Independent Pricing and Regulatory Tribunal

# Electricity transmission reliability standards

## An economic assessment

**Energy — Final Report**
August 2016

IPART
New South Wales

Independent Pricing and Regulatory Tribunal

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**Energy — Final Report**
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The Tribunal members for this review are:

Dr Peter J Boxall AO, Chairman

Ms Catherine Jones

Mr Ed Willett

Inquiries regarding this document should be directed to a staff member:

Ineke Ogilvy (02) 9290 8473

Mike Smart (02) 9113 7728

Independent Pricing and Regulatory Tribunal of New South Wales
PO Box K35, Haymarket Post Shop NSW 1240
Level 15, 2-24 Rawson Place, Sydney NSW 2000

T (02) 9290 8400 F (02) 9290 2061

www.ipart.nsw.gov.au

# Contents

# 1 Executive summary

The Independent Pricing and Regulatory Tribunal (IPART) has been asked to recommend reliability standards for electricity transmission in NSW, to apply from the next regulatory period which starts on 1 July 2018.[1]

Historically the level of reliability provided by the NSW electricity transmission network has been high. This has, at least in part, been driven by reliability standards that were set without reference to the value customers place on reliability.

As required by our terms of reference for the review, we have developed reliability standards by applying an economic assessment that aims to identify the level of reliability that would provide the most value to customers. This assessment takes into account both the cost of providing reliability, which is paid for by customers through their electricity prices, and the costs to customers of experiencing outages.

This report sets out standards that aim to strike the appropriate balance between these costs. The recommended standards would not lead to a significant change in the level of reliability customers will experience. They are designed to introduce the concept of customer value into TransGrid's decision making processes. They are also designed to achieve greater flexibility for using non-network solutions in combination with network investment.

This report also explains our methodology and the information we used to develop the recommendations. It outlines the consultation we undertook and our response to the issues raised by stakeholders during the review.

1 The terms of reference are in Appendix A.

## 1.1 Overview of the recommendations

We have recommended a standard for each bulk supply point[2] across the transmission network to apply for the 2018 regulatory period. Each standard requires the Transmission Network Service Provider (TNSP) – TransGrid – to plan and develop the network's supply capability to meet the forecast demand at that bulk supply point so that it provides:

- the required level of redundancy (that is, it specifies the number of back-up arrangements that must be in place to support continued supply of electricity in the event that part of the transmission network fails)
- an allowance within the standard for TransGrid to plan for having some expected unserved energy[3] at each bulk supply point, and
- for TransGrid to meet the requirements for redundancy and expected unserved energy using any combination of transmission network assets, non-network solutions (like back-up power generation) or agreements with distribution network service providers (DNSPs) to use part of an attached distribution network.

While the wording of the standards is common across each bulk supply point, each has its own level of redundancy and allowance for expected unserved energy. The values of these differ as a result of differences in the cost of providing reliability and the mix of customers at each bulk supply point.

The standards are planning standards, which means that TransGrid must plan its network in order to meet the requirements set out in the standards. In order to demonstrate compliance with the standards, TransGrid would need to undertake simulation modelling at each bulk supply point, which would be reviewed by IPART (in its role as license regulator) when assessing compliance with the standard. We are recommending that the standards be implemented as planning standards rather than requiring TransGrid to deliver particular reliability outcomes. Unlike distribution networks, transmission networks tend to have a low number of outages, which means that focusing on output measures may provide a false view of their reliability. There may be no outward signs that there is a major vulnerability in a transmission network until reliability is badly affected.

The recommended standards are provided in Appendix B.

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2 We define a bulk supply point as a location where supply is provided to DNSPs or directly connected customers. Generally the locations are the busbar(s) at TransGrid substations but sometimes the locations are where connections are made to TransGrid's transmission lines or cables (including "tee" connections). A more detailed definition is in the Glossary of this Final Report.

3 Expected unserved energy means the expected amount of energy that cannot be supplied, taking into account the probability of supply outages attributable to credible contingency events, expected outage duration, and forecast load.

At this stage we have not made a final recommendation on the unserved energy allowances for Inner Sydney, Broken Hill, Mudgee, Molong, Munyang and Wellington Town. We have released a separate draft report on the allowances for these bulk supply points and will make a recommendation after considering submissions.

In addition to the recommended standard, we are making a number of complementary recommendations, which we consider will improve future reliability standards. Those recommendations are:

- That further work should be done on the value customers place on reliability (VCR) and that work should be done in time to inform the next review of reliability standards. We consider that IPART is well placed to do this work for NSW, if no national study has been completed in time to be used as an input to the next review.
- That the reliability standards for transmission in NSW should be periodically reviewed. This review should be done 5-yearly prior to the commencement of each regulatory period.

We also support, in principle, the proposed change to the National Electricity Rules recently submitted to the Australian Energy Market Commission (AEMC) by the Australian Energy Regulator (AER) that would require replacement expenditure to be subject to the regulatory investment test for transmission (RIT-T) in the same way that augmentation expenditure is. The proposed rule change is subject to a process of public consultation which is currently being conducted by the AEMC.

We have not formed a view on the detail of the proposal but we agree that there should not continue to be a presumption that like-for-like replacement is the preferred option. In the current environment of lower demand growth and technological advancement it is important that network businesses are required to consider the full range of available options for replacement, in the same way as they are for network augmentations.

## 1.2 How the recommended standards differ from the current standards

There are several important differences between our recommended standards and the current standards. The first is that the recommended standards would allow TransGrid to plan to have a small amount of expected unserved energy at each bulk supply point, over the long term. The standards require TransGrid to consider both the probability and impact of different asset failures, including the load that may be put at risk and the expected duration of any outages.

While the standards continue to specify the level of redundancy that should be provided at each bulk supply point across the network, the recommended standards define redundancy in a flexible way. The recommended standards do not prescribe how TransGrid must invest but instead, explicitly provide for TransGrid to determine the combination of network and non-network solutions required to provide reliability.

By contrast, the current standards specify the network infrastructure that TransGrid must provide to achieve the required levels of redundancy based on specified demand forecasts. In our view this encourages TransGrid to plan the network to remove virtually all possibility of outages resulting from single asset failures, irrespective of how much this costs and without consideration of how much customers are willing to pay for it. On the other hand, it does not require TransGrid to consider other combinations of asset failure, which may have a relatively low probability of occurrence but a significant impact should they occur. The current standards also appear to favour transmission network options rather than alternative, potentially more cost-effective options.

## 1.3 What we expect the outcomes for customers will be

We do not expect that the standards would result in significantly different reliability or price outcomes for customers. The standards would allow TransGrid to accept some degree of expected unserved energy over the long term. However, the allowance for expected unserved energy in the standards is less than 10 minutes per year at 42% of bulk supply points, less than 20 minutes per year at 68% and less than one hour per year at 93% of bulk supply points.[4] This is consistent with the results of our Draft Report.

We have deliberately been conservative in setting the allowances for expected unserved energy. We recognise that substantial reductions in transmission reliability have the potential to create widespread and costly outages so the implications of setting the allowances for expected unserved energy too high could be significant. While we have included our best estimates, there are a number of inputs to the economic analysis that require further work. We consider that standards that are based on an economic approach are valuable. Our conservative recommendations are a first step towards this approach and are designed to ensure that changes in the level of transmission reliability are limited.

On the price side, the transmission component of a typical residential bill is less than 10%.[5] The capital projects that are funded through that component occur relatively infrequently but are costly and long lasting. As a result, the positive impact of lower reliability standards on a customer's bill is unlikely to be significant, particularly in the short term.

4 Number of minutes of expected unserved energy at average demand.

5 AEMO, 2*015 Residential Electricity Price Trends – Final Report*, 4 December 2015, p 54.

Nevertheless, we consider that the standards that are in place from 2018 should start to move TransGrid's network planning and decision-making process away from investing to remove any possibility of outages, regardless of the cost, towards a process that takes better account of the cost of providing reliability and customers' willingness to pay for it. Over the long term an investment process that better reflects the value customers place on reliability should continue to deliver reliability in line with customers' expectations while at the same time bringing some cost savings for customers.

## 1.4 Overview of our methodology

In line with our terms of reference, we conducted an economic assessment to estimate the level of reliability that provides the most value to customers, having regard to the most recent VCRs published by the Australian Energy Market Operator (AEMO). As part of our economic assessment, we developed an optimisation model which we then used to estimate the optimal amount (in MWh and minutes) of expected unserved energy per year for each bulk supply point in the network, except for Inner Sydney.[6]

The optimisation model takes into account variations between different locations that reflect technical aspects of the bulk supply point (for example, the mix of equipment, such as lines and transformers) and differences in the mix of customers supplied (different groups of customers have different VCRs).

The model has the capability to optimise both the level of redundancy and the value of expected unserved energy at each bulk supply point. However, we have decided to specify redundancy obligations at their current level, rather than using the optimal category identified by the model. We consider that this is a conservative approach that recognises that the model is new and there is uncertainty regarding a number of the inputs to the model, including the value of customer reliability (VCR).

As a result, at this stage we have applied the level of redundancy as a constraint and optimised only the value of expected unserved energy. In future reviews, where we expect to have better information available on VCRs and other inputs, we will consider whether to use the optimisation model to determine both the level of redundancy and the allowance for expected unserved energy. This might result in a change in redundancy category for some bulk supply points in the future.

6 Inner Sydney Refers to the Inner Metropolitan Transmission System which is constituted by cables 41 and 42, the 330/132kV substations at Rookwood Road, Beaconsfield, Haymarket, Sydney North and Sydney South and future associated 330kV cables and 330/132kV substations, as well as Ausgrid's 132k transmission network that links those supply points.

We used the optimisation model to identify the expected amount of unserved energy that provides the best balance between the cost of providing reliability and the cost to customers of supply interruptions. The optimisation model provides this 'optimal' amount of expected unserved energy for each bulk supply point across NSW.

The optimal amount of expected unserved energy calculated by the optimisation model is influenced by the level of redundancy assumed at the bulk supply point, the existing mix of assets serving that point, the cost of replacing those assets and the VCR at each bulk supply point, which depends on the mix of customers. Following the release of our Draft Report, we sought comments on the optimisation model we used to estimate the appropriate amount of expected unserved energy in the standards, including the inputs we used and the values we obtained. We have made some changes to the model as a result of the feedback we received.

At a small number of bulk supply points (Broken Hill 22 kV, Broken Hill 220 kV, Molong, Mudgee, Munyang and Wellington Town), the updates we made to our model since the draft report resulted in a large change in the modelled estimates of unserved energy. At these bulk supply points setting the unserved energy allowance based on these results may lead to a significant change in the current level of reliability. We have decided not to finalise the unserved energy allowances in the standards for these bulk supply points because we want to consult further on the appropriate allowances before making final recommendations.

For Inner Sydney, we have not yet made a recommendation on the expected unserved energy that should be included in the reliability standard. TransGrid and Ausgrid, the distribution network service provider for this area, are currently exploring options for the relief of emerging supply constraints. It is likely that substantial investment will need to be made over the 2018 AER revenue determination period.

We have released a separate draft report proposing unserved energy allowances for the Inner Sydney region and for Broken Hill, Molong, Mudgee, Munyang and Wellington Town, which outlines our proposed approach and resulting estimates of expected unserved energy in these areas. We are seeking feedback on this draft report before finalising our recommendations on the unserved energy allowances that should be included in the standards recommended in this report.

## 1.5 List of recommendations and finding

Our recommendations are:

Our finding is:

1 IPART supports, in principle, the AER's proposed rule change that would require replacement expenditure to be subject to the same regulatory process as augmentation expenditure. 55

## 1.6 Structure of this report

The remainder of this report is structured as follows:

- Chapter two provides an overview of our approach to the review.
- Chapter three discusses how we decided on the level of redundancy and allowance for expected unserved energy for each bulk supply point.
- Chapter four sets out the inputs to our analysis, discusses some of the issues associated with them and identifies areas for further work.
- Chapter five explains how TransGrid would demonstrate compliance with the proposed standard.
- Chapter six discusses the expected impact of the recommendations on TransGrid and customers.
- Appendix A provides the terms of reference for the review.
- Appendix B sets out the standards we propose.
- Appendix C provides background information about transmission reliability, the current reliability standards and TransGrid's recent performance.
- Appendix D documents the inputs and assumptions used in our modelling.

# 2 Overview of our approach

We consider that the NSW transmission reliability standards should move away from being heavily based on network capability and should better focus on what customers value. We also consider that the standards should introduce the concepts of probabilistic analysis and positive expected unserved energy into TransGrid's decision making processes as well as making explicit provision for the standards to be met using non-network solutions.

We recommend the following elements:

- an asset redundancy requirement is defined in a more flexible way than the current standard
- an allowance for TransGrid to plan for some expected unserved energy at each bulk supply point, and
- explicit wording within the standards aimed at making it clear that non-network solutions can be used to meet them.

We also considered whether to include a restoration of supply requirement in the standards but our view is that we should not.

Our recommendation is that each of the elements in the standards should be implemented as planning standards, which means that TransGrid must plan its network in order to meet the requirements set out in the standards.

Our general approach is consistent with those in our Draft Report. In our view, this approach will provide greater flexibility around how TransGrid meets the reliability standards than it currently has. It will also ensure that the reliability standards are more responsive to changes in technology. From the customers' point of view this approach is designed to deliver outcomes that are more closely aligned with their expectations around reliability and willingness to pay for it.

Recommendation

1 That the Minister adopts the reliability standards for electricity transmission in NSW set out in Appendix B of this report.

## 2.1 Our objectives

We consider that the recommended standards should achieve the following objectives:

- Move away from standards that are heavily based on network capability and towards one which better focuses on what customers value – our Issues Paper and Draft Report noted the high level of reliability being delivered by TransGrid and the fact that the existing standards were not developed with any reference to the value that customers place on the level of reliability.
- Introduce the concept of positive expected unserved energy into TransGrid's decision making processes – currently the standards that apply are deterministic. They focus on what happens in the event of different contingencies and require TransGrid to ensure it invests to reduce the expected unserved energy associated with these contingency events to zero. Requiring TransGrid to consider the likely probability and impact, in terms of expected unserved energy, of different assets failing provides a step away from a completely deterministic approach to setting reliability standards.
- Make explicit provision for the standards to be met using non-network solutions. The current standards are heavily focused on network capability. This effectively limits the scope for pursuing non-network solutions, even where these may be more economically desirable.
- Not result in a significant change from the current level of reliability experienced by customers – as this will be the first time an economic approach to setting reliability standards has been applied. There is significant uncertainty involved in some of the inputs, for example VCRs. We have undertaken sensitivity analysis but have also noted that there is further work that should be done to develop these concepts for future use.

We have had regard to these objectives in developing our approach for the review.

## 2.2 Which elements should be included in the standards

In order to achieve the objectives above we considered the following elements for inclusion in the standard:

- redundancy requirements – expressed in terms of the back-up arrangements that must be in place to ensure supply can continue to be provided in the event of a failure of part of the network
- an allowance for some amount of expected unserved energy as a complementary measure to work with the redundancy standard to provide greater flexibility around the investment required to meet it, and
- whether to include an additional obligation around the time to restore supply following an outage.

This is consistent with the approach we proposed in the Draft Report. Overall, stakeholders were supportive of this approach. TransGrid considers that it 'achieves an appropriate balance between, on the one hand, the certainty required for network planning and investment decisions and, on the other hand, the flexibility to respond to a changing environment and to pursue the most economically efficient option to address a need'.[7] The three NSW DNSPs, Ausgrid, Essential Energy and Endeavour Energy, also indicated support for the approach.[8] Endeavour Energy also noted that it represents a movement away from deterministic standards and provides for a transition to a more probabilistic planning approach.[9]

### 2.2.1 Redundancy requirements

Our terms of reference require the recommended standards to specify a level of network capability informed by an economic assessment process to be expressed in terms of a network redundancy/N-x standard. Redundancy refers to the back-up arrangements that are in place to allow supply to continue to be provided in the event that part of the transmission network fails.

The current standards are expressed in terms of redundancy for each area and are relatively prescriptive in terms of how TransGrid must invest to meet them. The inclusion of a redundancy requirement is consistent with how transmission reliability standards are specified in other states of Australia and with the recommendations of the Australian Energy Market Commission (AEMC) following its review of the transmission reliability standards. Moving away from a redundancy requirement would be a substantial departure from the standards that are currently in place. We do not consider that there is sufficient evidence to move entirely away from standards that are expressed in terms of redundancy. Therefore, we are proposing to continue to specify the level of 'redundancy' that should apply at each bulk supply point.

However, we are proposing complementary measures within the standards that provide greater flexibility around how the specified redundancy requirements can be met. For example, the standards explicitly provide that the specified level of redundancy can be met:

- even where the full load is not able to be supplied under all covered contingency circumstances, subject to the allowance for expected unserved energy being met (see discussion below)
- by an arrangement that involves the use of non-network solutions and/or the distribution network (see discussion below), or

7 TransGrid submission to IPART Draft Report, 4 July 2016, p 1.

8 Ausgrid submission to IPART Draft Report, 4 July 2016, p 1, Essential Energy submission to IPART Draft Report, 23 June 2016, p 1; Endeavour Energy submission to IPART Draft Report, 1 July 2016, p 2.

9 Endeavour Energy submission to IPART Draft Report, 1 July 2016, p 1.

- by means of an alternative arrangement that does not provide the specified level of redundancy provided TransGrid can demonstrate that this would provide a better outcome for customers.

The definition of redundancy will apply 'post-switching'. In other words, TransGrid may lose supply at a particular bulk supply point following the outage of a system element provided it has the capacity to put in place back-up arrangements that are able to supply a non-zero amount of load. The time that TransGrid will have available to switch to back-up arrangements will be limited by the expected unserved energy allowance. This approach ensures that the definition does not inadvertently prevent non-network solutions from being implemented.

TransGrid supports the additional flexibility that the recommended approach provides, noting that a range of potential solutions currently exist and more are likely to emerge over time.[10] TransGrid notes that allowing flexibility in how these requirements are met will help to ensure that the most efficient solutions are considered.[11] Endeavour Energy was also supportive of introducing a more flexible concept of redundancy, and considers that the 'relaxation of the "N-X" criteria is a suitable method to incorporate probabilistic planning concepts over time'.[12]

### 2.2.2 Allowance for expected unserved energy

We have included an allowance for expected unserved energy in the standard. This allowance gives TransGrid some flexibility in terms of how it meets the specified level of redundancy. Including an allowance for a positive amount of expected unserved energy avoids the need to be too prescriptive about the redundancy requirements (eg, we can avoid specifying the capacity required for each level of redundancy, the time within which it needs to be activated or what type of assets need to be used).

Our recommended standards include a positive value of expected unserved energy that effectively changes the definition of N-1 (or N-2 etc) from no loss of supply (no expected unserved energy) in the event of an asset failure to some expected loss of supply, with a limit around how much loss of supply it is acceptable to plan for. This would mean that where it is economic to do so TransGrid could reduce costs by, for example, having in place a back-up that may require some start-up time, putting in place load shedding agreements and/or downsizing the capacity of some of the assets.

10 TransGrid submission to IPART Draft Report, 4 July 2016, p 2.

11 TransGrid submission to IPART Draft Report, 4 July 2016, p 2.

12 Endeavour Energy submission to IPART Draft Report, 1 July 2016, p 1.

Some flexibility in the redundancy requirements that are in place in other states of Australia exists. However, rather than considering expected unserved energy these standards tend to focus on the amount of demand (in MW) that may be put at risk. In Queensland and Tasmania this flexibility is in the form of provision for loss of load. In South Australia, an availability standard of 95% applies to network support arrangements.[13]

After considering the approach taken in other jurisdictions, and the overall objective of providing some flexibility around how the redundancy standard is met, we prefer the inclusion of an expected unserved energy allowance over one that is based on energy at risk or on a percentage of time. In our view expected unserved energy is more relevant as a measure of reliability.

In response to the Draft Report, Essential Energy considered that the expected unserved energy allowance is likely to be converted into an energy at risk value for compliance purposes anyway and as such, specifying the energy at risk directly would be a simpler method.[14] We do not agree with this.

We remain of the view that expected unserved energy is a superior indicator of the level of reliability of the network and should be the focus of the standard. It is broader than a load (or energy) at risk measure as it takes into account both the probability of outages occurring and the expected impact, including the duration of outages, whereas load at risk does not. In order to demonstrate compliance with this expected unserved energy allowance TransGrid will need to consider both the probability and impact, in terms of unserved energy, of different asset failures occurring. The impact will be affected by the back-up and switching arrangements that are in place as well the time it would take to restore supply.

In the draft standards we proposed that TransGrid should plan for 'credible contingency events' as defined in the National Electricity Rules. However, in the final recommended standards we are more specific about the circumstances that must be considered when measuring expected unserved energy. The recommended standards now specify that the expected unserved energy is the amount of energy that cannot be supplied taking into account the following:

- System normal.
- Single transformer failure, or equivalent system element.
- Single line failure, or equivalent system element.
- Double transformer failure, or equivalent system elements.
- Double line failure, or equivalent system elements.

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13 Essential Services Commission of South Australia, *Electricity Transmission Code TC/08*, 29 October 2015, clause 2.12. The Essential Services Commission of South Australia notes that the current wording of the availability standard is ambiguous, in that it does not define the term "availability". Consequently, the Commission is proposing to replace the existing clause 2.12.1(a) of the Code to clarify that the network support arrangement must have at least 95% availability on the occasions it is called upon. (Essential Services Commission of South Australia, *Electricity Transmission Code Review - Draft Decision*, March 2016, p 11).

14 Essential Energy submission to IPART Draft Report, 23 June 2016, p 4.

We expect that including an allowance for TransGrid to have some expected unserved energy in the reliability standards and requiring TransGrid to consider the probability and impact of asset failures occurring will, over time, change the planning philosophy of TransGrid. It should provide greater flexibility to TransGrid to find the optimum mix of firm network capacity, network back-up (post-switching capacity), switching arrangements and network support in order to meet the expected unserved energy limit at the least cost. It also better reflects customers' willingness to pay for reliability than a requirement to have no expected unserved energy associated with a particular set of asset failures.

There was some confusion in relation to how the unserved energy allowance in the Draft Report should be interpreted as we expressed the value as a long term average.[15] We have now removed the word 'average' from the standards in order to eliminate this confusion. We consider that the allowance is a maximum amount in each year, not an average that is specified over a particular number of years. The reference to long term average contained in the draft standards refers to the need to use long term (life cycle) average asset failure rates, which were used to calculate the allowance for expected unserved energy. These long term average failure rates will also need to be used by TransGrid in demonstrating compliance with the standards (see Chapter 5 for more information).

