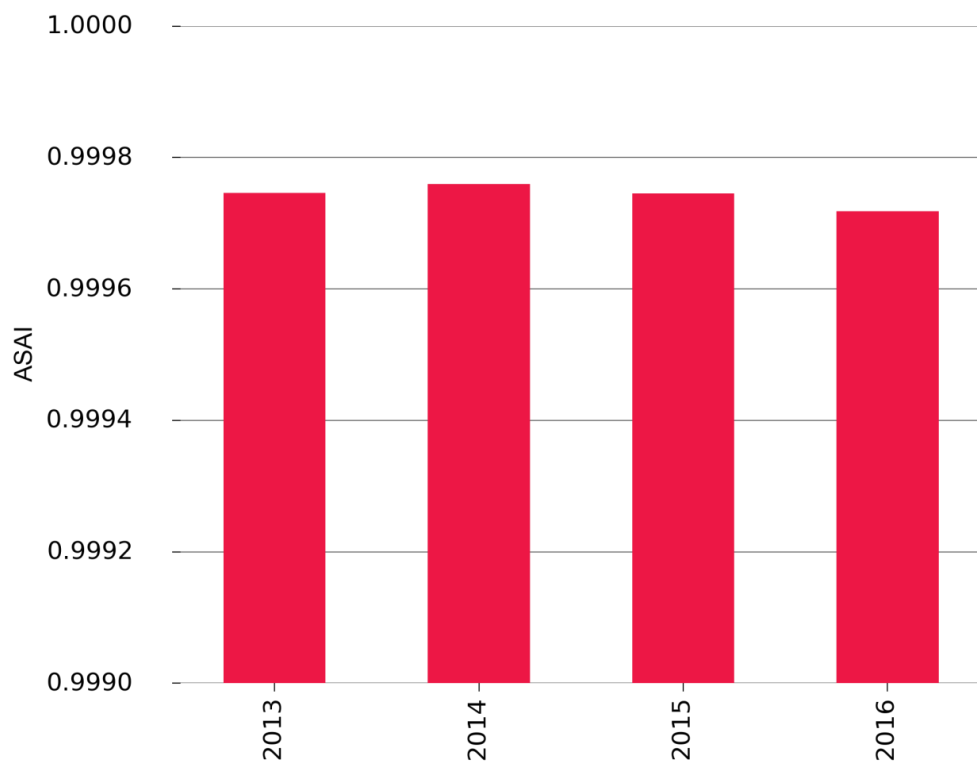


Figure 9: NZ ASAI 2013-2016

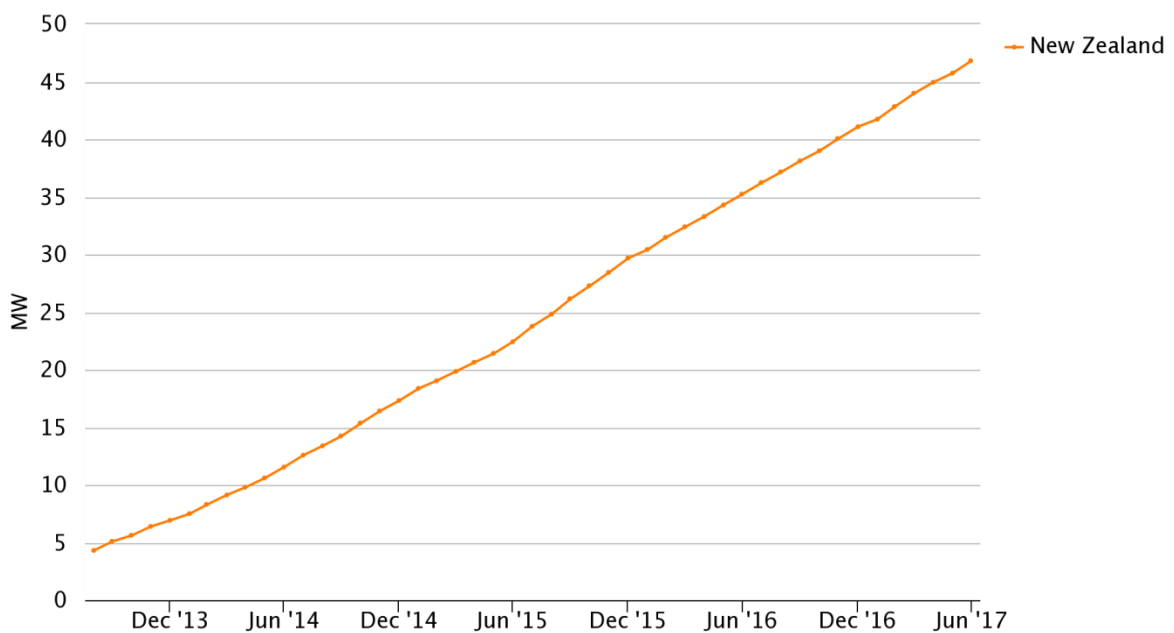


- 2.9.4 This dashboard is being extended to include a cross country comparison of transmission performance. At this point it is unclear if enough data exists to make meaningful comparisons of reliability performance. If such comparisons can be made we will include indicators in our reporting to the SRC.

2.10 Monitoring technology uptake

- 2.10.1 The main way that consumers could affect reliability is due to installing small distributed generation. This could have positive or negative impacts on reliability. A potential positive impact is that more distributed generation is generally good for reliability as it reduces the chance of a single large generation failure having a wide-ranging effect. A potential negative impact is that solar and other small generation can have voltage stability effects particularly at the end of lines in distribution networks.
- 2.10.2 Our EMI website publishes the amount of embedded generation of different sizes and fuel types by area and market segment. Tracking changes to trends in the adoption of distributed generation may provide a forward-looking indicator of reliability, if for example the uptake by consumers was concentrated in a few regions. **Figure 10** below is an example of what is already published on EMI. It shows distributed generation at residential ICPs that is less than 10kW in capacity for all of New Zealand.

Figure 10: Distributed generation less than 10kW capacity for residential ICPs



emi.ea.govt.nz/r/k1qu2

- 2.10.3 Further relevant data and metrics are likely to come from two projects on the Authority's 2017/18 work programme:
- Monitoring for new technologies* will look at what changes could be made to the registry to track emerging technologies such as batteries and electric vehicles. We can use the registry to track the location of installed technologies to identify trends and enable further enquiry.