### Flexibility in the unserved energy allowance

As noted above, we propose to include flexibility in the reliability standards for TransGrid to provide less redundancy than is specified in the standards in certain circumstances. TransGrid would need to demonstrate that its proposed alternative provides a greater net benefit. In response to the Draft Report, Ausgrid considers that there should be a similar provision in the standards that relates to the unserved energy allowance.[16] Ausgrid argues that this would likely result in better customer outcomes as cost benefit methodologies become more sophisticated.[17]

We have included the flexibility around redundancy largely as a means of allowing for new technologies that may improve reliability. We anticipated that this flexibility around redundancy would be limited by the unserved energy allowance, which would still need to be complied with. It is conceivable that new technologies may also arise that change the balance between the cost of providing reliability and the value to customers and as a result, that lead to a different optimal value of unserved energy.

15 Essential Energy submission to IPART Draft Report, 23 July 2016, p 4.
16 Ausgrid submission to IPART Draft Report, 4 July 2016, p 1.
17 Ausgrid submission to IPART Draft Report, 4 July 2016, p 1.

We consider that:

- Technological change would be expected to reduce, not increase, the cost of providing reliability, suggesting higher reliability/less expected unserved energy not lower reliability/more expected unserved energy.
- The standards may not have the requisite degree of certainty if there is a significant degree of flexibility allowed in the unserved energy allowance.
- It would be appropriate for any significant change to the reliability outcomes under the standards to be determined by the Minister, as standard setter, rather than through IPART's compliance process.

However, we also acknowledge that there may be a need for some flexibility in relation to the unserved energy allowance.

The expected unserved energy results from the combination of system capacity, available back-up, and switching and repair strategies. Our optimisation model, which finds the optimal value of unserved energy based on the least-cost combination of these strategies, for the most part assumes that these things are continuous.

In practice the assets and strategies available to TransGrid come in discrete amounts of capacity/time (eg, for lines and transformers only particular sizes are currently available, for non-network solutions there are likely to be practical minimum values). Essential Energy makes this point in its submission on our Draft Report noting that 'the assumption that standby capacity is divisible, appears to be an interesting simplification that may not well represent the bulk supply points modelled within regional NSW'.[18]

We are not recommending making any allowance for this by adding a margin to the optimal unserved energy allowances, other than we have rounded the optimal values up to the nearest whole minute.

However, we accept that there are circumstances when it would not be in the interests of customers to require TransGrid to meet the unserved energy allowance. For example, if a bulk supply point has a standard of 5 minutes per year – TransGrid may be able to put measures in place that achieve expected unserved energy of 5.6 minutes using available increments of capacity/switching/repair strategy. But, because it is not possible to invest in the increment needed to reduce the unserved energy allowance by an additional 0.6 minutes, TransGrid may be left facing a set of relatively costly options in order to comply with the standard. In these circumstances, allowing TransGrid to have expected unserved energy of 5.6 minutes would represent better value to customers than requiring TransGrid to invest to bring unserved energy down to less than 5 minutes.

18 Essential Energy submission to IPART Draft Report, 23 June 2016, p 3.

For these reasons we support Ausgrid's suggestion to incorporate some flexibility around the unserved energy allowances in the standards. We recommend that the standards include an additional clause that provides flexibility around the requirement to design for a level of expected unserved energy. We recommend that this clause includes an additional obligation that requires any plan submitted to IPART for approval under this clause would not result in a material reduction in the level of reliability at any BSP compared with what is required by the standards.

The inclusion of a materiality threshold means that there would be a limit to the amount of flexibility included in the standards. This would provide greater certainty to both TransGrid and customers. We also consider that this limit on the flexibility included in the standards would mean that there would be no need for IPART to consult during this process or to recommend a change to the standards to the Minister for decision. We recommend that the decision on whether a particular proposal would result in a material reduction in reliability at any bulk supply point would be made by IPART as part of the compliance process.

Further information about how we propose to assess compliance with the expected unserved energy allowance, is set out in Chapter 5 of this report.

### 2.2.3 Restoration times

The AEMC recommended, and our terms of reference ask us to include as part of the reliability standard, a requirement relating to when supply would need to be restored following an interruption, as well as a required level of network capability (ie, redundancy).

We noted in our Issues Paper that we were considering whether it was necessary to include supply restoration times or whether an alternative measure of reliability, such as an allowance for unserved energy, would be more suitable.

We consider that the reliability standards should not include supply restoration times. We understand that the AEMC's intention of including a time-to-restore component in the standards was to complement the redundancy requirement, which is an input parameter, with an output parameter that directly captures the level of reliability customers can expect from the transmission network.

We consider that the expected unserved energy parameter in our recommended standards is consistent with this intention. Indeed, as recognised by the AEMC, TransGrid will need to make assumptions about the expected time to restore supply in the event of an interruption in order to calculate the level of expected unserved energy. The reasonableness of these assumptions could be tested through the reliability compliance process.

Ausgrid supports the inclusion of an expected unserved energy parameter in the reliability standards in favour of a time-to-restore parameter in its submission to our Issues Paper:

> …there is an argument that [unserved energy] is a superior measure to simple restorations time because it is scaled to the size (and presumably economic impact) of the interruption. If a larger amount of load is affected, quicker restoration time is required to meet the unserved energy limit. If only a small amount is involved, the restoration time limit is relaxed. This is an appropriate economic trade-off. In addition, unserved energy calculations can account for situations where there is a more complex restoration profile. For example, where a large amount of interrupted load can be restored quickly and a smaller 'tail' takes longer.[19]

ETSE Consulting also noted that requiring specific restoration times for an unplanned outage may artificially constrain TransGrid if the outage were to occur at non-peak times.[20] We consider that the standards should not include a requirement around restoration times. In our view, it is not warranted because:

- The requirements around expected unserved energy provide some protection for customers, particularly in peak times as both the expected size and duration of outages contributes to the expected unserved energy.
- There is a broad range of reasonable restoration times depending on the particular circumstances of the supply interruption. Unless the time to restore standard caters for these situations, it may inadvertently drive significant and uneconomic expenditure. However, building this degree of flexibility into the standards undermines its value in providing certainty and protection for customers.
- A time to restore standard for electricity transmission would apply to bulk supply points and not to end-customers. To provide reassurance to end-customers that supply would not be off for an extended time but still acknowledge that in some circumstances reasonable restoration times for transmission may be significant, the standard would need to require the relevant DNSP to rotate the burden of unserved energy between different end-customers. Such an obligation would be outside the scope of the transmission reliability standard.

In response to our Draft Report, TransGrid supported our approach and agreed that expected unserved energy is a more appropriate measure than restoration time.[21] Endeavour Energy also supported this approach submitting that mandated standards around supply restoration times would not be conducive to increased efficiency and would be difficult to implement as a planning standard.[22]

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19 Ausgrid submission to IPART Issues Paper, 22 January 2016, p 6.
20 ETSE Consulting submission to Issues Paper, 27 January 2016, p 5.
21 TransGrid submission to IPART Draft Report, 4 July 2016, p 2.
22 Endeavour Energy submission to IPART Draft Report, 1 July 2016, p 1.

Recommendation

2 The NSW transmission reliability standards should include a requirement relating to the level of redundancy that must be provided together with an allowance for a positive value of expected unserved energy at each bulk supply point. The reliability standards should not include a requirement around restoration times.

## 2.3 Measures to introduce greater flexibility for non-network solutions

The way in which reliability standards are drafted can have a significant impact on the potential for non-network solutions to be a viable alternative to network investment.

The current standards, which specify reliability in terms of required redundancy (N-x), do not specify how that level of reliability will be met. For example, reliable electricity supply could be provided by a combination of cables, transformers, generators, demand-side management or battery storage. However, the form of the reliability standards may inadvertently limit the potential for some types of non-network alternatives, even if they are the most efficient option.

For example, in some cases a back-up generator may be much cheaper than a duplicate line to provide reliability in the event of the forced outage of a network element, but the generator may take some time to be called into operation. If the reliability standards require N-1 reliability 100% of the time, the generator option may be excluded, even if customers would prefer (on a cost basis) to endure a loss of supply for a short period of time until the generator is operational, rather than paying much more for a network solution.

It is not possible to consider all of the types of solutions that will be available over the 2018 regulatory period. Some of the potential options for providing reliability, particularly non-network solutions, are not able to be considered in advance of when an investment decision is needed. Others depend on the forecast maximum demand and load profile at each bulk supply point, which changes over time. In addition, unforeseen changes such as improved technology may also enable new options and/or reduce the cost of others. Part of our aim in making recommendations on the standards is to ensure that they provide enough flexibility so as not to prohibit the uptake of new technologies.

To facilitate the adoption of non-network solutions where they are the most efficient solution, we propose the following elements in the reliability standards:

- The terminology used in the proposed standards focuses on the supply of electricity (the service output), rather than the specific technology used to meet this supply (the inputs). This provides scope for non-network options to be pursued and reduces the bias towards transmission network assets such as cables and transformers.

- The standards specify the 'supply capability' at each bulk supply point. They do not specify how this supply capability is provided.
- The standards clarify the potential role of non-network solutions by noting that supply capability may be met by means of the transmission network, distribution network, network support arrangements, back-up supply capability, or any combination of these.
- The standards also allow for the supply capability to be met by an alternative arrangement that is equivalent to the specified level of contingency, if it meets the standards specified in relation to the level of expected unserved energy. These alternative arrangements could include alternative network options (for example, a single underground cable rather than two overhead cables), or non-network options (for example, generation or battery storage).

We propose that the reliability standards should be framed to promote the most efficient network or non-network solution by using technology-neutral language, rather than promoting a specific type of network or non-network solution. In response to the Draft Report, which also proposed these measures, TransGrid supported this 'use of output-focussed and solution-agnostic terminology'.[23]

Recommendation

3 The NSW transmission reliability standards should facilitate the use of non-network solutions and other complementary approaches, such as the use of distribution network assets, where this is the most cost-effective approach.

## 2.4 Planning vs performance standards

We have considered whether each of the elements in the standards should be specified as a 'planning' standard or a 'performance' standard. We are recommending that the standards should be implemented as planning standards, consistent with the current reliability standards.

The difference between these two types of standards is at what point compliance with the standard is assessed:

- Planning standard – TransGrid must plan its network according to specified criteria. Compliance with the standard is assessed at the planning stage. We expect that this would involve TransGrid undertaking simulation modelling as part of the planning process, which would be reviewed when assessing compliance with the standard.
- Performance standard – TransGrid must deliver outcomes that meet the specified standard of reliability. As with the planning standard, TransGrid will need to plan its network to meet this standard, but compliance with the standard is assessed by reviewing actual network performance.

23 TransGrid submission to IPART Draft Report, 4 July 2016, p 2.

Because redundancy is essentially about building/contracting for particular network capability, we consider that it is best characterised as a planning standard. As a result, the current standards, which are all about network redundancy, are heavily planning based and include no performance elements. The additional element that we are proposing to introduce into the standards – an allowance for unserved energy - could either be included as a planning or performance standard.

Performance standards have some advantages over planning standards: they are simpler to understand, the compliance process is likely to be less involved, and hence less costly, and they provide greater certainty to customers around what level of reliability they can expect to receive. However, for a performance standard to be appropriate there must be a sufficiently close relationship between planned outcomes and actual outcomes.

Prolonged under-investment in transmission networks may not translate to short term observable reductions in reliability outcomes. As a result, the AEMC considers that measures relating to the capability of network elements are more appropriate for transmission reliability standards.[24] The AEMC makes a distinction between the nature of transmission networks and distribution networks, pointing out that there is a greater ability to observe under-performance in distribution.[25]

Similarly, the Productivity Commission (PC) review identified a number of characteristics of transmission networks that make it difficult to use actual performance as a tool to assess their reliability:[26]

- a low number and short duration of outages at a given time can lead to false optimism about the inherent reliability of the network over time
- unlike distribution networks it is difficult to observe latent vulnerability in transmission networks, and
- unlike distribution networks, it may be difficult to hold TNSPs accountable for failures in network reliability since some factors affecting system reliability lie outside the control of the network business (such as major natural disasters).

The PC concluded that, unlike for distribution networks, it is impossible to rely on output measures as leading indicators of the reliability of transmission networks, noting that 'all arrangements involve 'big brother' in one form or another'.[27] The PC considered transmission reliability as analogous to safety management systems – just as for major failures with a transmission network, it

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24 AEMC, *Review of the national framework for transmission reliability - Final report*, 1 November 2013, pp 32-33.

25 AEMC, *Review of the national framework for transmission reliability - Final report*, 1 November 2013, p 33.

26 Productivity Commission, *Electricity Network Regulatory Frameworks – Inquiry Report*, 9 April 2013, Volume 2, pp 584-585.

27 Productivity Commission, *Electricity Network Regulatory Frameworks – Inquiry Report*, 9 April 2013, Volume 2, p 591.

is not acceptable to simply wait and see if a major safety problem eventually arises. It is necessary to agree on a set of risk reduction measures and have an auditing process to confirm that these are in place and operating as intended.

Including an expected unserved energy measure as a planning standard is both consistent with the arguments outlined above and would work together with the redundancy requirements within the planning process. As a result, we consider that it should be specified as a planning standard.

Ausgrid's submission to our Issues paper said that in recommending reliability standards we should have regard to minimising unnecessary administrative burden.[28] While we accept that there will be greater compliance costs involved in including an expected unserved energy measure as a planning standard, in our view the alternative, including this measure as a performance standard, is not suitable for a transmission reliability standard.

In response to the Draft Report, Essential Energy and Endeavour Energy supported the application of the standards as planning standards.[29]

Recommendation

4 The NSW transmission reliability standards should be assessed as 'planning' standards. TransGrid should be required to undertake simulation modelling as part of its network planning in order to demonstrate its compliance with the standards to IPART.

## 2.5 Bulk supply points covered by the standard

Our recommended standards include a list of bulk supply points and the redundancy category and unserved energy allowance that applies at each. We have made some changes to this list since the Draft Report and have included an additional clause within the standards setting out a process for adding new bulk supply points to the standards.

### 2.5.1 Changes made to the list of bulk supply points covered by the standard

We recognise that there are some bulk supply points that are so closely linked within the network that they are difficult to differentiate in terms of reliability. In our Draft Report we indicated that we would like to jointly model these grouped supply points for the final report.

Having considered how we would do this in more detail, we now consider that the additional level of complexity to model bulk supply points as a group is not warranted. As a result, we have continued to model each bulk supply point

28 Ausgrid submission to IPART Issues Paper, 22 January 2016, p 1.

29 Essential Energy submission to IPART Draft Report, 23 June 2016, p 3; Endeavour Energy submission to IPART Draft Report, 1 July 2016, p 1.

separately, but to present a 'group' standard where appropriate. To derive the unserved energy allowance for each group we:

- added the unserved energy allowances in MWh for the individual bulk supply points within the group, then
- converted this value to minutes by dividing it by annual average demand at the combined individual bulk supply points.

In response to the Draft Report, TransGrid identified four groups; each comprised of 2 to 3 BSPs. We have decided to adopt these groupings in the recommended standard (Table 2.1).

**Table 2.1 Supply point groupings included in the recommended standard**

| Group name in standard | Bulk supply points included in group |
|---|---|
| Canberra 132 kV and Williamsdale 132 kV | Canberra 132 kV<br>Williamsdale 132 kV |
| Macarthur 132 kV and 66 kV | Macarthur 132 kV<br>Macarthur 66 kV |
| Orange North 132 kV/ Orange 66kV | Orange North 132 kV<br>Orange 66 kV |
| Taree 66 kV and 33 kV | Taree 33 kV<br>Taree 66 kV |

**Source:** Advice from TransGrid.

This means that some of the individual bulk supply points that were listed in the draft standards have now been incorporated into a new supply point grouping.

In addition to this, we have also now decided to exclude from the standards some of the bulk supply points that were included in our Draft Report based on advice received from TransGrid. TransGrid has advised that seven BSPs that were included in the Draft Report should not be included in the standards for the reasons set out in Table 2.2.

**Table 2.2 List of bulk supply points not covered by the standard**

| BSP | Reason for not including |
|---|---|
| Boggabri East | Single customer on negotiated contract |
| Boggabri North | Single customer on negotiated contract |
| Brandy Hill 132 kV | Not distinguishable from Tomago 132kV |
| Cooma 11 kV | New Cooma site only has 132 and 66kV BSPs |
| Finley 132 kV | Used for back-up only (line usually open) |
| Munmorah 330 kV (via old Power Stn Txs) | Power station will be decommissioned |
| Yass 132 kV | Used for back-up only (line usually open) |

**Source:** Advice from TransGrid.

### 2.5.2 New bulk supply points established during the 2018 regulatory period

The current standards include a default level of redundancy specified for the entire network which is then varied as needed for specific areas. This means that any new bulk supply point is automatically captured by the standards. However, the standards we are recommending instead specify a level of redundancy and an allowance for unserved energy for the current bulk supply points. This means that unless we make provision for a standard to apply to any new BSPs that are put in place during the regulatory period, there will be no applicable standard.

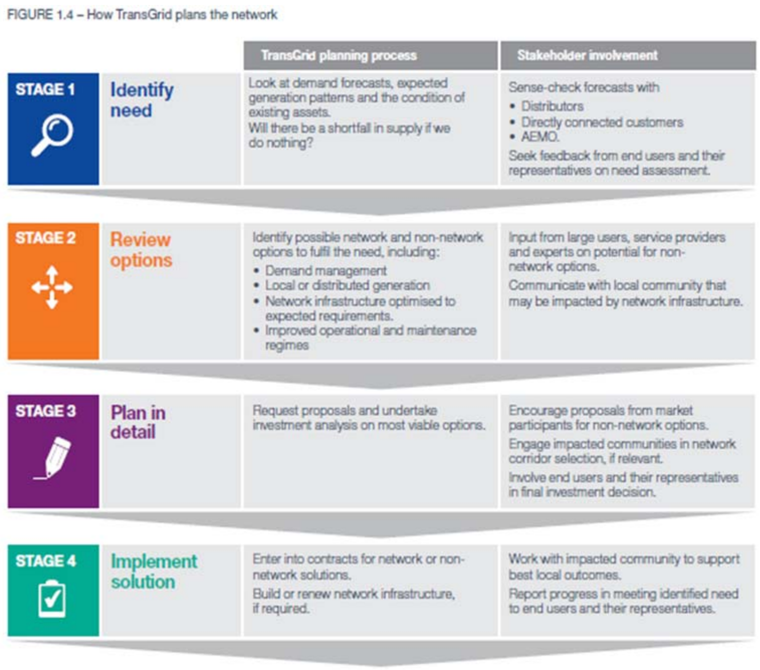
TransGrid indicated that there are possible new bulk supply points on the planning horizon but there is significant uncertainty regarding the timing of these.

We recommend that a process be put in place for bringing any new bulk supply point into the standards before the supply point starts operating. This would ensure that the standard that is in place at the time TransGrid makes its investment decisions is a reasonable reflection of the costs and benefits of reliability at that bulk supply point. Because transmission assets are costly and long-lived (45+ years) it is important that the right signal is sent at the planning stage. Once TransGrid has made the initial investment in infrastructure, subsequent changes to the reliability standard are unlikely to have much impact except in the very long term.

We have included a section in the recommended reliability standards that requires TransGrid to submit a proposal to IPART when a new bulk supply point is planned. TransGrid would be required to propose a level of redundancy and allowance for unserved energy at the new BSP and provide supporting information required for IPART to assess this proposal. TransGrid would be required to notify us at, or before, Stage 3 of TransGrid's network planning process (see Figure 2.1).

Once we receive a proposal from TransGrid, we would consult on this before making a recommendation to the Minister to include the proposed bulk supply point into the standard.

**Figure 2.1 TransGrid's network planning stages**




**Data source:** TransGrid, *Transmission Annual Planning Report 2016*, 30 June 2016, p 15.

## 2.6 How often reliability standards should be reviewed

Under IPART's terms of reference, the proposed standards are to be recommended to the Minister in time for standards to be set in advance of TransGrid's next revenue determination period, which starts on 1 July 2018.

We recommend the standards be reviewed again in time for them to be revised (if necessary) in the following regulatory period, which begins on 1 July 2023. There are several reasons for periodically revisiting the standards:

- It is likely that additional capital expenditure projects will be proposed for the following regulatory period, at which point more detailed modelling of the affected bulk supply points can be undertaken to provide a tailored estimate of the maximum level of expected unserved energy (given the VCR and capital expenditure cost at that bulk supply point).
- The modelling work undertaken involved a range of data that may be updated, or for which better estimates or data sources may become available. This could include, for example, the estimates of VCR for different customer groups or locations; asset degradation schedules; or capital expenditure costs. Stakeholders (in particular TransGrid and the distribution networks) will have an incentive to develop better data sources, given that these data are now used to establish reliability standards. In addition, new technology is likely to have

an impact on the type and cost of non-network options that can provide reliability.

- The methodology we have adopted is innovative and is likely to benefit from increasing sophistication over time. For example, the modelling has not included the cost of non-network options in estimating the reliability standards. Developing benchmark (or project specific) costs for non-network options would allow these options to be incorporated more directly in the modelling.
- The characteristics of bulk supply points change over time. For example, Essential Energy submitted that the urbanisation of a rural area should necessitate the re-categorisation of the corresponding bulk supply point.[30]

For these reasons, we consider that the reliability standards should be revised for each regulatory control period. We consider that IPART is well placed to provide advice on this matter, as licence compliance regulator and economic adviser to the NSW Government on a range of matters. In the past the reliability standards have remained constant over long periods of time, with infrequent changes in response to factors such as a growth in demand at a connection point (which may trigger an increase in the desired level of contingency), and changes in negotiated reliability levels (for example the Inner Sydney area).

Recommendation

5 IPART should review the NSW transmission reliability standards again in time for revised standards to be in place for the 2023 regulatory period.

30 Endeavour Energy submission to IPART Issues Paper, 21 January 2016, p 3.

# 3 How we decided on the level of redundancy and expected unserved energy in the standards

This is the first time an economic approach to setting reliability standards has been applied in NSW. As a result, we have taken a conservative approach in making our recommendations so as not to introduce a significant change to the level of reliability required.

We are recommending retaining the current level of redundancy for each bulk supply point. However, we are also recommending introducing flexibility around how the specified level of redundancy is met by including an allowance for TransGrid to plan for a positive value of expected unserved energy. As discussed in Chapter 3, one of the aims of this approach is to begin to introduce the concept of planning to have some expected unserved energy, where this is appropriate rather than continuing to encourage TransGrid to invest to reduce the expected value of unserved energy to zero.

We developed and applied an optimisation model to determine the value of the allowance for expected unserved energy to include in the recommended standards at each bulk supply point.

However, we have decided not to finalise the unserved energy allowances in the standards at this stage for the Inner Sydney area and for Broken Hill, Molong, Mudgee, Munyang and Wellington Town. We have released a separate draft report to seek feedback on the proposed allowances for unserved energy in these areas.

This chapter outlines our analysis and considerations in deciding the appropriate level of redundancy and allowance for expected unserved energy that should be included in the recommended standards for each bulk supply point.

## 3.1 Level of redundancy

We have taken a conservative approach to making recommendations on what reliability standards should apply over the 2018 regulatory period. As a result, we recommend that the standards include a specification of the level of redundancy at each bulk supply point that matches what currently occurs in practice.

This is consistent with the approach taken in our Draft Report, which was based on the list of bulk supply points and redundancy categories provided by TransGrid in its initial submission to the review. Following release of our Draft Report we received feedback that the draft standards had incorrectly categorised the current level of redundancy at a number of bulk supply points.[31] After further review we have corrected the redundancy category listed in the standards for these bulk supply points.

Most bulk supply points fall into the N-1 category. For these bulk supply points, the standards require TransGrid to have some back-up supply arrangements in place but allow it to determine what those arrangements should be. The flexibility inherent in the redundancy definition is limited by the allowance on expected unserved energy, as the back-up arrangements need to be sufficient to ensure that the expected value of unserved energy at the bulk supply point is below the allowance set out in the standard.

Our optimisation model has the capability to optimise both the level of redundancy and the value of expected unserved energy at each bulk supply point. We have decided to specify redundancy obligations at their current level, rather than using the optimal category identified by the model. We consider that this is a conservative approach that recognises that the model is new and there is uncertainty regarding a number of the inputs to the model, including the value of customer reliability (VCR).

As a result, at this stage we have applied the level of redundancy as a constraint and optimised only the value of expected unserved energy. However, in future reviews, where we expect to have better information available on VCRs and other inputs, we will consider whether to use the optimisation model to determine both the level of redundancy and the allowance for expected unserved energy. This might result in a change in redundancy category for some bulk supply points in the future, but for most, we expect the optimisation to indicate that no change is required.

Recommendation

6 The level of redundancy to be provided at each bulk supply point should be as set out in the recommended standards in Appendix B. The level of redundancy reflects the level of redundancy currently provided at each bulk supply point.

## 3.2 Value of expected unserved energy

In order to determine what MWh allowance for expected unserved energy should be included at each bulk supply point across the network we developed an optimisation model that identifies an optimal amount of expected unserved energy, estimated on a life-cycle basis.

31 Essential Energy submission to IPART Draft Report, 23 June 2016, p 3.

TransGrid proposed a number of reliability scenarios in November 2015 that maintained the number of redundant assets but reduced the capacity of those back-up arrangements compared to what is currently in place. Our Issues Paper indicated that we would compare the reliability outcomes of these scenarios. However, focusing on a limited number of given scenarios is unlikely to identify the 'optimal' quantum of expected unserved energy at each bulk supply point (see Box 3.1). By contrast, our optimisation approach performs a wider-ranging assessment specifically designed to identify the optimal expected amount of unserved energy at each bulk supply point. The optimisation approach also addresses concerns raised in submissions to our Issues Paper regarding the inclusion of additional scenarios.[32]

We provided an overview of the optimisation model in our Draft Report.[33] In response to the Draft Report, we received a number of questions regarding the model assumptions.[34] We held discussions with key stakeholders including TransGrid and the DNSPs and sought additional feedback on the model and its assumptions. We also discussed the model and the inputs at our public hearing.

An overview of the model and how we used it to determine the unserved energy allowances in the recommended standards is set out below. More detail regarding the inputs and assumptions included in the model, including the changes we made since the Draft Report, are set out in Chapter 4 and Appendix D. A copy of the model is available from our website (www.ipart.nsw.gov.au).

The optimisation model we developed covers all bulk supply points (substations) for the TransGrid network. The optimisation model allows us to optimise the annual amount of expected unserved energy at each bulk supply point. The model takes into account certain features that vary between substations. These include the number and capacity of transformers, the number and capacity of lines served by the substation, the maximum demand, load profile, and the VCR for end-users served by that substation. However, at this stage the model does not take account of details of the switchgear design or of the network surrounding the substation.

Given certain settings that affect reliability and the VCR and load characteristics at the bulk supply point, the model calculates both:

- the average cost of owning and operating the assets comprising the substation and associated lines, and
- the dollar value of the expected unserved energy.

32 Ausgrid submission to IPART Issues Paper, 22 January 2016, p 7; Essential Energy submission to IPART Issues Paper, 28 January 2016, p 4.

33 We also published a report we commissioned that documented the quality assurance process we went through and the key assumptions made – see Frontier Economics *Review of IPART model for reliability standards for electricity transmission*. May 2016.

34 Essential Energy submission to IPART Draft Report, 23 June 2016, pp 1 and 3, and Endeavour Energy submission to IPART Draft Report, 1 July 2016, p 2.

The sum of the asset cost and the expected unserved energy value is the total social cost[35] for the chosen reliability settings. This social cost incorporates two aspects of customer value – the value that customers place on a particular level of reliability and the cost to them of having this level of reliability provided. Different combinations of the reliability settings are examined, and the one that leads to the least social cost (highest customer value) is selected. The corresponding level of expected unserved energy is chosen as the optimal value. The corresponding level of expected unserved energy in MWh is then used to calculate the allowance for expected unserved energy in minutes per annum, which we propose should be adopted for the standard.

The allowance for expected unserved energy per annum is calculated by dividing the optimal expected unserved energy (in MWh) produced by the optimisation model, by estimated average annual demand at that bulk supply point (in MW) and converting it to minutes (by multiplying it by 60). We have estimated annual demand at each bulk supply point using forecast maximum demand (in MWh) and an estimated load factor.

The reliability settings that are used as the control variables in this optimisation are:

1. level of network redundancy (ie, N, N-1 or N-2)
2. load at risk (% of maximum demand) at each level of redundancy
3. time taken to restore service at each level of redundancy following an asset failure, and
4. time taken to repair or replace the failed asset.

Separate settings can be chosen for transformers and lines.

Unserved energy can arise from two sources: asset failure that places load at risk or growth in peak demand that places load at risk. The current version of the model includes only the first of these sources. However, we do intend to include the second source in the optimisation in the long term.

### 3.2.1 Model settings used to develop the unserved energy allowances

We have decided to use the optimal unserved energy associated with the N-1 level of redundancy for all bulk supply points.[36] This is consistent with the approach we took in our Draft Report. In the Draft Report we noted that, where an N-1 redundancy is modelled for bulk supply points that currently have no network redundancy (N standard) the model typically finds that a very high load

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35 Within the electricity market, consistent with the cost-benefit framework adopted in the NER for the RIT-T.

36 Note that the Inner Sydney area, which currently has a modified N-2 redundancy requirement, is being considered separately.

at risk is optimal anyway. However, in the Draft Report we did note that this approach may underestimate the expected unserved energy in the proposed standards for those bulk supply points.

Since the Draft Report, we have further considered whether this approach is appropriate, or whether we should instead constrain the model to the N standard of redundancy for N standard bulk supply points. We compared the expected unserved energy that results from the model when constrained to both the N and N-1 standards for these points and found that the results are typically very different. Having reviewed these results, we decided to continue to set the unserved energy allowances using the model results from the N-1 standard because:

- At most N standard bulk supply points there is actually some back-up capacity currently available (eg, back-up generation or the distribution network), which is not adequately captured in our model. As a result, constraining the model to an N standard significantly overestimates the expected unserved energy at these bulk supply points compared with the current expected value. This approach would allow a significant deterioration in reliability for end-customers in these areas.
- For most of the current N standard bulk supply points, the optimisation model finds that having some back-up capacity in place is the optimal outcome rather than an N standard, where there would be no back-up arrangements. The model allows for a range of load at risk parameters at the N-1 standard (up to 90%), which is a flexible approach to redundancy. This approach is consistent with what occurs in practice at these points, which means that modelling based on the N-1 standard does not underestimate the unserved energy allowance at these points and should not drive the need for additional investment.

Overall, we consider that the approach we have taken to modelling the expected unserved energy allowance is consistent with our objectives for the review, in particular, to move towards standards which better focus on what customers value and to not result in a significant change from the current level of reliability experienced by customers.

We therefore continue to recommend that the redundancy category in the standards be set to reflect the current level of redundancy (see section 3.1).

Recommendation

7 The allowance for expected unserved energy at each bulk supply point except for those in Inner Sydney should be as set out in Appendix B. This reflects the results of our optimisation model.

### Box 3.1 Optimisation vs reliability 'scenarios'

The AEMC approach focuses on reviewing the costs and benefits associated with a selected set of reliability scenarios, each with a particular cost of provision and value of expected unserved energy. The scenario that is most beneficial for customers is the one that delivers the lowest total cost – taking into account both the cost of providing reliability and the value customers place on reducing supply interruptions.

Using this approach means that the recommended outcomes depend on which scenarios the analyst chooses to examine. This is unlikely to identify the optimal outcome.

Some of the potential options for providing reliability, particularly non-network solutions, are not able to be considered very far in advance of when the investment decision is needed. Some depend on the forecast maximum demand and load profile at each bulk supply point, which changes over time. In addition, unforeseen changes such as improved technology may also enable new options and/or reduce the cost of others.

TransGrid proposed a number of reliability scenarios in November 2015 that maintained the number of redundant assets but reduced the capacity of those back-up arrangements compared to what is currently in place. Changing the capacity of assets used to provide redundancy in the network may reduce the capital and operating costs of delivering a particular contingency standard, but it may impose a higher value of expected unserved energy because some load is put at risk of not being supplied if certain contingency events occur.

While this is one strategy that TransGrid could adopt, there are a number of other investment options that would have implications for the cost of supply and the level of reliability provided, including:

- Entering into arrangements with third parties to deliver services as a substitute for network assets – for example, back-up supply could be provided through non-network solutions, such as on-site generation.
- Changing the timing of network investments – by replacing assets later than planned TransGrid could deliver the same level of redundancy but at a lower cost.

In order to identify the optimal value for inclusion in the standards we have chosen to move away from an approach that is based on modelling a limited number of 'reliability' scenarios to one that allows for a more holistic assessment.

## 3.3 Value of expected unserved energy for Inner Sydney

TransGrid proposes substantial additional investment that may occur in Inner Sydney in the 2018 regulatory period. The upcoming expenditure for the Inner Sydney is costly, long lasting and impacts a substantial number of customers. We have considered several ways of deriving an appropriate value for the expected unserved energy parameter in the reliability standard for Inner Sydney.

In our Draft Report, we outlined a separate process for determining the expected unserved energy allowance for Inner Sydney. Broadly, the process involved TransGrid and Ausgrid using their joint planning process to identify various reliability options in terms of the range of expected unserved energy values that could be delivered for this area.

We have now released a draft report for this area and will take into account stakeholder feedback on the proposed approach before making final recommendations on the unserved energy allowance that should be included in the standard.

Recommendation

8 The allowance for expected unserved energy for Inner Sydney should be considered separately and a recommendation made following a separate consultation process.

## 3.4 Value of expected unserved energy for Broken Hill, Molong, Mudgee, Munyang and Wellington Town

At Broken Hill, Molong, Mudgee, Munyang and Wellington Town the updates we made to our model since the draft report resulted in a large change in the modelled estimates of unserved energy. The change for each of these areas was substantial and we are concerned that setting the unserved energy allowance based on these results may lead to a significant change in the current level of reliability.

These bulk supply points fall into two categories:

- Broken Hill, Molong and Mudgee – the optimisation model suggests that the optimal value of unserved energy is likely to be less than the current expected value, implying that a higher reliability is warranted
- Munyang and Wellington Town – the changes we made to our modelling following the draft report led to significant increases in the value of unserved energy allowances, and the revised estimates are likely to be higher than the current expected value, allowing a reduction in the level of reliability at these bulk supply points.

We have decided not to finalise the unserved energy allowances in the standards for these bulk supply points as we consider that we should consult further before making final recommendations.

Recommendation

9 The allowance for expected unserved energy for Broken Hill, Molong, Mudgee, Munyang and Wellington Town should be considered separately and a recommendation made following a separate consultation process.

# 4 The inputs we used in the optimisation model and how we estimated them

At each bulk supply point, the optimisation model seeks to identify the level of reliability which minimises the sum of the cost of expected unserved energy plus the direct (capital and operating) costs of providing that level of reliability.

In order to do this analysis the model requires the following:

- the cost of expected unserved energy, which is a result of:
  - the value customers place on reliability (VCR)
  - the probability of asset failures
  - the duration of outages
  - the forecast maximum demand at each bulk supply point
- the direct costs of providing different levels of reliability, and
- a discount rate to convert capital costs to an annuity.

The values we used for these are discussed below. More detail on the inputs and assumptions used in the model is set out in Appendix D.

## 4.1 The value customers place on reliability

The value that customers place on reliability (known as VCR) is expressed as a dollar value per kWh of energy not delivered. This value is multiplied by the expected amount of unserved energy to obtain a customer value that is compared with the direct cost of providing reliability.

Our terms of reference require us to have regard to the most recent VCRs published by AEMO. AEMO separately identified VCRs for residential, commercial, industrial, agricultural and direct connect customers, as shown in Table 4.1.

**Table 4.1 AEMO VCR results ($2014-15)**

| | VCR ($/kWh) |
|---|---|
| Residential | 26.53 |
| Commercial | 44.72 |
| Industrial | 44.06 |
| Agricultural | 47.67 |
| Direct connect | 6.05 |

**Note:** Residential VCR results are for NSW (including the ACT); Commercial, Industrial, Agricultural and Direct connect results are across the National Electricity Market.

**Source:** AEMO, *Value of Customer Reliability Review - Final Report*, September 2014, pp 2, 18.

We received submissions in response to the Issues Paper that raised a number of concerns with the use of the AEMO estimates. Those concerns include that the AEMO estimates are calculated from a very small sample size,[37] overly dependent on the methodology used,[38] do not include important customers such as the Australian Stock Exchange, NSW Parliament, large financial institutions,[39] and do not adequately capture low probability but high impact supply interruptions.[40] However, submissions tended to acknowledge that these issues may need to be addressed over time and are unlikely to be resolved during this review.[41]

In our Draft Report, we considered that further work is needed to better understand the true value that different customers place on reliability. This work should be completed prior to any further review of reliability standards and would require periodical updating. IPART as the licence compliance regulator would be well placed to undertake this work. One of the benefits of IPART undertaking a study of VCR for NSW is that the timing of the study can be co-ordinated with the next review of reliability standards. Accurate VCRs will need to be based on high quality survey work.

In response to the Draft Report, stakeholders supported additional work being done on VCRs. Endeavour Energy submitted that a broader analysis is required to ensure that the full range of relevant information is captured, noting that VCR focuses on the willingness to pay of an average customer and does not take into account the fact that loss of electricity supply can disproportionately impact vulnerable customers.[42] Essential Energy similarly referred to elements that are not captured in the VCR calculation that it considers to be important and pointed to a study which considers how customers value different aspects of reliability.[43]

37 Essential Energy submission to IPART Issues Paper, 28 January 2016, p 5.
38 ETSE Consulting submission to Issues Paper, 27 January 2016, p 7.
39 Ausgrid submission to IPART Issues Paper, 22 January 2016, pp 7-8.
40 Ausgrid submission to IPART Issues Paper, 22 January 2016, p 9.
41 For example, Essential Energy submission to IPART Issues Paper, 28 January 2016, p 5.
42 Endeavour Energy submission to IPART Draft Report, 1 July 2016, p 1.
43 Essential Energy submission to IPART Draft Report, 23 June 2016, p 3.

TransGrid supported IPART's draft recommendation to develop a NSW specific calculation for VCR.[44] TransGrid also noted that the importance of developing NSW specific values of VCR was also supported by stakeholders at TransGrid's recent stakeholder forum.[45]

However, the Energy Networks Association (ENA), while supporting additional work on VCRs, considered that this work should be done by a national body and not by IPART. The ENA submitted that this would ensure consistency of approach and noted that there has been discussion within the COAG energy committee about the AER being given responsibility for determining VCRs.[46] The ENA submitted that 'if state agencies such as IPART separately establish and resource VCR estimation, this is unlikely to be either efficient or to expedite the development of a robust nationally comparable framework for VCR'.[47]

The benefit of IPART doing this work, and the reason we proposed this in our Draft Report, is that the VCRs will be done at a time and using a methodology that is appropriate for use in our next review of reliability standards, which are determined by the relevant jurisdictional Minister. However, VCRs are also used to estimate the value of electricity to consumers under the Regulatory Investment Test for Transmission (RIT-T) and Regulatory Investment Test for Distribution (RIT-D) processes.[48]

We agree nationally consistent approach to estimating VCRs would be preferable. We recommend that further work be undertaken on VCRs, and that unless updated, nationally consistent VCRs are available in time to inform the next review of reliability standards for NSW, the NSW Government should ask IPART to determine NSW-specific VCRs for this purpose.

We consider that the NSW DNSPs should collect consumption data by end-use customer type to provide for improved estimates of VCRs. We note that for this review data provided by DNSPs was not consistent with the AEMO categories.

In its submission to our Draft Report, Essential Energy noted that at a network or state wide level it may be possible to apportion VCR values based on broad assumptions, however, these assumptions do not hold true when creating a VCR value at a more granular level. Essential Energy further submitted that the current method of weighting VCRs by consumption adds no value but that where accurate information is available (Essential Energy suggested Australian

44 TransGrid submission to IPART Draft Report, 4 July 2016, p 2.

45 TransGrid submission to IPART Draft Report, 4 July 2016, p 2.

46 Energy Networks Association submission to IPART Draft Report, 4 July 2016, p 1.

47 Energy Networks Association submission to IPART Draft Report, 4 July 2016, p 1.

48 The AEMO Value of Customer Reliability Application Guide (Final Report, December 2014, p 12) notes that both the RIT-T and RIT-D require the network planner to use a reasonable forecast of the value of electricity to consumers when considering market benefits of an investment option that alleviates involuntary load shedding. It is also likely to be needed to calculate market benefits associated with voluntary load shedding (eg, for a demand side participation option).

Bureau of Statistics type customer splits) this data should be used to improve the VCR apportioned to specific bulk supply points.[49] At the public hearing for the review Essential Energy noted that:

> In looking at updating the VCR value in terms of the recommendation, it may be worth including in that looking at a better way of developing customer splits between categories of VCR as part of that, because I know from a DNSP point of view, we do not keep that data and it is critical to have customer classes and then apply the VCR.[50]

Collecting more accurate data on end-use customer type would allow better estimates of VCRs. In a competitive market, DNSPs would have an incentive to maintain this information in order to ensure that it can deliver the quality and quantity of energy required by end-customers. However, the nature of the electricity supply chain in NSW means that DNSPs do not have a commercial incentive to collect this information.[51]

In the meantime, we have used the AEMO VCRs as the basis for the analysis in our report. We engaged WSP Parsons Brinckerhoff (PB) to recommend VCRs for each bulk supply point, based on the values published by AEMO, weighted by customer type at each bulk supply point.[52] PB advised that this approach is consistent with the application of VCRs outlined by AEMO and used by TNSPs in undertaking transmission planning and preparing RIT–T investment plans.[53]

PB's VCRs for individual bulk supply points, excluding bulk supply points for direct connect customers, range from \$29.31/ kWh to \$44.83/ kWh (\$2014/15).[54] PB undertook sensitivity analysis to understand the impacts of any uncertainty in the split between customer types but found that significant changes in splits produced small changes in VCR.[55] As suggested by stakeholders in response to submissions on our Issues Paper,[56] PB also had regard to work done through

49 Essential Energy submission to IPART Draft Report, 23 June 2016, p 4.

50 IPART public hearing, Review of electricity transmission reliability standards, 28 June 2016, Transcript, p 18.

51 While retailers would have this information for retail customers in NSW, retail market competition means that no one retailer will have an entire dataset for a bulk supply point.

52 For bulk supply points that were based on Ausgrid data, PB developed a non-weighted VCR using the straight average of the customer type splits. This is because there was no consumption data provided to undertake a weighted average. Additionally, no weighting was required for direct connect customers as there is only one customer type at each bulk supply point.

53 WSP Parsons Brinkerhoff, *NSW Transmission Reliability Standards Review - Value of Customer Reliability*, May 2016, p 3.

54 WSP Parsons Brinkerhoff, *NSW Transmission Reliability Standards Review - Value of Customer Reliability*, May 2016, pp A-2 – A-6.

55 WSP Parsons Brinkerhoff, *NSW Transmission Reliability Standards Review - Value of Customer Reliability*, May 2016, p 6.

56 Endeavour Energy submission to IPART Issues Paper, 21 January 2016, p 5; Ausgrid submission to IPART Issues Paper, 22 January 2016, pp 1, 9.

other surveys but did not consider these values to provide any more certainty.[57] PB's report on VCRs is separately available on our website.[58]

We have adopted PBs recommended VCRs for most bulk supply points we modelled. However, following consultation on the Draft Report we have revised the VCRs for:

- Parkes 132kV – TransGrid has advised that this BSP supplies a mine.
- Tomago 132kV - previously assumed that this BSP supplied a direct connect customer but this was incorrect.
- Sydney North, Sydney East and Brandy Hill – Ausgrid has advised that WSP Parsons Brinkerhoff has assigned some loads to inappropriate categories.
- Essential Energy bulk supply points that have at least some HV and/or sub-transmission load – Essential Energy advised that WSP Parsons Brinkerhoff has assigned these loads to inappropriate categories.

In its submission on our Draft Report, Essential Energy noted that there was an inconsistency in how WSP/Parsons Brinckerhoff had mapped Essential Energy's 'sub-transmission' tariff type to AEMO's customer types.[59] WSP/Parsons Brinckerhoff allocated sub-transmission loads to AEMO's 'Agriculture' category but Essential Energy advised that most sub-transmission loads are mines. Essential Energy also noted that the mapping of its 'HV' tariff types might be problematic. We have updated the VCRs to address these concerns.

There is no AEMO 'mining' category. The closest matches are either the 'direct connect' category, which has a very low VCR, or 'industrial' category which has a lower VCR than 'agriculture' but still significantly higher VCR than 'direct connect'. Essential Energy recommended using an average AEMO value for NSW until a more accurate data source for assigning and developing granular VCR's can be determined.[60] AEMO's VCR values are shown in Table 4.2.

57 WSP Parsons Brinkerhoff, *NSW Transmission Reliability Standards Review - Value of Customer Reliability*, May 2016, p 7.