 - Our market monitoring team will also investigate the hosting capacity of networks. The idea is that the role of distribution networks will change to be more about providing hosting

capacity for various connecting technologies such as batteries. The project will produce a set of measures that will help us track the capacity of networks to host technologies.

3 Proposed reliability reporting to SRC

3.1.1 The following is a list of measures that are either already public, or can be reported to the SRC by the Authority at the indicated intervals.

3.2 Measures that are already public

3.2.1 The following security reporting is publicly available:

- a) any Authority reports into AUFLS events
- b) the ASA and any ad hoc system operator studies
- c) hydro risk curves available from the system operator and on EMI
- d) Transpower information disclosures
- e) changes in embedded generation volumes and trends available on EMI.

3.3 Measures that we can deliver

3.3.1 We could deliver the following measures annually:

- a) the count of under-frequency events (**Figure 2**)
- b) the count of grid warning notices
- c) the count of voltage and frequency excursion notices (**Figure 3** and **Figure 4**)
- d) the count of times when reserves are less than required for security (**Figure 5**)
- e) key metrics derived from our EDB monitoring of disclosed data starting with the ASAI.

3.3.2 We could deliver the following measures every six months:

- a) primary and secondary outage counts (**Figure 6**)
- b) primary and maximum outage duration in minutes (**Figure 7**)
- c) changes in embedded generation volumes and trends available on EMI.

4 Questions for the SRC to consider

4.1.1 The SRC is asked to consider and provide advice on the following questions:

- | | |
|------------|--|
| Q1. | Which of the proposed metrics 2.2 to 2.10 does the SRC wish to see? |
| Q2. | Does the SRC have any preference about when it would receive any of the proposed metrics? |
| Q3. | What further information, if any, does the SRC wish to have provided to it by the secretariat? |
| Q4. | What advice, if any, does the SRC wish to provide to the Authority? |