58 WSP Parsons Brinkerhoff, *NSW Transmission Reliability Standards Review - Value of Customer Reliability*, May 2016.

59 Essential Energy submission to IPART Draft Report, 23 June 2016, p 4.

60 Essential Energy submission to IPART Draft Report, 23 June 2016, p 4.

**Table 4.2 AEMO VCR results ($2014-15)**

| | VCR ($/kWh) |
|---|---|
| Residential | 26.53 |
| Commercial | 44.72 |
| Industrial | 44.06 |
| Agricultural | 47.67 |
| Direct connect | 6.05 |
| Aggregate NSW, including direct connects | 34.15 |

**Note:** Residential VCR results are for NSW (including the ACT); Commercial, Industrial, Agricultural and Direct connect results are across the National Electricity Market.

**Source:** AEMO, *Value of Customer Reliability Review - Final Report*, September 2014, pp 2, 18, 31.

To address these concerns, we have used the 'aggregate NSW, including direct connects' VCR for both Essential Energy's HV and sub-transmission loads (see Table 4.3). This results in lower VCRs for around 50 BSPs.

**Table 4.3 Essential Energy load type and customer type mapping**

| Essential Energy load type | AEMO customer type | |
|---|---|---|
| | PB advice | IPART final report modelling |
| Controlled Load | Residential | Residential |
| LV Residential Continuous | Residential | Residential |
| LV Residential TOU | Residential | Residential |
| LV Demand | Commercial | Commercial |
| LV <160MWh | Commercial | Commercial |
| HV Demand | Industrial | Aggregate NSW |
| Sub-transmission | Agriculture | Aggregate NSW |

**Source:** PB advice is from WSP Parsons Brinkerhoff, *NSW Transmission Reliability Standards Review - Value of Customer Reliability*, May 2016.

## Recommendation

10 IPART supports a nationally consistent approach to the value of customer reliability (VCR). However, unless updated, nationally consistent VCRs are available in time to inform the next review of reliability standards for NSW, the NSW Government asks IPART to determine VCRs for NSW 12 months prior to the next review of reliability standards.

## 4.2 Probability and duration of outages

The optimisation model calculates expected unserved energy by considering the:

- failure rate for each asset type at the bulk supply point (transformers, overhead cables and underground cables)
- load at risk – the load supplied from a bulk supply point, which is at risk of being interrupted if an asset fails, after allowing for available backup capability, but before repair of the asset that has failed
- restoration time – the time to restore the network to the relevant redundancy level, using back-up capability (which depends on switching arrangements), and
- repair time – the time to restore or repair failed assets.

The failure rate of each asset depends on the type of asset and its age. The model considers the lifecycle average failure rate of a typical asset of that type. In reality the condition of a specific asset may be better or worse than average, and that will affect the likelihood of failure, but this is not taken into account in the model.

We have made several changes to the inputs to the optimisation model since the Draft Report. Most of these changes were made following consultation with TransGrid and the DNSPs on the assumptions in the model.

The most significant changes we made to these assumptions were:

- We updated the model to reflect the load duration curves/load factors at each BSP – the Draft Report used a generic load duration curve that reflected the TransGrid average.
- We updated the calculations for bulk supply points with no transformers – the draft model was treating these incorrectly (note that this does not affect many bulk supply points).[61]
- We have now based the transformer repair time on TransGrid's updated repair times for transformers – the draft model was based on assumptions made by our expert consultant Brian Nuttall, which were significantly lower than those subsequently provided by TransGrid. On further review and consultation we consider TransGrid's transformer repair times to be more realistic.
- We updated the transformer failure frequency, based on further advice from TransGrid (TransGrid advised that we should interpret some of their historical failure data differently which resulted in relatively minor changes).

61 In the Draft Report we noted that Broken Hill had a very high value of unserved energy. This was caused by the incorrect calculation associated with no transformers.

The above changes have had different impacts on different BSPs depending on their particular circumstances (for example, whether the use of actual load duration curves led to a higher or lower optimal unserved energy value depends on how that BSP sat relative to the average that was used in the Draft Report). Appendix D sets out further information.

## 4.3 Demand at each bulk supply point

We have used estimates of maximum demand at each bulk supply point published by TransGrid[62], which use information provided by DNSPs. This is based on the 50% POE maximum demand forecast.

AEMO's current statement of opportunities forecasts that maximum demand is relatively stable over the period to 2024-25.[63] For this reason, we consider that the use of this value of maximum demand for modelling is reasonable.

In the Draft Report, we used demand estimates for 2015-16. Since we released the Draft Report, we have updated the forecasts for maximum demand (still using the 50% POE forecast) to reflect the most recent estimates for 2018-19.

## 4.4 The cost of providing reliability

Reliability is provided, in the model, by having standby assets available. The cost of reliability depends on the extent of standby capacity, which is partly determined by the amount of load at risk that can be tolerated. The load at risk drives both the direct cost of providing reliability and the expected cost of unserved energy.

Standby capacity can be accessed by switching—to an alternate transformer at a possibly different location, or to an alternate line that follows a different route. The model does not identify these alternate locations or routes specifically, and it assumes that standby capacity is divisible, perhaps by having several bulk supply points share the same standby transformer or line. These simplifying assumptions make the model tractable.

We have used data provided by TransGrid which reflects the costs of network solutions, that is, cables, transformers and associated network components. Data on the potential for non-network options to provide the various levels of reliability was not available. TransGrid has noted that the potential for non-network solutions and their cost tend to be highly project-specific, depending on factors such as the availability of suitable demand-side management.

62 TransGrid, *Reliability Scenarios, NSW Electricity Transmission System*, November 2015, pp 6-12. For some bulk supply points we sought further clarification from TransGrid on the maximum demand forecasts in this publication.

63 AEMO, 2015 *Electricity Statement of Opportunities*, p 16.

While we have focused on network costs, there may be non-network solutions to provide reliability to customers, and these solutions could be cheaper than the network options considered. If reliability can be increased (ie, expected unserved energy reduced) more cheaply than the cost estimates provided by TransGrid, this will affect the optimised levels of expected unserved energy specified in the standard. In essence, if a cheaper non-network (or network) option is available then we would expect the optimised allowance for expected unserved energy to be lower.

Following release of the Draft Report, we made several changes to the network assets considered in the model, which impact the expected unserved energy calculation. Those changes include:

- We updated the model to more accurately account for the number of transformers and lines going into each bulk supply point – the Draft Report used an estimate of the number of lines based on lines going in and out, and the total line length was then halved to avoid double counting. Following the Draft Report, we received more accurate information on this from TransGrid.
- We changed the asset lives used in the model – in response to the Draft Report we received a number of submissions indicating that the asset lives in the draft model were too high, particularly for overhead lines.[64] For the final report model we have now updated asset lives consistent with in TransGrid's Regulatory Information Notice submitted to the AER.[65]

## 4.5 Discount rate

The discount rate used in the optimisation model converts capital costs into annuity values.

The discount rate used in the model for our report is 5.6% (real pre-tax). This is IPART's estimate of TransGrid's Weighted Average Cost of Capital (WACC). In calculating the WACC IPART assumed an equity beta of 0.7 and 60% gearing level. These assumptions are specific to the electricity transmission industry. Other market parameters (market risk premium, risk free rate, inflation forecast and debt margin) used in the calculation are based on IPART's standard WACC methodology.[66]

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64 Essential Energy submission to IPART Draft Report, 23 June 2016, p 4; Comment from Mr Paul Harrington at IPART public hearing, Review of Electricity Transmission Reliability Standards, 28 June 2016, Transcript, p 16.

65 TransGrid 2014-15, Economic Benchmarking RIN – Templates https://www.aer.gov.au/networks-pipelines/network-performance/transgrid-network-information-rin-responses accessed 11 August 2016, Table 3.3.4.

66 IPART completed a major review of the WACC in 2013 (IPART, *Review of WACC Methodology – Final Report,* December 2013). More recently we updated the method of estimating the debt margin and the inflation adjustment (IPART, *WACC – IPART's New Approach to Estimating the Cost of Debt – Fact Sheet,* April 2014; IPART, *New approach to forecasting the WACC inflation adjustment – Fact Sheet, March 2015*).

We note that the appropriate discount rate might not be equal to TransGrid's WACC. NSW Treasury policy is to apply a standard set of real discount rates of 4%, 7% and 10%, regardless of the horizon for the relevant investment.[67]

The discount rate used in the final report modelling is slightly different to that used in the Draft Report modelling, as we have updated the market parameters to reflect data to July 2016. We have not changed the methodology.

## 4.6 Sensitivity testing

At each bulk supply point, the model selects the unserved energy that is associated with the optimal combination of reliability settings it identifies based on the various inputs. An input change may result in a different value of unserved energy because it leads to a change in the optimal combination of reliability settings or it may result in the same unserved energy because it does not lead to a change in the optimal combination of reliability settings.

We tested the following input sensitivities in coming to our decision on the unserved energy allowances in the recommended standard:

- VCR – up and down 30%.
- Maximum demand - up and down 30%.
- Cost co-efficient/exponent – up and down 30%.
- Asset lives – up and down 30%.
- Discount rate – 4.7% and 6.4% (compared to a base of 5.6%).
- Failure rate – up and down 10%.
- Line length – up and down 30%.

The sensitivity analysis suggests that:

- Lower VCRs tend to lead to higher unserved energy and higher VCRs tend to lead to lower unserved energy – but in many cases they do not lead to any change in the results.
- The results are fairly insensitive to changes in the discount rate and asset lives, with changes in these assumptions leading to changes in the unserved energy allowance at very few bulk supply points.
- The results tend to be fairly sensitive to asset failure rates.

67 NSW Treasury Office of Financial Management, *NSW Government Guidelines for Economic Appraisal*, July 2007, p 52.

## 4.7 Accounting for non-catastrophic transformer failures

In response to the Draft Report, TransGrid advised that the transformer failure rates they initially provided included both catastrophic and non-catastrophic failures. In our modelling, only catastrophic failures (that is, where the transformer needs to be replaced following failure) are included.[68] However, the rate of non-catastrophic transformer failure (failures that can be repaired) is significant and this adds to the expected unserved energy for the network. So, as not to exclude the impact of non-catastrophic transformer failure, we have separately estimated an allowance for the unserved energy associated with these failures at each BSP.

To estimate the allowance for non-catastrophic transformer failures we used information on the rate of these failures (provided by TransGrid) as well as information on the average repair time (also from TransGrid) and the speed of switching available at the BSP (based on our modelled optimum). Where back-up capacity is available, we assumed that a non-catastrophic failure would lead to an outage lasting only as long as it takes to switch to backup capacity. Where no backup capacity is available, then we assumed that the non-catastrophic outage would last for the repair time (TransGrid's average is approximately 35 hours).

These allowances are added to the optimal USE allowances estimated by the model. We consider that TransGrid would need to factor non-catastrophic transformer failures and the expected value of the associated unserved energy into its compliance return (see Chapter 5).

In most cases the additional allowance included is relatively small and adds around a minute of unserved energy to the unserved energy allowance in the standard; at some bulk supply points no adjustment is required at all. This is because, where there is fast switching available, the impact of a transformer failure is minimal.

68 Because this rate and the cost of minor repairs are largely independent of the planning criteria adopted, the presence of non-catastrophic transformer failures would not affect the optimisation calculation.

# 5 The compliance process

How TransGrid would need to demonstrate compliance with the reliability standards depends on whether they are specified as 'planning' standards or 'performance' standards. We have recommended that the reliability standards be put in place as planning standards, consistent with the current reliability standards. IPART, as licence compliance regulator, would be responsible for assessing TransGrid's compliance with the reliability standards.

The key difference between the recommended standards and the current standards is that the recommended standards would require TransGrid to apply a probabilistic approach to network planning. Currently TransGrid is not required to do this as the reliability standards are specified in a deterministic way (eg, if asset X fails, the network must still be able to supply a given proportion of maximum demand).

Under the recommended standard, TransGrid would need to estimate an *expected unserved energy* associated with its network at each bulk supply point. It would need to do this by considering:

- the range of assets available to provide supply, including transmission system assets and other supply elements (including non-network solutions and complementary networks that provide back-up)
- the probability of different assets failing, alone and in combination with each other, and the impact of these failures on TransGrid's ability to maintain supply, and
- the load not served and the duration of outages (including the measures in place for switching to back-up arrangements and how long this switching takes, as well as repair and replacement arrangements).

This chapter provides an overview of how we would assess compliance with the standard. However, we will undertake consultation both with TransGrid and other stakeholders to further develop the compliance process more fully during 2017.

## 5.1 The licence compliance process

The NSW Government recently transferred responsibility for the electricity safety and reliability regulatory functions from the NSW Department of Industry to IPART.[69] This means that IPART is responsible for considering whether TransGrid has met its licence obligations, including the obligation to meet the reliability standard.

As outlined in Chapter 2, we are recommending that the reliability standards continue to be expressed as planning standards rather than as performance standards. This means that in order to demonstrate that TransGrid has met the standard that is in place at each bulk supply point, it will be required to demonstrate that it has planned and implemented its transmission system to meet that standard.

The allowance for expected unserved energy included in the standards is based on both the probability of asset failures occurring and the impact of those failures on supply given the demand at each bulk supply point. As a result, to demonstrate compliance with the reliability standard, TransGrid will need to undertake simulation modelling and will need to report on the process, assumptions and outcomes it uses.

In response to the Draft Report a number of stakeholders requested more detail regarding how IPART would assess compliance with the proposed reliability standards.[70] Stakeholders also asked for clarity around what the 'average' in the allowance for expected unserved energy in the draft standard meant and over what timeframe it would be calculated.[71]

There is a need for consistency between the optimisation model we have used to determine the allowances for expected unserved energy and the modelling that TransGrid will need to do to demonstrate compliance with the standard. We will consult on the approach to assessing compliance during 2017.

### 5.1.1 Approach and assumptions

To demonstrate compliance TransGrid would need to undertake probabilistic simulation modelling of the network taking into account system elements (including non-network elements), a defined set of combinations of asset failures, asset failure rates and assumed maximum demand/load profile at each BSP.

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69 This transfer took effect from 4 June 2015 when the *Electricity Network Assets (Authorised Transactions) Act 2015* was enacted.

70 Essential Energy submission to IPART Draft Report, 23 June 2016, p 3; Ausgrid submission to IPART Draft Report, 4 July 2016.

71 Essential Energy submission to IPART Draft Report, 23 June 2016, p 3.

Following stakeholder feedback on the Draft Report we have modified the wording of our recommended standards to clarify:

- that the unserved energy allowances in the standard are annual maximum values
- which possible asset failures TransGrid must take into account in network planning.

We consider that these changes address stakeholders' submissions in relation to the interpretation of the standards for compliance purposes (see Chapter 3 for more information). The general approach and assumptions required to demonstrate compliance with the standards are also set out below.

### What set of asset failures to consider

It is important that the set of risks that TransGrid is asked to consider as part of the planning standards reflect the set of risks that were used to determine the allowance for expected unserved energy (the optimisation model). If the definition in the standards is broader than was included in the optimisation model TransGrid may find it difficult to meet the standards without significant additional investment in reliability. This is not efficient and not driven by the value that customers place on reliability. On the other hand if the definition in the standards is narrower than what was included in the optimisation model TransGrid may find it too easy to meet the standards and not invest when there would be value in doing so.

We propose that TransGrid is required to consider the probability and impact of the following situations:

- System normal.
- Single transformer failure.
- Single line failure.
- Double transformer failure.
- Double line failure.

Where there are other equivalent system elements that are used, they would also be captured in assessing compliance. This is consistent with our optimisation modelling.[72]

TransGrid should use actual system capacity, informed by asset condition (eg, we are aware that some of their cables in inner Sydney have been 'de-rated' so that their capacity is less than what it was).

72 See separate draft report for the proposed set of asset failures relevant to the Inner Sydney area.

### Demand assumptions

We ran our optimisation using a 50% POE maximum demand forecast (the forecast of maximum demand that has a 50% probability of being exceeded). Basing compliance on this forecast would be consistent with the optimisation model. Using a higher demand forecast for compliance, for example, the 10% POE forecast, would provide expected unserved energy values systematically higher than the allowances in the standard.

In response to the Draft Report, we received feedback that the use of the 50% POE forecast may not be sufficient to capture the impact of the planned network on reliability for customers, particularly for BSPs where an N standard applies.[73] The current standards are relatively prescriptive in that they require TransGrid to plan for 10% POE at system normal. If we consider only the 50% POE demand forecast in the compliance assessment, the recommended standards do not require TransGrid to undertake any analysis on the expected unserved energy associated with a higher value of peak demand.

We will further consult on whether TransGrid should use a weighted maximum demand that takes into account the 10% POE, 50% POE and 90% POE forecasts in the compliance calculation in order to ensure that potential unserved energy under each of these different maximum demand forecasts is captured by the compliance process.

### Failure rates

The standards have been estimated by modelling that uses system assets and life cycle failure rates. In the optimisation we used TransGrid's historical average values as proxies for the life cycle average failure rates and consider that these should also be used for compliance purposes. We consider that it is the best option available (see Box 5.1).

[73] Endeavour Energy submission, 1 July 2016, p 2.

**Box 5.1 Life cycle failure rates vs actual expected failure rates**

The unserved energy allowances in the draft and final recommended standards are based on life-cycle average failure rates. In reality, TransGrid's assets will have different expected failure rates over the planning horizon because their network will contain assets with an age and/or condition that does not reflect the life-cycle averages.

To be consistent with the way the standards are expressed, life-cycle average failure rates should be used in the compliance assessment and not expected rates over the planning horizon. Using condition based failure rates would have unintended consequences – for example, requiring TransGrid to bring forward asset replacement when that would not be efficient or easily allowing TransGrid to meet the standards where assets are relatively young.

However, focusing compliance on life-cycle averages creates a risk that TransGrid could run down its assets by delaying replacement, accepting a higher probability of asset failure and worsening reliability, without affecting its ability to meet the reliability standard.

To address this issue the unserved energy allowances in the standards could be recalculated based on the actual condition of TransGrid's assets – this condition could also be used for the compliance assessment. However, this means aligning the standards more closely to TransGrid's transmission network assets which is inconsistent with moving towards technology neutral standards. It also means that the standards would require constant updating in response to changes in TransGrid's network and the resulting allowances for unserved energy would fluctuate significantly over time.

We are already proposing significant changes to the way TransGrid is required to consider reliability (eg, building restoration times, switching arrangements and failure probabilities into the reliability assessment). Capturing condition-based failure rates in the standards would be a further significant change.

For these reasons, we do not recommend trying to capture actual condition based failure rates. However, we recommend that as part of the compliance process TransGrid provides information on its asset replacement strategy. This should provide additional information on the appropriateness of TranGrid's life-cycle failure rates. It should also provide information on changes to asset condition that may impact reliability. For more information see the 'other information requirements' section below.

In response to our Draft Report, Ausgrid requested information on how the proposed standards would apply to asset replacement projects and specifically, whether the standards would delay asset replacement projects that are currently planned by TransGrid.[74] Using the average life cycle failure rates as outlined above will mean that the standards would not influence the timing of asset replacement decisions (see Box 5.1 for further information). However, we would expect them to influence the timing of investment for demand driven augmentations.

We do not currently have life-cycle failure rates for non-network assets. This may become an issue in the future if TransGrid adopts non-network solutions as a means of meeting the reliability standards. In this case, we will need to consider what failure rates should be used for assessing compliance. We would need to consider this on a case by case basis, as it is not possible to lock in failure rates for all future possibilities in advance.

#### Flexibility around redundancy or expected unserved energy

To provide some flexibility there is provision in the standards for TransGrid to submit a proposal to IPART for approval. The recommended standards set out the process that must be followed and the analysis that TransGrid would need to provide in support of any such proposal.

We have now included a requirement that such a plan may not materially reduce the level of reliability provided at any bulk supply point compared with the redundancy category and unserved energy values specified in the standard. We would assess any such proposal submitted by TransGrid on a case-by-case basis.

### 5.1.2 Supporting information to be provided

In addition to the calculations described above, we also recommend that some additional supporting information be provided by TransGrid as part of the compliance process.

#### Asset plan

As discussed above, we are recommending that compliance be assessed using life-cycle average failure rates for lines and transformers based on historical averages from TransGrid. However, these historical averages only provide a good estimate of the life-cycle failure rates for the network where TransGrid does not make significant changes to its asset replacement strategy. A policy change that allows assets to stay in service longer or their condition to deteriorate would, over time, raise the life-cycle failure rate above what we have included in the optimisation model.

74 Ausgrid submission to IPART Draft Report, 4 July 2016, p 2.

As a result, we recommend TransGrid provides additional information relevant to its asset replacement decisions that would allow us to identify any changes to its asset replacement strategy or risk profile. This information may signal worsening reliability for customers and might change the appropriate life-cycle failure rates used in the compliance calculation. It would also provide useful input to the next review of reliability standards.

### Evidence of back-up that is not part of TransGrid's network

One of the main elements of the recommended standards is explicitly allowing TransGrid to use non-transmission network system elements to meet the standards. The recommended standards make it clear that non-network arrangements include load shedding agreements, back-up generation and use of the distribution network. As part of TransGrid's compliance assessment they would need to provide some evidence of the agreements in place relating to non-network arrangements or distribution assets.[75]

In response to the Draft Report, Essential Energy was concerned that where distribution network assets are used to meet the standards this may oblige the DNSP to 'take responsibility and raise revenue in order to fund the maintenance and construction of the assets required to meet customer outcomes.'[76] We note that the standards apply to the TNSP and not to the DNSP.

### Reporting of actual unserved energy outcomes by bulk supply point

Essential Energy submitted that TransGrid should be required to report actual unserved energy outcomes by bulk supply point.[77] This information would be useful in checking how the standards have affected outcomes for customers and in further development of modelling approaches.

The recommended standards state that TransGrid must provide any information that IPART considers is reasonably necessary in monitoring compliance. The standards are planning standards, which require TransGrid to estimate an *expected value* of unserved energy at each bulk supply point based on a combination of expected failure rates and the expected impact that asset failures would have on supply.

Performance outcomes by bulk supply point would not be useful for compliance purposes because the standards do not require TransGrid to deliver specific performance outcomes.

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75 We understand that typically arrangements with distribution networks are informal. This means that in some cases currently limited supporting evidence may be available.

76 Essential Energy submission to IPART Draft Report, 23 June 2016, p 3.

77 Essential Energy submission to IPART Draft Report, 23 June 2016, p 3.

We agree with Essential Energy that this information would be useful for informing future reviews of the standards as it would allow us to consider what impact the new planning standards have had on the reliability experienced by customers. But, rather than include this in the standards as an additional compliance requirement, we consider that it would be sufficient to request this information as part of the next review process.

## 5.2 The Australian Energy Regulator's process

The reliability standards set by the Minister work as part of the regulatory framework governing transmission services. TransGrid's incentives will depend on the overall regulatory framework and the interaction of the various elements within that framework. This includes the reliability standards set at a jurisdictional level, the AER's determination of maximum allowable revenue, and the AER's Service Target Performance Incentive Scheme (STPIS).

By themselves, the reliability standards set by the Minister do not ensure that the TNSP only makes efficient investments – this also depends on the AER's regulatory process. The standards set by the Minister establish *minimum* standards for reliability, by prescribing both a redundancy level and average level of expected unserved energy at different bulk supply points. However, they may not prevent over-investment, even if this investment is expensive for customers.

The incentives for TNSPs to make efficient investments also depend on the regulatory framework implemented by the AER.

Chapter 6A of the National Electricity Rules requires the AER to set allowable revenue based on the provision of "prescribed transmission services" – which include services required under jurisdictional electricity legislation, at the standard required under jurisdictional legislation.[78]

The AER must consider any reliability standards set by jurisdictional legislation as an obligation on TNSPs.[79] The AER's role is to assess the efficient level of capital and operating expenditure to meet these standards, using the reliability standards as an input.

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78 See National Electricity Rules, available at: http://www.aemc.gov.au/Energy-Rules/National-electricity-rules/Current-Rules, accessed 27 May 2016.

79 HoustonKemp, *Economic Regulation of NSW Electricity Network Businesses*, 7 May 2015, pp 4-5.

If a TNSP proposes an augmentation to the network of $6m or more, it must undertake the RIT-T.[80] The RIT-T aims to identify the option that maximises the net present value to the market, *given* the reliability standards established by jurisdictional legislation (as well as the standards set under the National Electricity Rules to ensure system reliability, for example voltage requirements).[81]

The AER has proposed changes to replacement expenditure reporting and planning arrangements in the National Electricity Rules.[82] The proposed changes would extend the Regulatory Investment Test for Transmission (RIT-T) and Regulatory Investment Test for Distribution (RIT-D) to replacement expenditure above the existing cost thresholds (for augmentation expenditure).[83] It would also introduce new requirements for annual reporting on asset retirement decisions and options to address network limitations arising from a decision to retire a network asset, for both transmission and distribution businesses.

Although the AER had not submitted the proposal to the AEMC at the time of our Draft Report we were aware of the proposed rule change and the reasons for it and we included a draft finding supporting the extension of the RIT-T to replacement expenditure. We noted that there is substantial and costly investment involved in some replacements. For example, TransGrid's Powering Sydney's Future project for Inner Sydney, which could cost in excess of $400 million,[84] is driven by the need for cable retirements,[85] and therefore may not be captured by the existing RIT-T requirements.

Both TransGrid and the Energy Networks Association (ENA) questioned IPART's support for the AER's proposal.

The ENA submitted that TransGrid's Powering Sydney's Future project, which we included as an example high cost investment driven by the need for cable retirements, was not necessarily representative of the majority of asset replacement programs of transmission businesses. And, that under the current rules, it was widely recognised for the innovative, proactive efforts of TransGrid and Ausgrid to develop alternative non-network solutions.[86]

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80 AER, *Cost thresholds review for the regulatory investment test - Final determination,* November 2015, p 1.

81 System standards are set out in schedule 5.1a of the National Electricity Rules.

82 On 1 July 2016, the AEMC received a rule change request from the Australian Energy Regulator to amend the National Electricity Rules. The AEMC has not yet initiated this rule change request. When the AEMC initiates this process, the AEMC will publish a Consultation Paper to facilitate stakeholder consultation on the request. (See: http://www.aemc.gov.au/Rule-Changes/Replacement-Expenditure-Planning-Arrangements#)

83 The current RIT-T does not apply in circumstances where the estimated capital cost of new network investment is less than $6 million. Further, where transmission investment is subject to the RIT-T and the preferred option does not exceed a cost threshold of $41 million, the network service provider preparing the RIT-T may be exempted from parts of the RIT-T consultation procedures. (AER, *Cost thresholds review for the regulatory investment test - Final determination*, November 2015, p 1.)

84 TransGrid, *Appendix L - Contingent Projects*, Regulatory proposal, May 2014, p 8.

85 TransGrid, *Powering Sydney's Future*, Fact Sheet, May 2014.

86 Energy Networks Association (ENA) submission on Draft Report, 4 July 2016, p 2.

While TransGrid and Ausgrid have consulted on non-network solutions for the Powering Sydney's Future project, we maintain that consultation and reporting requirements should be mandated for significant investments like this. The AER's proposed changes to the RIT-T and annual planning review reporting requirements appear in principle to be an appropriate way to ensure such consultation and reporting occurs.

TransGrid's submission called for careful consideration of a cost threshold which is appropriate for replacement projects, as well as a clear and simple exemption process for like-for-like replacements if the RIT-T was extended beyond its current scope.[87] In regard to these comments, we note that:

- The AER considered but decided against introducing specific cost thresholds for replacement projects.

  > In principle, consideration of alternative credible options should be similar for both replacement and augmentation. For example, both the consideration of reinvestment as a result of the retirement of a transformer at its 'end of life' and the installation of a new transformer would give rise to similar types of alternatives. Thus, the existing cost thresholds should be sufficient for replacement projects. Further, different cost thresholds for replacement and augmentation projects would likely create unnecessary regulatory complexity, particularly for projects which have both an augmentation and replacement component.[88]

- Under the proposal service providers would be exempt from having to go through a RIT-T process for replacements if the proponent of the RIT-T determines on reasonable grounds that the only credible option to address the identified need is a like-for-like replacement.[89]

As observed by ENA, the AER's proposal will be the subject of a thorough rule change consultation at a national level.[90]

However, we continue to share the AER's concerns that the existing rules do not provide sufficient transparency on investment decisions in an environment of low demand growth and the increased focus on asset replacement rather than network augmentation.[91] We consider that there should not be a presumption that like-for-like asset replacement is the preferred option. In the current environment of lower demand growth and technological advancement it is important that network businesses are required to consider the full range of available options, in the same way as they are for network augmentations.

87 TransGrid submission on Draft Report, 4 July 2016, p 3.

88 AER, Proposal to introduce new replacement expenditure reporting and planning arrangements to the Chapter 5 planning framework, June 2016, p 18.

89 AER, Proposal to introduce new replacement expenditure reporting and planning arrangements to the Chapter 5 planning framework, June 2016, pp 17- 18.

90 Energy Networks Association (ENA) submission on Draft Report, 4 July 2016, p 2.

91 AER, Proposal to introduce new replacement expenditure reporting and planning arrangements to the Chapter 5 planning framework, June 2016, pp 10-11.

Finding

1 IPART supports, in principle, the AER's proposed rule change that would require replacement expenditure to be subject to the same regulatory process as augmentation expenditure.

The AER is also responsible for designing and operating the STPIS, which is designed to provide incentives for transmission businesses to improve the quality of the services they provide and to avoid seeking to reduce their costs by reducing service quality.

The STPIS currently has three elements:

- a service component – which provides incentives for the TNSP to avoid loss of supply (using measures of average circuit outage rate, the frequency of loss of supply, average outage duration, and proper operation of equipment)
- a market impact component – which provides incentives to avoid outages which result in a significantly higher cost of generation, and
- a network capability component – which measures improvements in the capability of the transmission network at times most important to spot prices or times when customers place greatest value on reliability.

The reliability standards we have recommended are intended to work with the regulatory framework that the AER operates within and to complement, rather than duplicate the STPIS.

# 6 Expected impact of the recommendations

We have recommended reliability standards that better reflect how customers' value reliability than the current standards, which are heavily based on network capability. The recommended standards introduce the concepts of probabilistic analysis and positive expected unserved energy into TransGrid's decision making processes as well as making explicit provision for the standards to be met using non-network solutions.

However, we also consider that our recommendations would not result in a significant change from the current level of reliability experienced by customers. This will be the first time an economic approach to setting reliability standards has been applied and as discussed in Chapter 4, there is some uncertainty involved in some of the inputs, in particular, the VCRs. As a result, we have been conservative in the allowances for expected unserved energy that we have included in the recommended standards.

We expect that in the short term the recommendations will have an impact on TransGrid, in terms of its processes for determining the available and most cost effective investment options, but are unlikely to have a significant impact on customers.

## 6.1 Impact on TransGrid

There are several important differences between our recommended standards and the current standards, which are likely to have an impact on TransGrid. The recommended standards would allow TransGrid to plan to have a small amount of expected unserved energy at each bulk supply point. The standards require TransGrid to consider both the probability and impact of different asset failures, including the load that may be put at risk and the expected duration of any outages.

While the standards continue to specify the level of redundancy that should be provided at each bulk supply point across the network, the recommended standards define redundancy in a flexible way. The recommended standards do not prescribe how TransGrid must invest in order to meet them but instead, explicitly provide for TransGrid to determine the combination of network and non-network solutions required to provide reliability.

By contrast, the current standards specify the network infrastructure that TransGrid must provide to achieve the required levels of redundancy based on specified demand forecasts. In our view this encourages TransGrid to plan the network to remove virtually all possibility of outages resulting from single asset failures, irrespective of how much this costs and without consideration of how much customers are willing to pay for it. On the other hand, it does not require TransGrid to consider other combinations of asset failure, which may have a relatively low probability of occurrence but a significant impact should they occur. The current standards also appear to favour transmission network options rather than alternative, potentially more cost-effective options.

The recommendations included in this report would drive a change in terms of how TransGrid undertakes its transmission planning and ensure that its investments are more aligned with customers' willingness to pay for reliability.

Combined with the AER's regulatory process, TransGrid will need to adopt cost effective means of meeting the reliability standard, whether this is through changes to the transmission network or complementary arrangements. The standards are less prescriptive and provide greater flexibility than the current standards. This would require TransGrid to consider a broader range of options than is available under the current standards. For example, TransGrid would need to ensure that it considers non-network solutions and new technologies as they become available.

For the first time, the standards would require TransGrid to consider the probability of asset failures in its transmission planning, as well as the potential impact of them. The current standards focus on what happens if a contingency event occurs, without consideration of how likely it is that this will happen. We note that a number of submissions raised the issue of high impact, low probability events.[92] Some stakeholders have argued that we should make special provision within the economic analysis for these events.

Certain combinations of asset failures are explicitly captured by the recommended standards including some with quite a low probability of occurrence but a high impact on customers should they occur such as double transformer and double line failures. However, we have not considered other very low probability events such as some of those raised in a submission we received on our Draft Report.[93] To alter the analysis to give a different weighting to these events would be inconsistent with the probabilistic approach to standard setting that underpins our analysis (this approach relies on both the probability of asset failures and the impact of failure, should it occur). However, we have taken a conservative approach in that we are not recommending any changes to

92 For example, ETSE Consulting submission to IPART Issues Paper, 27 January 2016, p 5, Ausgrid submission to IPART Issues Paper, 22 January 2016, p 9.

93 Anonymous submission to IPART Draft Report, 28 June 2016, p 1. The submission mentioned system black, space weather, cyber attack, SCADA failure, market operator control room failure, malicious attacks and rare coinciding (Black Swan) events.

the level of redundancy provided at any bulk supply point – our recommendations include complementary measures aimed at providing more flexibility around how these redundancy requirements are met. In addition, we note that the Minister, as standard setter may choose to set standards that are not based on an economic analysis where he considers that it fails to adequately address low probability, high impact events.

## 6.2 Impact on customers

We do not expect that the standards would result in significantly different reliability or price outcomes for customers, particularly in the short term.

The reliability performance of the TransGrid network is very high. Over the five years from 2009-10 to 2013-14, the level of network availability has been between 98.2% and 99.1%, and system minutes not supplied has been at or below 2.2 minutes.[94] TransGrid has also achieved its target level of maintenance.[95] Analysis undertaken by HoustonKemp indicates that, based on system minutes of energy not supplied, NSW and the ACT enjoyed the highest reliability performance in Australia between 2002–03 and 2011-12.[96]

As discussed earlier in this report, this high level of reliability has been in part driven by standards that effectively require the network to be planned to avoid any amount of expected unserved energy. We are not recommending significant changes to the reliability standard. Instead we are proposing small changes that we expect will be significant in terms of TransGrid's ability to reduce costs, which will over the longer term lead to electricity price savings for customers.

We have deliberately been conservative in setting the unserved energy allowances in the reliability standards. We recognise that substantial reductions in transmission reliability have the potential to create widespread and costly outages, so the implications of setting the allowances for expected unserved energy too high could be significant. The standards proposed in this report would allow TransGrid to plan its network to accept a maximum expected supply interruption of less than 10 minutes per year, at average demand, for 42% of bulk supply points, less than 20 minutes per year at 68% and less than one hour per year at 93% of bulk supply points.

In terms of the impact on electricity prices, the transmission component of a typical residential bill is less than 10%.[97] The capital projects that are funded through that component occur relatively infrequently but are costly and long lasting. As a result of these two things, the impact of lower reliability standards on a customer's bill is unlikely to be significant, particularly in the short term.

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94 TransGrid, *Annual Report 2014*, p 55.

95 TransGrid, *Annual Report 2014*, p 55.

96 HoustonKemp, *Electricity Networks Service Standards: An Overview*, 2 September 2014, p 27.

97 AEMC, 2*015 Residential Electricity Price Trends – Final Report*, 4 December 2015, p 54.

However, we consider that the recommended standards will start to move TransGrid's network planning and decision-making process away from investing to remove any possibility of outages, regardless of the cost, towards a process that takes better account of the cost of providing reliability and customers' willingness to pay for it. Over the long term an investment process that better reflects the value customers place on reliability should continue to deliver reliability in line with customers' expectations while at the same time bringing some cost savings for customers.

# Appendices

# A Terms of reference

Premier of New South Wales

IPART

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RECEIVED

INDEPENDENT PRICING & REGULATORY TRIBUNAL

Reference: A1330398

28 SEP 2015

Dr Peter Boxall
Chairman
Independent Pricing and Regulatory Tribunal
PO Box K35
HAYMARKET POST SHOP NSW 1240

Dear Dr Boxall Peter

Pursuant to section 12A of the *Independent Pricing and Regulatory Tribunal Act 1992*, I am referring the following matter to the Tribunal for investigation and report: Transmission Reliability Standards. The Terms of Reference are enclosed.

This investigation should result in the development of a set of transmission reliability standards in advance of the next regulatory control period for the NSW Transmission Operator (currently known as TransGrid), commencing on 1 July 2018.

If your officers wish to discuss this matter they should contact Laura Christie, Director, Resources and Land Use Branch, Economic Policy Group, Department of Premier and Cabinet on 9228 4213.

Yours sincerely

**MIKE BAIRD MP**
Premier

GPO Box 5341, Sydney NSW 2001 ▪ P: (02) 9228 5239 ▪ F: (02) 9228 3935 ▪ www.premier.nsw.gov.au

A1330398

**Terms of Reference**

I Michael Bruce Baird, Premier of New South Wales, pursuant to section 12A of the *Independent Pricing and Regulatory Tribunal Act 1992*, refer the following matter to the Independent Pricing and Regulatory Tribunal "IPART" for investigation and report:

**The recommendation of Electricity Transmission Reliability Standards**

In November 2013 the Australian Energy Market Commission "AEMC" recommended a new framework for setting and regulating transmission reliability standards in its report *Review of the national framework for transmission reliability*, 1 November 2013 "the AEMC November 2013 Report".

In December 2014, the COAG Energy Council published its *Response to the Australian Energy Market Commission's Review of the National Framework for Distribution Reliability and Review of the National Framework for Transmission Reliability* "the COAG Energy Council Response".

The NSW Government has decided to broadly adopt the approach to standard setting recommended by the AEMC in the AEMC November 2013 Report and the National Electricity Network Reliability Principles and the Minimum Requirements for setting reliability targets set out in the COAG Energy Council Response.

IPART's investigation will result in a set of transmission reliability standards being recommended to the NSW Minister for Industry, Resources and Energy (the "Minister") in time for the standards to be set in advance of the next regulatory control period for the NSW Transmission Operator (currently known as TransGrid) commencing on 1 July 2018.

Consistent with this, IPART, under this reference, is to provide advice to the Minister and carry out the role of economic advisor as set out in the AEMC November 2013 Report:

- **Standard setter**. As standard setter, the Minister will set the transmission reliability standards for NSW.

  IPART is to assist the Minister in this role by:
  a. selecting the reliability scenarios to be economically assessed from scenarios initially provided by the NSW Transmission Operator; and
  b. recommending the transmission reliability standards to the Minister.

  When recommending the transmission reliability standards to the Minister, IPART should consider the transmission reliability standards recommended by the AEMC (if any) and any other matter considered relevant including:
  i. a required level of network capability informed by an economic assessment process to be expressed in terms of a network redundancy/N-x standard; and
  ii. a requirement relating to when supply would need to be restored following planned and unplanned interruptions at a connection point.

- **Economic advisor.** IPART should undertake an economic assessment of the efficient costs and reliability impact for each selected reliability scenario, based on information obtained from the NSW Transmission Operator and any other information considered relevant by IPART and provide a report to the Minister on its assessment.

As part of undertaking its investigation:

IPART is to develop an economic assessment methodology having regard to, amongst other considerations, the most recent values of customer reliability published by AEMO. That methodology is to be used during the standard setting process in formulating IPART's recommendations

After development of the methodology, IPART is to:

a. select a range of feasible reliability scenarios from reliability scenarios developed by the NSW Transmission Operator following a customer consultation process;
b. undertake an economic assessment using probabilistic analysis, or other appropriate analytical techniques, to evaluate how efficient network capital and operating costs vary with different levels of reliability, and then compare the level of expected capital and operating expenditure against the value that customers place on reliability for each selected scenario; and
c. recommend the transmission reliability standards for the NSW Transmission Operator to the Minister to apply to the regulatory control period commencing 1 July 2018.

**Consultation**
IPART should, when undertaking its investigation, conduct a public consultation process at appropriate stages of the review to ensure that the standard setting process is open and transparent and involves all relevant stakeholders.

**Timeline**
IPART is to conduct the review and publish a draft report on its economic assessment on selected scenarios within 6 months of receiving TransGrid's scenarios and will provide a final report to the Minister and recommendations on reliability standards within a further 3 months from publishing its draft report.

The target date for the final report recommending reliability standards to the Minister is end May 2016, however it is recognised that meeting this date will depend upon the NSW Transmission Operator providing reliability scenarios to the Tribunal by October 2015.

# B Recommended reliability standards

**1. Status of this standard**

(a) This standard is a reliability and performance standard issued by the *Minister* for the purposes of clause 3(a) of the *Licence*.

(b) This standard may be cited as the *Transmission Reliability and Performance Standard 2016 No. 1*.

**2. Interpretation**

(a) In this standard, where the terms below are italicised they have the corresponding meanings set out below.

***Expected unserved energy*** means the expected amount of energy that cannot be supplied, taking into account the probability and expected impact (including expected outage duration and forecast load) of the following:

(i) failure of a single *system element*;

(ii) double transformer failure, or failure of equivalent *system elements*; and

(iii) double line failure, or failure of equivalent *system elements*.

***Inner Sydney*** means the inner metropolitan transmission system, which is that part of the *transmission system* constituted by:

(i) cables 41 and 42;

(ii) the 330/132kV substations at Rookwood Road, Beaconsfield, Haymarket, Sydney North and Sydney South;

(iii) any future associated 330kV cables and 330/132kV substations; and

(iv) any of Ausgrid's 132k transmission network that links any of the above.

***Level of redundancy*** means:

(i) for category 1 bulk supply points, a supply interruption may occur following the outage of a single *system element*;

(ii) for category 2 bulk supply points, a non-zero amount of load must be supplied following the outage of a single *system element*; and

(iii) for category 3 bulk supply points, a non-zero amount of load must be supplied following the outage of a single *system element*. In addition, for *Inner Sydney*, a non-zero amount of load must be supplied following the simultaneous outage of a single 330 kV cable and any 132 kV feeder or 330/132 kV transformer.

***Licence*** means the Transmission Operator's Licence under the *Electricity Supply Act 1995* granted to NSW Electricity Networks Operations Pty Limited (ACN 609 169 959) as trustee for the NSW Electricity Networks Operations Trust dated 7 December 2015, or a licence that replaces it.

***Licence Holder*** has the same meaning as under the *Licence*.

***Minister*** has the same meaning as under the *Licence*.

***RIT-T*** means the *Regulatory investment test for transmission and application guidelines 2010* published by the Australian Energy Regulator, or any replacement of that document from time to time.

***System element*** means:

(i) a transmission circuit (a line or a cable);

(ii) a transformer;

(iii) a component of physical infrastructure other than a transmission circuit or transformer; or

(iv) network support arrangements, back-up supply capability, or other measure that provides supply capacity.

***Transmission system*** has the same meaning as under the *Licence*.

***Tribunal*** has the same meaning as under the *Electricity Supply Act 1995*.

(b) Headings and notes which appear in this standard are intend as an aide to usage only, and do not form part of this standard.

(c) References to clauses in this standard are references to clauses of this standard, unless this standard expressly provides otherwise.

**3. Requirement to design for a specified *level of redundancy* for each bulk supply point**

Subject to clause 5(a) below, the *Licence Holder* must ensure that the *transmission system* is designed such that, for each bulk supply point listed in the table in clause 8, the *transmission system* achieves the *level of redundancy* category specified for that bulk supply point in the table in clause 8.

**4. Requirement to design for a level of *expected unserved energy* for each bulk supply point**

Subject to clause 6(a) below, the *Licence Holder* must ensure that the *transmission system* is designed such that the annual *expected unserved energy* in respect of a bulk supply point listed in the table in clause 8 does not exceed the allowance for *expected unserved energy* specified for that bulk supply point in the table in clause 8.

**5. Flexibility in planning for the level of redundancy**

(a) The *Licence Holder* is not required to comply with clause 3 above in respect of a bulk supply point listed in the table in clause 8 provided that:

(i) the *Licence Holder* has developed and submitted to the *Tribunal* a plan regarding measures for altering the reliability of the supply capacity of the bulk supply point;

(ii) that plan provides a greater net-benefit, using the cost-benefit methodology defined in the *RIT-T*, than the net-benefit of complying with clause 3 above; and

(iii) the *Tribunal* has advised the *Licence Holder* in writing that it is satisfied that the plan submitted under clause 5(a)(i) above would, if implemented, be likely to provide a greater net-benefit than would be provided by the *Licence Holder* complying with clause 3 above in relation to the bulk supply point.

(b) The *Licence Holder* must implement the plan within a time specified by the *Tribunal* to the *Licence Holder*, and such implementation must be to the reasonable satisfaction of the *Tribunal*.

(c) For the avoidance of any doubt:

(i) the *Licence Holder* may submit, from time to time, a proposed replacement for a plan referred to in clause 5(a); and

(ii) clause 5(a) applies to such a plan in the same way that it would apply to the first plan submitted under that clause in relation to a bulk supply point.

(d) Where the *Tribunal* has expressed satisfaction in writing under clause 5(a)(iii) about a plan that relates to a bulk supply point or bulk supply points listed in the table in clause 8, the *Licence Holder* may advise the *Tribunal* in writing that it has elected not to implement the plan. If the *Licence Holder* so advises the *Tribunal* of such an election:

(i) the *Licence Holder* is not required to implement the plan in question, despite clause 5(b);

(ii) despite clause 5(a), the *Licence Holder* must comply with clause 3 in respect of the bulk supply point or bulk supply points to which the plan in question relates; and

(iii) the *Licence Holder's* election not to implement the plan may not be reversed, unless the *Tribunal* provides its written consent for the reversal.

**6. Flexibility in planning for the level of *expected unserved energy***

(a) The *Licence Holder* is not required to comply with clause 4 above in respect of a bulk supply point listed in the table in clause 8 provided that:

(i) the *Licence Holder* has developed and submitted to the *Tribunal* a plan regarding measures for altering the reliability of the supply capacity of the bulk supply point;

(ii) that plan provides a greater net-benefit, using the cost-benefit methodology defined in the *RIT-T*, than the net-benefit of complying with clause 4 above; and

(iii) the *Tribunal* has advised the *Licence Holder* in writing that it is satisfied that the plan submitted under clause 6(a)(i) above would, if implemented:

(A) be likely to provide a greater net-benefit than would be provided by the *Licence Holder* complying with clause 4 above in relation to the bulk supply point; and

(B) not result in a material reduction in the level of *expected unserved energy* at any bulk supply point.

(b) The *Licence Holder* must implement the plan within a time specified by the *Tribunal* to the *Licence Holder*, and such implementation must be to the reasonable satisfaction of the *Tribunal*.

(c) For the avoidance of any doubt:

(i) the *Licence Holder* may submit, from time to time, a proposed replacement for a plan referred to in clause 6(a); and

(ii) clause 6(a) applies to such a plan in the same way that it would apply to the first plan submitted under that clause in relation to a bulk supply point.

(d) Where the *Tribunal* has expressed satisfaction in writing under clause 6(a)(iii) about a plan that relates to a bulk supply point or bulk supply points listed in the table in clause 8, the *Licence Holder* may advise the *Tribunal* in writing that it has elected not to implement the plan. If the *Licence Holder* so advises the *Tribunal* of such an election:

(i) the *Licence Holder* is not required to implement the plan in question, despite clause 6(b);

(ii) despite clause 6(a), the *Licence Holder* must comply with clause 4 in respect of the bulk supply point or bulk supply points to which the plan in question relates; and

(iii) the *Licence Holder's* election not to implement the plan may not be reversed, unless the *Tribunal* provides its written consent for the reversal.

**7. Requirement to provide information to the *Tribunal***

(a) The *Licence Holder* must comply with any request notified to the *Licence Holder* by the *Tribunal* for information that the *Tribunal* reasonably considers to be necessary or convenient for the *Tribunal* in monitoring the *Licence Holder's* compliance with this standard.

(b) The *Licence Holder* must comply with a request under clause 7(a) within a reasonable timeframe notified to the *Licence Holder* by the *Tribunal*.

(c) If reasonably requested to do so by the *Tribunal*, the *Licence Holder* must commission an audit of its compliance with this standard (or specified aspects of this standard). Such an audit must be conducted:

(i) by an auditor approved by the *Tribunal* in writing;

(ii) at the expense of the *Licence Holder*; and

(iii) such that a report on the audit by the auditor is provided to the *Tribunal* within a reasonable timeframe notified to the *Licence Holder* by the *Tribunal*.

(d) At least 90 days before entering into any contract for the construction of a new bulk supply point intended to form part of the *transmission* system (or within a different timeframe proposed by the *Licence Holder* and agreed to in writing by the *Tribunal*), the *Licence Holder* must submit a proposal regarding the new bulk supply point to the *Tribunal*. The proposal must:

(i) propose a *level of redundancy* category that this standard should specify for the new bulk supply point;

(ii) propose a level of *expected unserved energy* that this standard should specify for the new bulk supply point; and

(iii) set out reasons justifying the *level of redundancy* category and level of *expected unserved energy* proposed.

## 8. Table of values

| | Redundancy category | Unserved energy allowance, maximum minutes per year at average demand |
|---|---|---|
| **1. Inner Sydney** | | |
| Beaconsfield West 132 kV | 3 | To be determined |
| Haymarket 132 kV | 3 | To be determined |
| Rookwood Road 132 kV | 3 | To be determined |
| Sydney North 132 kV | 3 | To be determined |
| Sydney South 132 kV | 3 | To be determined |
| **2.Other bulk supply points** | | |
| Albury 132 kV | 2 | 14 |
| ANM 132 kV | 2 | 6 |
| Armidale 66 kV | 2 | 7 |
| Beryl 66 kV | 2 | 5 |
| Boambee South 132 kV | 2 | 18 |
| Canberra 132 kV and Williamsdale 132 kV | 2 | 3 |
| Coffs Harbour 66 kV | 2 | 10 |
| Coleambally 132 kV | 2 | 32 |
| Cooma 66 kV | 2 | 28 |
| Cooma 132 kV | 2 | 11 |
| Cowra 66 kV | 2 | 25 |
| Dapto 132 kV | 2 | 4 |
| Darlington Point 132 kV | 2 | 4 |
| Deniliquin 66 kV | 2 | 19 |
| Finley 66 kV | 2 | 12 |
| Forbes 66 kV | 2 | 19 |
| Gadara (132 kV & 11 kV) | 2 | 13 |
| Glen Innes 66 kV | 2 | 43 |
| Griffith 33 kV | 2 | 12 |
| Gunnedah 66 kV | 2 | 19 |
| Holroyd 132 kV | 2 | 24 |
| Ingleburn 66 kV | 2 | 5 |
| Inverell 66 kV | 2 | 40 |
| Kempsey 33 kV | 2 | 24 |
| Koolkhan 66 kV | 2 | 19 |
| Liddell 330 kV | 2 | 2 |
| Lismore 132 kV | 2 | 4 |

| | Redundancy category | Unserved energy allowance, maximum minutes per year at average demand |
|---|---|---|
| Liverpool 132 kV | 2 | 5 |
| Macarthur 132 kV and 66 kV | 2 | 3 |
| Macksville 132 kV | 2 | 23 |
| Manildra 132 kV | 2 | 6 |
| Moree 66 kV | 2 | 5 |
| Mount Piper 66 kV | 2 | 19 |
| Munmorah 132 kV | 2 | 20 |
| Murrumburrah 66 kV | 2 | 19 |
| Muswellbrook 132 kV | 2 | 3 |
| Nambucca 66 kV | 2 | 65 |
| Narrabri 66 kV | 2 | 5 |
| Newcastle 132 kV | 2 | 2 |
| Orange North 132 kV / Orange 132 kV and 66 kV | 2 | 7 |
| Panorama 66 kV | 2 | 5 |
| Parkes 132 kV | 2 | 9 |
| Parkes 66 kV | 2 | 51 |
| Port Macquarie 33 kV | 2 | 14 |
| Queanbeyan 66 kV | 2 | 4 |
| Raleigh 132 kV | 2 | 32 |
| Regentville 132 kV | 2 | 13 |
| Stroud 132 kV | 2 | 21 |
| Sydney East 132 kV | 2 | 2 |
| Sydney West 132 kV | 2 | 1 |
| Tamworth 66 kV | 2 | 4 |
| Taree 66 kV and 33 kV | 2 | 15 |
| Tenterfield 22 kV | 2 | 79 |
| Tomago 132 Note 3 | 2 | 13 |
| Tomago 330 kV | 2 | 14 |
| Tuggerah 132 kV | 2 | 13 |
| Tumut 66 kV | 2 | 13 |
| Vales Pt 132 kV | 2 | 3 |
| Vineyard 132 kV | 2 | 1 |
| Wagga 66 kV | 2 | 33 |
| Wagga North 132 kV | 2 | 5 |
| Wallerawang 132 kV | 2 | 26 |
| Wallerawang 66 kV | 2 | 31 |

| | Redundancy category | Unserved energy allowance, maximum minutes per year at average demand |
|---|---|---|
| Waratah West 132 kV | 2 | 3 |
| Wellington 132 kV | 2 | 6 |
| Yanco 33 kV | 2 | 41 |
| Balranald 22 kV | 1 | 115 |
| Broken Hill 22 kV | 1 | To be determined |
| Broken Hill 220 kV | 1 | To be determined |
| Casino 132 kV | 1 | 7 |
| Dorrigo 132 kV | 1 | 41 |
| Hawks Nest 132 kV | 1 | 42 |
| Herons Creek | 1 | 17 |
| Ilford 132 kV | 1 | 14 |
| Marulan 132 kV | 1 | 10 |
| Molong 66 kV | 1 | To be determined |
| Morven 132 kV | 1 | 33 |
| Mudgee 132 kV | 1 | To be determined |
| Munyang 33 kV | 1 | To be determined |
| Murrumbateman 132 kV | 1 | 49 |
| Snowy Adit 132 kV | 1 | 52 |
| Wagga North 66 kV | 1 | 42 |
| Wellington Town | 1 | To be determined |
| Yass 66 kV | 1 | 22 |

# C What is transmission reliability, why is it important and what standards currently apply?

Reliability refers to the extent to which consumers have a continuous supply of electricity. Reliability standards establish the level of reliability that a transmission network is required to provide.

Due to their role, outages in transmission networks could cause severe disruptions to the supply of electricity that affect very large areas and numbers of consumers. For this reason, their reliability standards are set at a high level, to ensure that the number of outages that occur as a result of transmission faults is very low.

Transmission services are a natural monopoly and are therefore not subject to competition. To protect customers from excessive prices, the amount of revenue a TNSP can collect from customers and the method it uses to charge customers (its pricing methodology) are regulated. Reliability standards are also regulated to counterbalance the incentive for TNSPs to increase profits by cutting expenditure to the extent it would reduce reliability levels.

The regulation of standards also helps counterbalance the incentive for TNSPs to under-provide network reliability that results from their intermediary role in the electricity supply chain. This intermediary role means they are not directly accountable to small business and residential consumers.

## C.1 What is transmission reliability and why is it important?

Transmission networks are a key part of the electricity network system. As Box C.1 illustrates, they transport electricity from the generation plants to the distribution networks (which then deliver the electricity to residential, commercial and industrial consumers) or to directly connected customers (typically large industrial consumers). In NSW, TransGrid's network comprises:

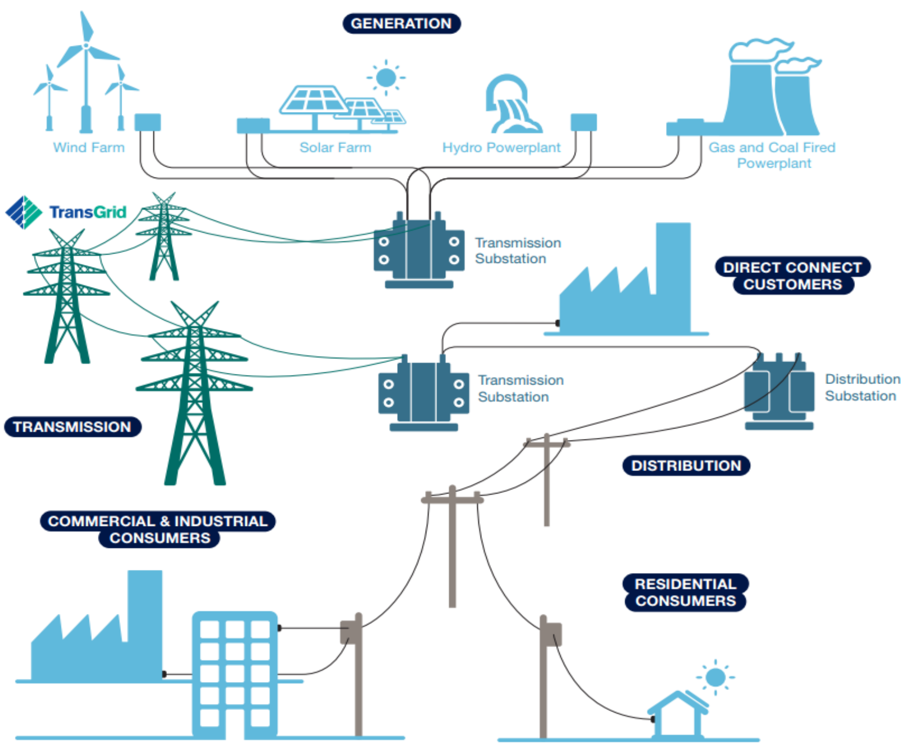
- **97 substations,** where the voltage of the electricity is either raised for efficient transportation through the transmission network, or lowered for safe transportation through the distribution network
- **over 12,900 kilometres of transmission lines and cable,** which transport the electricity around NSW, and

- **400 connection points**, which connect the transmission network to the distribution network or directly to customers.[98]

Transmission networks also play a key role in overall electricity system security, including the functioning of the National Electricity Market (NEM). TransGrid's network is interconnected with the Victorian and Queensland transmission networks. Thus, it enables the trading of electricity between the three largest states on the East Coast, and supports the competitive wholesale electricity market.[99]

Transmission network charges in NSW account for less than 10% of a typical residential bill.[100]

**Box C.1 The electricity supply chain**




**Source**: TransGrid, *NSW Transmission Annual Planning Report*, July 2015, p 14.

98 TransGrid, Our Network, https://www.transgrid.com.au/what-we-do/our-network/Pages/default.aspx, accessed 2 December 2015. Note: A bulk supply point may consist of several customers (Distribution Network Service Providers or directly connected customers) connected to it. The count "400 connection points" treats these connections individually.

99 TransGrid, *NSW Transmission Annual Planning Report*, July 2015, p 13.

100 AEMO, *2015 Residential Electricity Price Trends – Final Report*, 4 December 2015, p 54.

## C.2 What reliability standards currently apply to TransGrid?

TransGrid's obligations in relation to reliability are set out in the transmission operator's licence under the *Electricity Supply Act 1995* (NSW), which was granted to NSW Electricity Networks Operations Pty Limited in December 2015.

Condition 3 of the licence states that:

a) The Licence Holder must ensure that it and all other network operators of its transmission system comply with any reliability and performance standards issued by the Minister for the transmission system.

b) If no reliability and performance standards have been issued by the Minister, the Licence Holder must operate its transmission system to meet the reliability and performance standards which were developed and applied by the network operator of the transmission system in response to the Transmission Network Design and Reliability Standard for NSW dated December 2010, notified to TransGrid by the Director General of NSW Industry and Investment on 23 December 2010.

In all other jurisdictions of the NEM, transmission standards are also set independently of the TNSP. In most cases, they are set by the relevant state government or jurisdictional regulator.[101] The exception is Victoria, where investment decisions (and hence reliability outcomes) are made by the AEMO on a project-by-project basis, using an economic cost-benefit assessment.[102]

### C.2.1 The Transmission Network Design and Reliability Standard for NSW

TransGrid's current reliability standards are set out in the Transmission Network Design and Reliability Standard for NSW (the Transmission Standard), which is issued by Industry and Investment NSW.[103] The Transmission Standard reflects a deterministic approach to standard setting. It focuses on the standards that TransGrid should achieve in planning the network ('input standards'), rather than the network reliability performance the network must deliver ('output standards').

Consistent with the Transmission Standard, TransGrid plans its network to meet specified redundancy criteria that are expressed in terms of a deterministic N-x:

- For most of NSW, an N-1 standard applies. This means that TransGrid is required to build sufficient redundancy to ensure supply is not interrupted if one element of the transmission network fails.

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101 AEMC, *Review of the national framework for transmission reliability*, *Final Report*, November 2013, p 7.

102 AEMC, *Review of the national framework for transmission reliability*, *Final Report*, November 2013, pp 109- 110.

103 Industry and Investment NSW, *Transmission Network Design and Reliability Standard for NSW*, December 2010. (Industry and Investment NSW is now the NSW Department of Industry.)

- For Inner Sydney, a modified N-2 standard applies. This means that TransGrid is required to build sufficient redundancy into the network to ensure supply to Inner Sydney is not interrupted if there is:
  - a simultaneous outage of a single 330 kV cable and any 132 kV feeder or 330/132 kV transformer, or
  - an outage of any section of 132 kV busbar.

The higher level of redundancy required for the Inner Sydney reflects the greater economic cost associated with supply disruptions to the CBD area, compared with other parts of the transmission network.[104]

There are also some bulk supply points where there is no network redundancy. The transmission customers that connect to these points (usually the Distribution Network Service Providers) usually have an alternative supply via distribution networks or using standby generation. Normally there would be a short interruption before the changeover of the supply, in the event the supply from the transmission system is interrupted.[105]

If TransGrid forecasts that the network will not meet these standards in the future, it may decide to build additional assets to address the shortfall. Planning and building new assets can take up to 10 years. It may also decide to use non-network solutions (eg, load curtailment or local generation) to address some, or all, of the shortfall. These decisions are subject to TransGrid's annual planning review (described in section C.2.3 below).

### C.2.2 The Australian Energy Regulator's determination

Under the National Electricity Rules, the AER is responsible for the economic regulation of electricity transmission in the NEM.

The AER determines the amount of revenue TransGrid can recover from consumers over a defined regulatory control period. It must take the reliability standards as an independent obligation on the business and determine the efficient expenditure required to meet this obligation. The current regulatory control period commenced 1 July 2015 and ends on 30 June 2018. We are reviewing the reliability standards that will apply in the following regulatory control period which commences 1 July 2018.

Under the AER's price determination, the STPIS adjusts the maximum allowed revenue each year based on a TNSP's service performance in the preceding year. The AER approves parameter values for each TNSP as part of its determination.

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104 The standard is a 'modified' N-2 standard, as it refers to no inadvertent loss of load under agreed combinations of two circuits, two transformers or a circuit and a transformer (rather than all possible combinations of two elements). (HoustonKemp, *Electricity Networks Service Standards: An Overview*, p 6.)

105 TransGrid, *Reliability Scenarios; NSW Electricity Transmission System*, November 2015, p 2.

Also as part of its determination the AER must approve TransGrid's pricing methodology and negotiating framework. The revenue cap and pricing methodology only apply to TransGrid's prescribed transmission services which are those services which TransGrid is required to provide and are subject to regulated performance requirements.[106]

### C.2.3 Annual transmission planning requirements

The National Electricity Rules require TransGrid to undertake an annual planning review. The purpose of the review is to identify an optimum level of transmission investment so that TransGrid can deliver its services efficiently. The annual review identifies any emerging constraints within the transmission network and identifies possible options to overcome them including considering non-network solutions.

In planning transmission augmentations, TransGrid must apply the RIT-T to most planned investments. The RIT-T involves cost benefit analysis to identify the investment option that maximises net economic benefits and, where applicable, meets the relevant jurisdictional or Electricity Rule based reliability standards.[107] The process considers all credible options that are technically and economically feasible, including non-network options.

The NSW Government has directed TransGrid to implement the Transmission Standard in developing its investment plans.[108]

Its investment plans must also consider the demand for electricity (ie, load). To understand the likely changes in the demand for electricity, TransGrid looks at forecast annual energy use published by the AEMO for the NSW region, and forecast maximum demands for the NSW region (including the ACT). The need for network augmentation is driven by maximum demand, but energy forecasts can usefully reflect broader drivers that may impact the future use of the network.

106 The National Electricity Rules define which transmission network services are 'prescribed services' and 'negotiated services'. (See National Electricity Rules - Glossary, available at: http://www.aemc.gov.au/Energy-Rules/National-electricity-rules/Current-Rules, accessed 27 May 2016.)

107 The RIT-T does not apply in circumstances where the estimated capital cost of new network investment is less than $6 million. Further, where transmission investment is subject to the RIT-T and the preferred option does not exceed a cost threshold of $41 million, the network service provider preparing the RIT-T may be exempted from parts of the RIT-T consultation procedures. (AER, *Cost thresholds review for the regulatory investment test - Final determination,* November 2015, p 1.)

108 TransGrid, *NSW Transmission Annual Planning Report 2015*, p 18.

For the 2015 annual planning review, the forecasts that TransGrid relies on indicate that annual electricity consumption in the NSW region (including the ACT) is likely to grow by an average of 1% per annum for the next 10 years, driven mainly by lower energy prices, population growth and increased income.[109] In comparison, the projected annual growth rate in the 2014 annual planning review was 0.4%.[110] Maximum demand is projected to grow at 1.2% per annum in summer and 1.4% in winter, based on 50% Probability of Exceedance (POE) conditions (see Box C.2).[111]

While the aggregated maximum demand is increasing, individual bulk supply point forecasts increase at some locations, and decrease at others.

**Box C.2 Maximum demand forecasts**

The AEMO produces maximum demand forecasts for the NEM and each of the five NEM regions, including NSW, over a 20-year outlook period. It has also produced transmission bulk supply point forecasts for 2015-16 to 2024-25.

The maximum demand for a bulk supply point or region is the highest level of electricity drawn from the transmission network in that area in any half hour increments It is measured in megawatts (MW).

The maximum demand forecasts are based on 10%, 50% and 90% POE, for both summer (2015-16 to 2024-25) and winter (2015 to 2024). A POE refers to the likelihood that a maximum demand forecast will be met or exceeded at least once during the season. For any given season:

- The 10% POE implies that there is a 10% probability of the forecast maximum being met or exceeded at least once during the season.
- The 50% POE implies that there is a 50% probability of the forecast maximum being met or exceeded at least once during the season.

The key driver of variability in demand is usually ambient temperature.

The bulk supply point forecasts are “non-coincident”. Non-coincident forecasts are the maximum demand forecasts of a bulk supply point, regardless of when the system peak occurs. Coincident forecasts are the maximum demand forecasts of a bulk supply point at the time the system peak occurs.

**Sources**: AEMO, *Detailed Summary of 2015 Electricity Forecasts; 2015 National Electricity Forecasting Report*, Published: June 2015; AEMO, *2015 AEMO Transmission Connection Point Forecasting Report; For New South Wales Including (sic) The Australian Capital Territory*, Published: June 2015.

109 TransGrid, *NSW Transmission Annual Planning Report 2015*, pp 8, 23, 27.
110 TransGrid, *NSW Transmission Annual Planning Report 2015*, pp 8, 23.
111 TransGrid, *NSW Transmission Annual Planning Report 2015*, pp 8, 29, 30.

TransGrid identified that the only areas where load growth is expected to lead to network limitations are the Gunnedah/Narrabri area and the Beryl/Mudgee area.[112]

TransGrid's Transmission Annual Planning Report 2015 takes into account the AER's final revenue determination for the 2014-15 to 2017-18 regulatory control period.[113]

## C.3 TransGrid's reliability performance in recent years

TransGrid reports its reliability performance against incentive targets that are determined as part of the AER revenue determination (see below). If it does not achieve the targeted level of performance, it is not eligible to receive the relevant performance payments. However, non-achievement of targets does not necessarily mean the network is unreliable.

The reliability performance of the TransGrid network is very high. As Table C.1 shows, over the five years from 2009-10 to 2013-14, the level of network availability has been between 98.2% and 99.1%, and system minutes not supplied has been at or below 2.2 minutes. TransGrid has also achieved its target level of maintenance.

In addition, analysis undertaken by HoustonKemp[114] indicates that, based on system minutes of energy not supplied, NSW and the ACT enjoyed the highest reliability performance in Australia between 2002–03 and 2011-12.

**Table C.1 TransGrid – performance statistics**

| | 2009-10 | 2010-11 | 2011-12 | 2012-13 | 2013-14 |
|---|---|---|---|---|---|
| Energy usage (GWh) | 75,278 | 74,950 | 72,318 | 68,826 | 67,238 |
| Maximum summer peak demand (MW) | 14,039 | 14,907 | 12,207 | 13,997 | 12,169 |
| Network reliability (system minutes[a] lost) | 1.3 | 2.2 | 0.4 | 1.1 | 0.64 |
| Network availability (%) | 98.2 | 99.0 | 99.1 | 98.9 | 98.6 |
| Percentage of maintenance achieved[b] | 97 | 97 | 96 | 98 | 99 |

**a** A system minute is the amount of energy which would not be supplied if the whole NSW system was unavailable for a minute at peak usage.

**b** Maintenance achievement is calculated by comparing the maintenance work carried out during the year to the work specified by TransGrid's maintenance policies. TransGrid strives to complete at least 96% of planned work during the year with any outstanding work being completed during the first three months of the next financial year.

**Source:** TransGrid, *NSW Transmission Annual Planning Report 2015*, pp 27, 29. TransGrid, *Annual Report 2014*, pp 54-55.

112 TransGrid, *NSW Transmission Annual Planning Report 2015*, pp 8, 23, 35.

113 TransGrid, *NSW Transmission Annual Planning Report 2015*, p 20.

114 HoustonKemp, *Electricity Networks Service Standards: An Overview*, 2 September 2014, p 27.

# D Model inputs and assumptions

This appendix describes the inputs and assumptions used in the optimisation model.

The model finds the 'least total cost' set of planning criteria (see D.1) for each BSP, where *total cost* = *cost of supply arrangements* + *cost of expected unserved energy.*

Where two or more sets of planning criteria produce the same total cost, the model selects the set which involves the least load at risk and the quickest restoration time.

In calculating total costs, the model includes the following scenarios:

- system normal
- a single transformer failure
- a single line failure
- a double transformer failure, and
- a double line failure.

## D.1 Planning criteria

The model uses **planning criteria** to inform both the cost of expected unserved energy and the cost of supply arrangements.

The planning criteria include the required level of redundancy at each BSP. The model is able to find the optimal level of redundancy at each BSP. However, we have recommended that the level of redundancy at each BSP remains the same as that which is required by the current electricity transmission reliability standard.

The values for other planning criteria are determined through the optimisation process. For each of these criteria, the model defines a range of discrete options. The criteria cover:

- **Load at risk** - load supplied from the BSP which is at risk of being interrupted, **after** allowing for any available backup capacity but **before** repair of the asset/s.

- **Restoration strategy** - the strategy to bring any available backup capacity into service following an asset failure or failures. An integer parameter from 0 to 5 is defined to select different forms and timescales of switching to the backup supply capacity, from no switching allowed (ie, no backup capacity), to automatic switching, remote switching and manual switching. This criterion imposes design requirements on switching arrangements.
- **Repair strategy** - the strategy to repair the failed asset(s) to their normal service levels (or to replace failed asset(s)). An integer parameter from 1 to 4 is defined to reflect the length of repair time, with longer repair times requiring less costly actions to achieve. This criterion imposes requirements on the management of spares, asset procurement and repair and replacement protocols.

The model assumes an upper bound for repair of transformers of 6,570 hours, repair of overhead lines of 120 hours, and repair of underground cables of 15,351 hours. These values were based on consultant advice to IPART, and correspond to the least-cost repair options.

**Table D.1 Planning criteria (0 level of redundancy required, ie, N standard)**

| Planning criteria | Range of possible values | | |
|---|---|---|---|
| | System normal (no failures) | Single failure | Double failure[a] |
| Load at risk for transformers | 0%, 10%, 20%, …, 80% 90% | n/a | n/a |
| Load at risk for lines | 0%, 10%, 20%, …, 80% 90% | n/a | n/a |
| Restoration strategy (same for transformers, lines and cables) | n/a | n/a | n/a |
| Repair strategy for transformers[b] | n/a | 1 = 24 hrs<br>2 = 720 hrs<br>3 = 6,579 hrs<br>4 = 8,772 hrs | Equal to repair strategy for single failure |
| Repair strategy for overhead lines | n/a | 1 = 8 hrs<br>2 = 24 hrs<br>3 = 48 hrs<br>4 = 120 hrs | Equal to repair strategy for single failure |
| Repair strategy for underground cables | n/a | 1 = 168 hrs<br>2 = 672 hrs<br>3 = 1,344 hrs<br>4 = 2,016 hrs | Equal to repair strategy for single failure |

**a** Many BSPs with 0 level of required redundancy (N standard) may only have one transformer or line. For these BSPs the planning criteria for a double failure are not relevant. However, some BSPs with 0 level of required redundancy (N standard) may have multiple transformers or lines. For example, three transformers might supply a load and a failure of any one of the three transformers would mean that the required supply cannot be met. In this situation, the repair strategy for transformers becomes relevant.
**b** The repair times for transformers have been updated since IPART's Draft Report, based on advice from TransGrid.
**Data source:** IPART based on consultant advice and advice by TransGrid.

**Table D.2 Planning criteria (1 level of redundancy required, ie, N-1 standard)**

| Planning criteria | Range of possible values | | |
|---|---|---|---|
| | System normal (no failures) | Single failure | Double failure |
| Load at risk for transformers | 0% | 0%, 10%, 20%, …, 80% 90% | n/a |
| Load at risk for lines | 0% | 0%, 10%, 20%, …, 80% 90% | n/a |
| Restoration strategy (same for transformers, lines and cables)[a] | n/a | 0 = 0<br>1 = 0-5 mins<br>2 = 5 to 30 mins<br>3 = 0.5 to 1 hr<br>4 = 1 to 4 hrs<br>5 > 4 hrs | n/a |
| Repair strategy for transformers[b] | n/a | 1 = 24 hrs<br>2 = 720 hrs<br>3 = 6,579 hrs<br>4 = 8,772 hrs | Equal to repair strategy for single failure |
| Repair strategy for overhead lines | n/a | 1 = 8 hrs<br>2 = 24 hrs<br>3 = 48 hrs<br>4 = 120 hrs | Equal to repair strategy for single failure |
| Repair strategy for underground cables | n/a | 1 = 168 hrs<br>2 = 672 hrs<br>3 = 1,344 hrs<br>4 = 2,016 hrs | Equal to repair strategy for single failure |

**a** A restoration time of 0 means that no backup is available. The model assumes a restoration time of 8 hours for strategy option 5.

**b** The repair times for transformers have been updated since IPART's Draft Report, based on advice from TransGrid.

**Data source:** IPART based on consultant advice, and advice from TransGrid.

**Table D.3 Planning criteria (2 levels of redundancy required, ie, N-2 standard)**

| Planning criteria | Range of possible values | | |
|---|---|---|---|
| | System normal (no failures) | Single failure | Double failure |
| Load at risk for transformers | 0% | 0% | 0%, 10%, 20%, …, 80% 90% |
| Load at risk for lines | 0% | 0% | 0%, 10%, 20%, …, 80% 90% |
| Restoration strategy (same for transformers, lines and cables)[a] | n/a | 0 = 0<br>1 = 0-5 mins<br>2 = 5 to 30 mins<br>3 = 0.5 to 1 hr<br>4 = 1 to 4 hrs<br>5 > 4 hrs | 0 = 0<br>1 = 0-5 mins<br>2 = 5 to 30 mins<br>3 = 0.5 to 1 hr<br>4 = 1 to 4 hrs<br>5 > 4 hrs<br>But such that it is longer than or the restoration time for a single failure. |
| Repair strategy for transformers[b] | n/a | 1 = 24 hrs<br>2 = 720 hrs<br>3 = 6,579 hrs<br>4 = 8,772 hrs | 1 = 24 hrs<br>2 = 168 hrs<br>3 = 2,190 hrs<br>4 = 4,380 hrs<br>But such that it is longer than or equal to the repair time for a single failure. |
| Repair strategy for overhead lines | n/a | 1 = 8 hrs<br>2 = 24 hrs<br>3 = 48 hrs<br>4 = 120 hrs | 1 = 8 hrs<br>2 = 24 hrs<br>3 = 48 hrs<br>4 = 120 hrs<br>But such that it is longer than or equal to the repair time for a single failure. |
| Repair strategy for underground cables | n/a | 1 = 168 hrs<br>2 = 672 hrs<br>3 = 1,344 hrs<br>4 = 2,016 hrs | 1 = 168 hrs<br>2 = 672 hrs<br>3 = 1,344 hrs<br>4 = 2,016 hrs<br>But such that it is longer than or equal to the repair time for a single failure. |

**a** A restoration time of 0 means that no backup is available. The model assumes a restoration time of 8 hours for strategy option 5.

**b** The repair times for transformers have been updated since IPART's Draft Report, based on advice from TransGrid.

**Data source:** IPART based on consultant advice, and advice from TransGrid.

## D.2 Existing network inputs and assumptions

The model also uses input data and assumptions about the existing network and demand for electricity to inform both the cost of expected unserved energy and the cost of supply arrangements.

It uses the following input data, supplied by TransGrid, which is specific to each BSP:

- estimated maximum demand for 2018-19 (50% Probability of Exceedance (POE) forecast)[115]
- actual number of transformers, and
- actual number of lines.

For simplicity it assumes that:

- each transformer at each BSP is of equivalent capacity
- each line at each BSP is of equivalent capacity, and
- lines at each BSP are all either overhead or underground.

Where necessary to meet required level of redundancy, the model will increase the number of transformers or lines at a BSP. For example, if an N-2 BSP has only two transformers and no ability to switch to backup capacity, the model will add one transformer to allow the N-2 requirement to be met.

While the number of transformers and lines is based on the actual configuration at the BSP (subject to the caveat in the prior paragraph), the sizing of these assets is done dynamically by the model. Normally the assets are sized so that the maximum demand can just be met. For example, at a BSP with four transformers and a maximum load of 100 MW, each transformer would be sized to 25 MW capacity. However, if the transformer load at risk criterion is set to 40%, then the model will "shrink" the transformers so that each would be sized to 15 MW capacity.

IPART estimated line lengths based upon the location type for each BSP (ie, whether it is CBD, suburban, regional, or remote).

115 Probability of Exceedance (POE) refers to the likelihood that a maximum demand forecast will be met or exceeded. A 50% POE maximum demand projection is expected to be exceeded, on average, five years in 10.

**Table D.4 Estimated line lengths**

| Location type | Estimated line length (km) |
|---|---|
| CBD | 15 |
| Suburban | 30 |
| Regional | 150 |
| Remote | 300 |

**Data source:** IPART estimates.

## D.3 Cost of supply arrangements

The supply arrangement costs cover the capital and operating costs for the following elements:

- transformer and line capacity
- backup capacity and restoration obligations, and
- repair obligations.

Transformer and line capacity costs provide the cost of system capacity in its normal state, ie, no asset failures. The cost of backup capacity, restoration obligations and repair obligations drive the cost of system capacity to deal with a single or double asset failure.

The model only includes costs that vary when the planning criteria change. This means, for example, that it excludes the cost of substation land, fencing and other site costs as they are the same across all the possible planning criteria.

### D.3.1 Capital cost of transformer and line capacity

#### Life time capital costs

The model uses a power law to calculate the capacity cost of transformers and lines of a given MW rating.[116] It then multiplies the cost per transformer/ line circuit for each BSP by the number of transformers/ lines at each BSP.

**Transformer** unit costs are calculated using the following equation:

Cost = c.MW^b

where:

c = 0.094214

b = 0.640401

116 It assumes that transformers (and circuits) of any capacity can be purchased at a price given by the power law function. In practice, organisations like TransGrid tend to buy transformers of standard types and sizes to minimise purchase prices and inventory costs.

IPART derived the values for 'c' and 'b' by fitting a power law function to transformer purchase price data provided by TransGrid.

For **lines**, the capacity cost is multiplied by the line length to give a per circuit cost. An underground scaling factor is applied if the circuit is defined as an underground (UG) cable. Line circuit costs are calculated using the following equation:

Cost =(UG scaling factor if UG cable).km.c.MW^b

where:

c = 0.024784

b = 0.640401

UG scaling factor = 15

IPART assumed the value for 'b' in the line equation is the same that is used in the transformer equation. The value for 'c' and the underground scaling factor were based on consultant advice to IPART. The assumed line lengths are shown in Table D.4.

Cost multipliers are applied to the unit costs for transformers and circuit costs for lines to allow for installation. The multipliers vary by location type and the values used are shown in Table D.5.

**Table D.5 Transformer and line cost multipliers**

| Location type | Transformer cost multipliers | Overhead line cost multipliers | Underground cable cost multipliers |
|---|---|---|---|
| **CBD** | 2 | 2 | 1 |
| **Suburban** | 1.5 | 1.5 | 1 |
| **Regional** | 1 | 1 | 1 |
| **Remote** | 1.5 | 1.5 | 1 |

**Data source:** IPART based on consultant advice.

### Annualising capital costs

**Transformer and line capacity** capital costs are transformed to an average annual basis using the following formula:

Annualised capital cost = d . capital cost / [(1-(1+d)$^{-L}$) . (1+d)];

where d = discount rate

L = life of asset

**Discount rate**

The model assumes a discount rate of 5.6% (real pre-tax).[117]

**Life of asset**

The model assumes the following asset lives, based on TransGrid's Regulatory Information Notice submitted to the AER:

- Transformer average life = 40 years.
- Overhead line average life = 50 years.
- Underground cable average life = 45 years.[118]

### D.3.2 Backup capacity and restoration obligation costs

The total cost per MW of transformer and line capacity at each BSP is used as a proxy to cost backup capacity.[119] There are two further assumptions that scale these costs down:

- it is assumed backup capacity is shared between two BSPs, and therefore, only 50% of the cost is assigned to the BSP being assessed, and
- an additional efficiency factor of 50% is included to allow for backup capacity primarily being installed to service other requirements (For example, backup capacity may be provided by the distribution network, but it is likely that this distribution capability will also be being used for its own supply purposes. Therefore, only part of the distribution network costs are assigned to backup for the transmission system).

The costs of equipment or labour associated with having and using backup capacity include:

- the capital costs associated with any facilities or services necessary to achieve the required restoration times (eg, automatic control schemes), and
- the operating costs associated with using these facilities or services, when an asset failure occurs.

117 Using IPART's WACC methodology sampled to 22 July 2016 for inflation and interest rates, and to the end of June 2016 for market risk premium and debt margin.

118 The asset lives have been updated since the Draft Report.

119 Note: backup capacity could be provided by various forms that are not explicitly modelled.

**Table D.6 Backup capacity and restoration strategy costs**

| Restoration time | Form of switching | Fixed capital cost ($m) | per MW capital costs ($m) | Fixed operating cost (per use) ($m) | per MW operating cost (per use) ($m) |
|---|---|---|---|---|---|
| 0 | firm - no requirement for switching | - | - | - | - |
| 0 to 5 mins | fast-automatic | 1.000 | 0.002 | - | - |
| 5 to 30 mins | slow-automatic | 0.500 | 0.001 | - | - |
| 0.5 to 1 hr | fast-remote | 0.100 | 0.0002 | - | - |
| 1 to 4 hrs | slow-remote / manual | - | - | 0.050 | 0.0002 |
| > 4 hrs | manual | - | - | 0.100 | 0.0004 |

**Data source:** IPART based on consultant advice.

### D.3.3 Repair obligation costs

The costs of equipment or labour associated with repairing (or replacing) assets include:

- the capital costs associated with any facilities or services necessary to achieve the required repair times (eg, spares, network arrangements, etc), and
- the operating costs associated with implementing the repair (or replacement), when an asset failure occurs.

**Table D.7 Transformer repair strategy costs**

| Repair time[a] | Comment | Fixed capital cost ($m) | per MW capital costs ($m) | Fixed operating cost (per repair) ($m) | per MW operating cost (per repair) ($m) |
|---|---|---|---|---|---|
| 24 hours | Requires on-site bay spare and fast change over | - | 0.0144 | 0.050 | 0.001 |
| 720 hours | Requires spares and fast installation | - | 0.0036 | 0.100 | 0.003 |
| 6,579hours | Fast procurement, delivery and normal installation | - | - | - | 0.0018 |
| 8,772 hours | Normal procurement, delivery and installation | - | - | - | - |

**a** The repair times for transformers have been updated since IPART's Draft Report, based on advice from TransGrid.

**Data source:** IPART based on consultant advice and advice from TransGrid.

**Table D.8 Overhead line repair strategy costs**

| Repair time | Comment | Fixed capital cost ($m) | per MW capital costs ($m) | Fixed operating cost (per repair) ($m) | per MW operating cost (per repair) ($m) |
|---|---|---|---|---|---|
| 8 hours | Requires special equipment and fast response | 0.100 | 0.001 | 0.050 | 0.002 |
| 24 hours | Requires fast response | - | - | 0.050 | 0.002 |
| 48 hours | Enhanced response | - | - | 0.050 | 0.0015 |
| 120 hours | Normal response | - | - | 0.050 | 0.0005 |

**Data source:** IPART based on consultant advice.

**Table D.9 Underground cable repair strategy costs**

| Repair time | Comment | Fixed capital cost ($m) | per MW capital costs ($m) | Fixed operating cost (per repair) ($m) | per MW operating cost (per repair) ($m) |
|---|---|---|---|---|---|
| 168 | requires special equipment, spares and fast response | 0.2000 | 0.0020 | 0.1000 | 0.0070 |
| 672 | requires spares and fast response | - | 0.0020 | 0.1000 | 0.0070 |
| 1,344 | enhanced response and repair | - | - | 0.0500 | 0.0025 |
| 2,016 | normal response and repair | - | - | 0.0500 | 0.0010 |

**Data source:** IPART based on consultant advice.

### D.3.4 Operating costs

The long-term average annual operating costs associated with capital costs (eg, to cover maintenance activities)[120] are assumed to be linearly proportional to the calculated capital cost, with a single constant input in the model to define this relationship. The constant used in the model is 2%. That is, the annual operating cost of equipment is 2% of the annual capital cost of the equipment.

The average annual operating costs are separate to the operating costs associated with particular repair or restoration strategies which are only incurred when there is an asset failure.

## D.4 Cost of expected unserved energy

### D.4.1 Expected amount of unserved energy

The expected unserved energy at each BSP is the sum of the expected amount of unserved energy for each scenario[121] at that BSP.

The expected amount of unserved energy for each scenario=

expected number of asset failures (forced outages) per year *

duration of supply outage associated with the asset failure(s) *

proportion of annual energy required that cannot be supplied while the asset is in a failed state *

annual energy required (MWh)

Where backup capacity is available, the model calculates:

1) the expected unserved energy before switching has occurred, and

2) the expected unserved energy after switching has occurred but before repair of the asset.[122]

[120] These are in addition to operating costs associated with the use of specific restoration or repair strategies as described in sections D.3.2 and D.3.3.

[121] The scenarios are: system normal, a single transformer failure, a single line failure, a double transformer failure and a double line failure.

[122] For double contingency events (double transformer failures of double line failures) the model performs an equivalent four-stage process as it steps through the two restorations and two repair stages.

### Expected number of asset failures (forced outages)

The expected number of asset failures (forced outages) is the probability of asset failure multiplied by the number of assets, for each asset type at each BSP.

The probabilities of asset failure used in the model are summarised in Table D.10. They are reflective of the average life-cycle failure rates for each asset type. For transformers and overhead lines, IPART derived these values using TransGrid's historic failure data, weighted by asset subcategory. For underground cables, IPART derived the values from Ausgrid failure data for Inner Sydney, provided by TransGrid. TransGrid provided separate rates for catastrophic transformer failure (requiring replacement) and non-catastrophic transformer failure (not-requiring replacement).

**Table D.10 Asset failure frequency**

| Asset type | Failure frequency |
|---|---|
| Transformers (catastrophic failures per year per transformer) | 0. 557% |
| Transformers (non-catastrophic failures per year per transformer) | 17.0% |
| Overhead lines (failures per year per 100km) | 29.01% |
| Underground cables (failures per year per 100km) | 5.95 % |

**Data source:** IPART based on TransGrid historic performance data and Ausgrid underground failure rates provided by TransGrid**.**

The model assumes the primary and secondary buses of the transformers are effectively solid and fully switched (ie, a fault on any transformer or line will not automatically result in the outage of other transformers or lines).[123]

### Duration of supply outage

The duration of supply outages associated with a particular scenario is determined by the restoration and repair strategies (see section D.1).

### Proportion of annual energy required that cannot be supplied

The model uses a normalised integral of a load duration curve to determine the proportion of annual energy required that cannot be supplied while an asset remains in a failed state. The curve relates the proportion of annual energy required that cannot be served to the proportion of maximum demand that can still be served following a failure event.

The proportion of maximum demand that can be served following a failure event is equal to (1- %load at risk) for the relevant scenario (see section D.1).

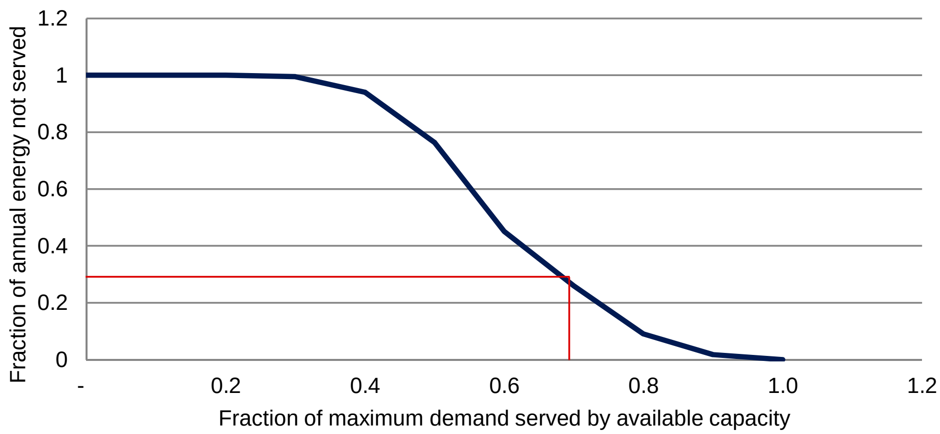
123 An underlying assumption is that for actual circumstances where this is not the case, operating arrangements would be such that any "good" assets would be rapidly switched back into service following the fault, such that the resulting actual reliability is approximately equal to these assumed arrangements.

A hypothetical example is provided in Box D.1.

The model uses curves which are specific to each BSP.[124] IPART derived the curves using TransGrid data (load at 15 minute intervals for the 2011 calendar year).

**Box D.1 Proportion of annual energy required that cannot be supplied if a single transformer fails**

**Normalised integral of the load duration curve for a hypothetical BSP**




In this example, the load at risk if a transformer fails is 30% of maximum demand at the BSP (as set by the planning criteria). Therefore 70% of maximum demand can be served following a transformer failure (ie, capacity is reduced to 70% of maximum demand).

If the transformer failure occurs during a period of low demand then it is likely that the required supply at that point in time could be met. However, if the failure occurs during a period of high demand, then it is possible that none of the required supply could be met.

Because we do not know when a transformer failure will occur, we consider what proportion of energy would be lost if the failure lasts for an entire year (which includes periods of low and high demand). The curve tells us that, on average across all possible moments of failure, around 30% of energy required at this BSP would not be served if capacity of the BSP was reduced to 70% of maximum demand.

**Note**: If there are load shedding protocols in place, some supply may still be met even if the failure occurs during a period of high demand.

124 The model used for IPART's Draft Report used TransGrid's state-wide load duration curve.

### Annual energy required

The **annual energy required** (MWAh) at each BSP is the maximum demand (MW) multiplied by the load factor (%) multiplied by the number of hours in a year.

IPART estimated a load factor for each BSP using TransGrid data (load at 15 minute intervals for the 2011 calendar year).[125] Maximum demand assumptions are discussed in section D.2.

### D.4.2 Cost of expected unserved energy

The cost of unserved energy (ie, annual reliability cost) is the total amount of expected unserved energy for each BSP multiplied by the value of customer reliability (VCR) for that BSP.

The model uses the most recent VCRs published by AEMO[126], weighted by customer type at each bulk supply point.

IPART engaged WSP Parsons Brinckerhoff (PB) to recommend VCRs for each bulk supply point, based on the values published by AEMO, weighted by customer type. For bulk supply points that were based on Ausgrid data, PB developed a non-weighted VCR using the straight average of the customer type splits. This is because there was no consumption data provided to undertake a weighted average. Additionally, no weighting was required for direct connect customers as there is only one customer type at each bulk supply point.

Since publishing our Draft Report we have updated the VCRs for some BSPs based on advice from TransGrid, Ausgrid and Essential Energy.

## D.5 Unserved energy allowance

The unserved energy allowance for each BSP that IPART has adopted for our recommended reliability standards takes the expected unserved energy associated with the 'least total cost' set of the following planning criteria, given the required level of redundancy:

- load at risk
- restoration strategy
- repair strategy.

125 The model used for IPART's Draft Report had an average load factor of 51% for all BSPs, based on TransGrid's state-wide load duration curve.

126 AEMO, *Value of Customer Reliability Review - Final Report*, September 2014, pp 2, 18.

To this value we add an allowance for non-catastrophic transformer failure. While the optimisation model only takes into account catastrophic failures (that is, where the transformer needs to be replaced following failure),[127] the rate of non-catastrophic transformer failure (failures that can be repaired) is significant and this adds to the expected unserved energy for the network.

To estimate the allowance for non-catastrophic transformer failures we used information on the rate of these failures (provided by TransGrid) as well as information on the average repair time (also from TransGrid) and the speed of switching available at the BSP (based on our modelled optimum). Where back-up capacity is available, we assumed that a non-catastrophic failure would lead to an outage lasting only as long as it takes to switch to backup capacity. Where no backup capacity is available, then we assumed that the non-catastrophic outage would last for the repair time (TransGrid's average is approximately 35 hours).

While the model identifies the optimal level of redundancy, we have recommended that the level of redundancy at each BSP remains the same as that which is required by the current electricity transmission reliability standard.

The expected unserved energy in MWh is then used to calculate the allowance for expected unserved energy in minutes per annum by dividing it by estimated average annual demand at that BSP (in MW) and converting it to minutes (by multiplying it by 60).

We have estimated annual demand at each bulk supply point using forecast maximum demand (in MW) and the estimated load factor.

127 Because this rate and the cost of minor repairs are largely independent of the planning criteria adopted, the presence of non-catastrophic transformer failures would not affect the optimisation calculation.

## D.6 Bulk Supply Point (BSP) data

**Table D.11 BSP data**

| Bulk Supply Point/s | Level of redundancy (category)[a] | Maximum demand (MW) | Number of transformers | Number of lines/ cables | Location type | Line/ cable length (km) | Overhead line or underground cable | Load factor | VCR ($/MWh) |
|---|---|---|---|---|---|---|---|---|---|
| Albury 132 kV | 2 | 112 | 0 | 3 | Regional | 150 | o'head line-s | 0.49 | 36,119 |
| ANM 132 kV | 2 | 100 | 0 | 3 | Regional | 150 | o'head line-s | 0.73 | 6,050 |
| Armidale 66 kV | 2 | 26 | 2 | 4 | Regional | 150 | o'head line-s | 0.57 | 34,827 |
| Balranald 22 kV | 1 | 4 | 1 | 1 | Remote | 300 | o'head line-s | 0.45 | 33,793 |
| Beryl 66 kV | 2 | 67 | 2 | 2 | Regional | 150 | o'head line-s | 0.55 | 34,024 |
| Boambee South 132 kV | 2 | 22 | 0 | 2 | Regional | 150 | o'head line-s | 0.54 | 33,835 |
| Broken Hill 22 kV | 1 | 38 | 2 | 1 | Remote | 300 | o'head line-s | 0.48 | 34,676 |
| Broken Hill 220 kV | 1 | 22 | 0 | 1 | Remote | 300 | o'head line-s | 0.75 | 34,150 |
| Canberra 132 kV and Williamsdale 132 kV | 2 | Canberra 132 kV =435<br>Williamsdale 132 kV =180 | Canberra 132 kV = 4<br>Williamsdale 132 kV = 2 | Canberra 132 kV = 5<br>Williamsdale 132 kV = 4 | Regional | 150 | o'head line-s | 0.55 | 37,279 |
| Coffs Harbour 66 kV | 2 | 48 | 3 | 6 | Regional | 150 | o'head line-s | 0.54 | 36,373 |
| Coleambally 132 kV | 2 | 11 | 0 | 2 | Regional | 150 | o'head line-s | 0.38 | 38,166 |
| Cooma 66 kV | 2 | 17 | 3 | 3 | Regional | 150 | o'head line-s | 0.24 | 34,357 |
| Cooma 132 kV | 2 | 40 | 0 | 2 | Regional | 150 | o'head line-s | 0.52 | 34,357 |
| Cowra 66 kV | 2 | 30 | 2 | 3 | Regional | 150 | o'head line-s | 0.43 | 33,831 |
| Dapto 132 kV | 2 | 571 | 4 | 3 | Regional | 150 | o'head line-s | 0.65 | 39,575 |
| Darlington Point 132 kV | 2 | 18 | 2 | 1 | Regional | 150 | o'head line-s | 0.9 | 37,691 |
| Deniliquin 66 kV | 2 | 45 | 2 | 2 | Regional | 150 | o'head line-s | 0.53 | 35,547 |
| Dorrigo 132 kV | 1 | 2 | 0 | 1 | Regional | 150 | o'head line-s | 0.62 | 34,513 |

| **Bulk Supply Point/s** | **Level of redundancy (category)**[a] | **Maximum demand (MW)** | **Number of transformers** | **Number of lines/ cables** | **Location type** | **Line/ cable length (km)** | **Overhead line or underground cable** | **Load factor** | **VCR ($/MWh)** |
|---|---|---|---|---|---|---|---|---|---|
| Finley 66 kV | 2 | 18 | 2 | 2 | Regional | 150 | o'head line-s | 0.49 | 35,460 |
| Forbes 66 kV | 2 | 31 | 2 | 2 | Regional | 150 | o'head line-s | 0.54 | 34,721 |
| Gadara 132 kV and 11 kV | 2 | 60 | 2 | 2 | Regional | 150 | o'head line-s | 0.61 | 6,050 |
| Glen Innes 66 kV | 2 | 8 | 2 | 3 | Regional | 150 | o'head line-s | 0.54 | 34,432 |
| Griffith 33 kV | 2 | 80 | 3 | 2 | Regional | 150 | o'head line-s | 0.47 | 36,683 |
| Gunnedah 66 kV | 2 | 25 | 2 | 2 | Regional | 150 | o'head line-s | 0.52 | 36,353 |
| Hawks Nest 132 kV | 1 | 8 | 0 | 1 | Regional | 150 | o'head line-s | 0.37 | 32,849 |
| Herons Creek | 1 | 9 | 0 | 1 | Regional | 150 | o'head line-s | 0.53 | 38,350 |
| Holroyd 132 kV | 2 | 313 | 2 | 4 | Suburban | 30 | u'ground cable-s | 0.46 | 40,650 |
| Ilford 132 kV | 1 | 8 | 0 | 1 | Regional | 150 | o'head line-s | 0.47 | 38,350 |
| Ingleburn 66 kV | 2 | 142 | 2 | 2 | Suburban | 30 | o'head line-s | 0.47 | 39,149 |
| Inverell 66 kV | 2 | 35 | 2 | 3 | Regional | 150 | o'head line-s | 0.49 | 34,248 |
| Kempsey 33 kV | 2 | 24 | 2 | 5 | Regional | 150 | o'head line-s | 0.56 | 34,693 |
| Koolkhan 66 kV | 2 | 48 | 3 | 3 | Regional | 150 | o'head line-s | 0.5 | 35,143 |
| Liddell 330 kV (33 kV supply via Mac Gen) | 2 | 25 | 0 | 6 | Regional | 150 | o'head line-s | 0.65 | 40,211 |
| Lismore 132 kV | 2 | 116 | 2 | 2 | Regional | 150 | o'head line-s | 0.48 | 36,003 |
| Liverpool 132 kV | 2 | 373 | 3 | 2 | Suburban | 30 | o'head line-s | 0.42 | 36,330 |
| Macksville 132 kV | 2 | 8 | 0 | 2 | Regional | 150 | o'head line-s | 0.57 | 35,223 |
| Macarthur 132 kV and 66 kV | 2 | Macarthur 132 kV =162<br>Macarthur 66 kV =162 | Macarthur 132 kV = 1<br>Macarthur 66 kV = 1 | Macarthur 132 kV = 2<br>Macarthur 66 kV = 1 | Suburban | 30 | o'head line-s | 0.47 | 37,364 |
| Marulan 132 kV | 1 | 104 | 1 | 6 | Regional | 150 | o'head line-s | 0.61 | 36,865 |
| Molong 66 kV | 1 | 4 | 1 | 3 | Regional | 150 | o'head line-s | 0.51 | 32,176 |
| Moree 66 kV | 2 | 27 | 2 | 2 | Regional | 150 | o'head line-s | 0.54 | 37,147 |

| Bulk Supply Point/s | Level of redundancy (category)[a] | Maximum demand (MW) | Number of transformers | Number of lines/ cables | Location type | Line/ cable length (km) | Overhead line or underground cable | Load factor | VCR ($/MWh) |
|---|---|---|---|---|---|---|---|---|---|
| Morven 132 kV | 1 | 7 | 0 | 1 | Regional | 150 | o'head line-s | 0.49 | 38,350 |
| Mount Piper 66 kV | 2 | 41 | 2 | 3 | Regional | 150 | o'head line-s | 0.5 | 38,401 |
| Mudgee 132 kV | 1 | 21 | 0 | 1 | Regional | 150 | o'head line-s | 0.48 | 34,311 |
| Munmorah 33 kV and 132 kV | 2 | 113 | 1 | 2 | Regional | 150 | o'head line-s | 0.41 | 35,530 |
| Munyang 33 kV | 1 | 2 | 2 | 1 | Regional | 150 | o'head line-s | 0.18 | 39,965 |
| Murrumbateman 132 kV | 1 | 5 | 0 | 1 | Regional | 150 | o'head line-s | 0.44 | 29,314 |
| Murrumburrah 66 kV | 2 | 36 | 2 | 2 | Regional | 150 | o'head line-s | 0.53 | 34,661 |
| Muswellbrook 132 kV | 2 | 227 | 2 | 2 | Regional | 150 | o'head line-s | 0.51 | 40,211 |
| Nambucca 66 kV | 2 | 6 | 2 | 2 | Regional | 150 | o'head line-s | 0.49 | 33,775 |
| Narrabri 66 kV | 2 | 44 | 2 | 3 | Regional | 150 | o'head line-s | 0.56 | 36,084 |
| Newcastle 132 kV | 2 | 425 | 3 | 6 | Regional | 150 | o'head line-s | 0.33 | 39,507 |
| Orange North 132 kV/ Orange 132kV and 66kV | 2 | Orange North 132 kV/ Orange 132kV =144 Orange 66 kV =49 | Orange North 132 kV/ Orange 132kV = 3 Orange 66 kV = 3 | Orange North 132 kV/ Orange 132kV = 2 Orange 66 kV =5 | Regional | 150 | o'head line-s | Orange North 132 kV/ Orange 132kV = 0.74 Orange 66 kV = 0.54 | 34,366 |
| Parkes 132 kV | 2 | 29 | 0 | 3 | Regional | 150 | o'head line-s | 0.83 | 6,050 |
| Parkes 66 kV | 2 | 25 | 2 | 3 | Regional | 150 | o'head line-s | 0.46 | 34,215 |
| Port Macquarie 33 kV | 2 | 55 | 3 | 3 | Regional | 150 | o'head line-s | 0.53 | 35,051 |
| Queanbeyan 66 kV | 2 | 63 | 2 | 1 | Regional | 150 | o'head line-s | 0.52 | 32,756 |
| Raleigh 132 kV | 2 | 7 | 0 | 2 | Regional | 150 | o'head line-s | 0.52 | 33,951 |
| Regentville 132 kV | 2 | 264 | 2 | 2 | Regional | 150 | o'head line-s | 0.37 | 36,346 |
| Snowy Adit 132 kV | 1 | 10 | 0 | 1 | Regional | 150 | o'head line-s | 0.31 | 44,549 |

| Bulk Supply Point/s | Level of redundancy (category)[a] | Maximum demand (MW) | Number of transformers | Number of lines/ cables | Location type | Line/ cable length (km) | Overhead line or underground cable | Load factor | VCR ($/MWh) |
|---|---|---|---|---|---|---|---|---|---|
| Stroud 132 kV | 2 | 34 | 0 | 3 | Regional | 150 | o'head line-s | 0.37 | 32,960 |
| Sydney East 132 kV | 2 | 533 | 4 | 2 | Suburban | 30 | o'head line-s | 0.52 | 36,952 |
| Sydney West 132 kV | 2 | 1,107 | 5 | 9 | Suburban | 30 | o'head line-s | 0.46 | 38,534 |
| Taree 66 kV and 33 kV | 2 | Taree 33 kV =24<br>Taree 66 kV =47 | Taree 33 kV = 2<br>Taree 66 kV = 2 | Taree 33 kV = 3<br>Taree 66 kV = 3 | Regional | 150 | o'head line-s | Taree 33 kV = 0.47<br>Taree 66 kV = 0.53 | 34,906 |
| Tamworth 66 kV | 2 | 101 | 2 | 2 | Regional | 150 | o'head line-s | 0.52 | 36,250 |
| Tenterfield 22 kV | 2 | 5 | 2 | 2 | Regional | 150 | o'head line-s | 0.57 | 33,891 |
| Tomago 132 kV | 2 | 210 | 3 | 4 | Regional | 150 | o'head line-s | 0.97 | 39,507 |
| Tomago 330 kV | 2 | 965 | 4 | 4 | Regional | 150 | o'head line-s | 0.97 | 6,050 |
| Tuggerah 132 kV | 2 | 182 | 2 | 2 | Regional | 150 | o'head line-s | 0.43 | 35,530 |
| Tumut 66 kV | 2 | 32 | 2 | 2 | Regional | 150 | o'head line-s | 0.59 | 33,997 |
| Vales Pt 132 kV | 2 | 99 | 2 | 4 | Regional | 150 | o'head line-s | 0.37 | 35,530 |
| Vineyard 132 kV | 2 | 474 | 3 | 2 | Regional | 150 | o'head line-s | 0.32 | 35,546 |
| Wagga 66 kV | 2 | 73 | 3 | 4 | Regional | 150 | o'head line-s | 0.38 | 34,842 |
| Wagga North 132 kV | 2 | 54 | 0 | 2 | Regional | 150 | o'head line-s | 0.73 | 34,842 |
| Wagga North 66 kV | 1 | 20 | 1 | 3 | Regional | 150 | o'head line-s | 0.38 | 34,842 |
| Wallerawang 132 kV | 2 | 79 | 2 | 4 | Regional | 150 | o'head line-s | 0.35 | 34,085 |
| Wallerawang 66 kV | 2 | 4 | 2 | 4 | Regional | 150 | o'head line-s | 0.47 | 34,085 |
| Waratah West 132 kV | 2 | 204 | 2 | 2 | Regional | 150 | o'head line-s | 0.38 | 39,507 |
| Wellington 132 kV | 2 | 164 | 2 | 2 | Regional | 150 | o'head line-s | 0.57 | 34,747 |
| Wellington Town | 1 | 10 | 0 | 1 | Regional | 150 | o'head line-s | 0.55 | 34,747 |
| Williamsdale 132 kV | 2 | 180 | 2 | 4 | Regional | 150 | o'head line-s | 0.55 | 37,279 |
| Yanco 33 kV | 2 | 38 | 2 | 4 | Regional | 150 | o'head line-s | 0.53 | 35,914 |

| Bulk Supply Point/s | Level of redundancy (category)[a] | Maximum demand (MW) | Number of transformers | Number of lines/ cables | Location type | Line/ cable length (km) | Overhead line or underground cable | Load factor | VCR ($/MWh) |
|---|---|---|---|---|---|---|---|---|---|
| Yass 66 kV | 1 | 12 | 2 | 6 | Regional | 150 | o'head line-s | 0.51 | 32,581 |

**a** This is the level of redundancy required by the current electricity transmission reliability standard. It is not used an input to the model.

**Source:** TransGird; IPART based on TransGrid data; IPART assumptions.

# Glossary

| | |
|---|---|
| Australian Energy Regulator (AER) | The AER is responsible for the economic regulation of electricity transmission in the NEM. It determines TransGrid's maximum allowed revenue and approves its pricing methodology and negotiating framework. |
| Australian Energy Market Commission (AEMC) | The AEMC makes rules which govern the electricity and natural gas markets. It also provides advice to the COAG Energy Council.<br><br>The AEMC has proposed a national framework to establish better ways to set reliability standards which take account of the value placed on reliability by customers. |
| Australian Energy Market Operator (AEMO) | AEMO is the system operator for the NEM.<br><br>The AEMO publishes electricity demand forecasts and VCR values. |
| Average demand | Total energy supplied during the year (MWh) divided by the number of hours in the year. |
| Bulk supply point | A location where supply is provided to Distribution Network Service Provider(s) (DNSP) or directly connected customer(s) at a particular voltage. For the avoidance of doubt:<br>▾ Generally the locations are the busbar(s) at TransGrid substations (where there can be multiple individual connections to the DNSP's or directly connected customer's network). Sometimes the locations are where connections are made to TransGrid's transmission lines (or cables). These can be at "tee" connections or at busbars or substations owned by the DNSP or directly connected customer;<br>▾ Where there are multiple connections at the same voltage at a particular location, such as the connection of several DNSP lines to the busbar(s) at a TransGrid substation, that constitutes a single bulk supply point;<br>▾ Where there are supplies provided at different voltages at a particular location, such as from the higher voltage busbar(s) as well as the lower voltage busbar(s) of a TransGrid substation, each voltage level constitutes a separate bulk supply point. |

| | |
|---|---|
| Direct connect customers | Customers that connect directly to the transmission network, excluding DNSPs. |
| Distribution Network Service Provider (DNSP) | A business in the NEM that operates an electricity distribution network system. |
| Expected unserved energy | The expected amount of energy that cannot be supplied, taking into account the probability of supply outages attributable to credible contingency events, expected outage duration, and forecast load. |
| Inner Sydney | Refers to the Inner Metropolitan Transmission System which is constituted by cables 41 and 42, the 330/132kV substations at Rookwood Road, Beaconsfield, Haymarket, Sydney North and Sydney South and future associated 330kV cables and 330/132kV substations, as well as Ausgrid's 132k transmission network that links those supply points. |
| Megawatt (MW) | A MW is a unit of power referring to the rate of energy conversion. 1 MW is equal to 1,000,000 W. |
| Megawatt-hour (MWh) | A MWh is a unit of energy measuring the amount of electricity produced or consumed. Using 1 MW of power for 1 hour consumes 1 MWh of energy. |
| N-x | The N-x expression of transmission reliability is often used by TNSPs when planning augmentations of transmission networks. Starting from the 'Normal' network operating configuration, the N-x expression specifies the number (x) of network elements that can be out-of-service without causing load curtailment, system instability, thermal overloading, or cascading outages.<br><br>With the value of x commonly set at one, and less often at zero (no redundancy) or two (two levels of redundancy), the N-x expression is easily applied to set the broad expectations of reliability at a connection point.<br><br>The x value is applied as the required level of redundancy in the network, which can be achieved by either network or non-network solutions. |
| National Electricity Market (NEM) | The NEM is a wholesale electricity market. It spans Australia's eastern and south-eastern coasts and comprises five interconnected states: Queensland, New South Wales, Victoria, South Australia and Tasmania. TransGrid is one of five state-based transmission networks in the National Electricity Market. |
| National Electricity Rules | The National Electricity Rules govern the operation of the NEM. |

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| Non-network solutions | Non-network solutions are alternatives to traditional transmission assets, such as lines and transformers, which can be used to address supply constraints. They include demand-side management (eg, load curtailment arrangements) or local generation. |
| Regulatory Investment Test for Transmission (RIT-T) | As defined in the *National Electricity Rules*. The test is developed and published by the AER. It prescribes how costs and market benefits of transmission investment options should be assessed. |
| Transmission Network Service Provider (TNSP) | A business in the NEM that operates an electricity transmission network system. |
| Values of customer reliability (VCR) | These measures, expressed as dollars per kilowatt-hour, indicate the value different types of customers place on having reliable electricity supply. |