Appendix A

NCIPAP

Contents

1.

Introduction

2.

Approach

3.

Action Plan

1 Introduction

This plan is the Network Capability Incentive Project Action Plan for the 2014/15 to 2017/18 period.

The network capability component is a component of the electricity transmission Service Target Performance Incentive Scheme (STPIS), which was introduced in the December 2012 version of the scheme. It will apply to TransGrid from 1 July 2014.

1.1 Overview of the Network Capability Parameter

The network capability parameter is set out in Section 5 of the STPIS guideline.[1] The parameter measures the improvements in the capability of transmission assets through operating expenditure and minor capital expenditure on a TNSP's network that results in:

1. improved capability of those elements of the transmission system most important to determining spot prices, or
2. improved capability of the transmission system at times when Transmission Network Users place greatest value on the reliability of the transmission system.

The parameter has been designed to benefit both consumers and market participants, as described in the AER's draft decision to introduce the component.

> The network capability component seeks to incentivise TNSPs to reveal the capability of parts of their existing network and to identify measures that would provide greater value to generators and customers. Generators benefit from increased network capability as they are less likely to be constrained from dispatching generation by network limits, leading to more efficient dispatch. Customers benefit from the resulting lower wholesale costs and efficient improvements in network capability to meet increases in peak demand. In this way, the new component seeks to encourage low cost solutions for limitations on all transmission equipment on the TNSP's transmission network which unnecessarily restricts energy flows.[2]

The parameter has also been designed to encourage innovative projects to improve the capability of the network. The AER's draft decision notes that:

> The AER considers that TNSPs are best placed to identify network limits and develop solutions to improve them. Thus, the network capability component has minimal regulatory oversight to ensure TNSPs have flexibility in implementing solutions.[3]

[1] AER, *Final Electricity Transmission Network Service Providers Service Target Performance Incentive Scheme*, December 2012, pp11-16.
[2] AER, *Electricity Transmission Network Service Providers Draft Service Target Performance Incentive Scheme*, September 2012, p36
[3] AER, *Electricity Transmission Network Service Providers Draft Service Target Performance Incentive Scheme*, September 2012, p38.

This plan proposes 28 projects that will improve the capability of the network in terms of both the elements most important to determining spot prices and the times when users place the greatest value on the reliability of the system.

The elements most important to determining spot prices tend to be interconnectors and intra-regional cut sets. Many of the projects in the plan, such as dynamic line ratings and improved fault location, have been targeted at these network elements.

During its consumer engagement program TransGrid asked consumers about the times when they place greatest value on the reliability of the system. Different types of consumers have indicated different times when they place greatest value on reliability. Some consumers indicated that they place higher value on the reliability of the system in peak times or during the day. Others, including businesses who rely on electricity 24 hours each day (whether small or large), indicated that they place value on the reliability of the system at all times.

1.2 Period of the Plan

In its transitional revenue proposal TransGrid has provided expenditure and revenue forecasts over five years, as required by the transitional arrangements in the National Electricity Rules.[4] However, TransGrid intends to propose a regulatory control period of four years in its full revenue proposal, from 2014/15 to 2017/18. Under the transitional arrangements in the National Electricity Rules, the AER has discretion on whether to approve a length of regulatory control period of four years[5] or set the length of the period at five years.

It is envisaged that the period of the plan will be reviewed in conjunction with the determination on the length of regulatory control period and the plan adjusted if necessary.

1.3 TransGrid's Existing Practice

The identification of network needs and implementation of low cost solutions to improve network capability is normal planning practice for TransGrid. In the 2009/10 to 2013/14 regulatory control period TransGrid has undertaken numerous low cost projects, including those shown in Table 1.1.

[4] *National Electricity Rules*, Rule 11.58.2(b)(6).
[5] *National Electricity Rules*, Rule 11.58.4(l).

Table 1.1
Low Cost Projects Completed in 2009/10 to 2013/14

Type of Project	Projects Completed
Increases to line ratings through raising conductor height	86 330kV Tamworth – Armidale Line 03 330kV Lower Tumut – Yass Line 07 330kV Lower Tumut – Canberra Line
Replacement of terminal equipment with limits below transmission line thermal limits, to accommodate load growth	11 330kV Dapto – Sydney South Switchbay 98F 132kV Dapto – Mt Terry Switchbay 98W 132kV Dapto – Mt Terry Switchbay 9JA 132kV Vineyard – Parklea Switchbay
Changes to current transformer ratios to remove secondary system limitations	70 330kV Mt Piper – Wallerawang Switchbay 71 330kV Mt Piper – Wallerawang Switchbay 96X 132kV Waratah West – Mayfield West Switchbay 96Y 132kV Waratah West – Kooragang Switchbay
Installation of dynamic line rating systems	8 330kV Dapto – Marulan Line 16 330kV Avon – Marulan Line 96C 132kV Armidale – Coffs Harbour Line
The establishment of line overload load shedding schemes or tripping schemes	SCADA-based load shedding scheme for overloads on transmission lines between Armidale and the far north coast
Installation of additional switchbays to improve reliability, through double selectable connections or bus coupling	84 330kV Liddell – Tamworth Line Newcastle Substation 330kV Bus Coupler
Capacitor banks	Various 330kV capacitor banks in the Sydney area

The projects improve network capability, supporting the wholesale electricity market by reducing network constraints or benefiting consumers by deferring the need for higher cost capital projects.

TransGrid has also undertaken similar projects in previous regulatory control periods, which continue to provide benefits to network capability.

2 Approach

This chapter outlines the approach TransGrid has used to identify and rank projects for the plan.

2.1 Requirements of the Scheme

The STPIS requires this plan to:

- identify for every transmission circuit or injection point on its network, the reason for the limit for each transmission circuit or injection point.
- propose the priority projects to be undertaken in the regulatory control period to improve the limit of the transmission circuits and injection points listed above through operational and/or minor capital expenditure projects. This proposal must include:
  i. the total operational and capital cost of each priority project
  ii. the proposed value of the priority project improvement target in the limit for each priority project
  iii. the current value of the limit for the transmission circuits and/or injection points which the priority project improvement target is seeking to improve, and
  iv. the ranking of the priority projects in descending order based on the likely benefit of the priority project on customers or wholesale market outcomes[6]

The plan describes the proposed projects to be undertaken in the regulatory control period in Chapter 3. Identification of the limits of transmission line, connection points and transformers has been provided under separate cover.

2.2 Approach to Identifying Projects

TransGrid has systematically reviewed limits, operating conditions and constraints on its network to identify projects for inclusion in the plan. The reviews that have been undertaken to identify projects are:

- Review of the limits for each transmission line, connection point and transformer, including identification of all limiting factors less than the conductor thermal rating
- Identification of single and double contingencies where increased capability would improve wholesale market outcomes or supply to loads
- Studies on interconnectors

[6] AER, *Final Electricity Transmission Network Service Providers Service Target Performance Incentive Scheme*, December 2012, p11.

- Review of binding transmission constraints from 2009 onwards to identify capability improvements that would improve wholesale market outcomes
- Discussions with TransGrid's system operators to identify operating conditions where capability improvements could provide benefits
- Discussions with planning and operations staff at AEMO to identify operating conditions where capability improvements could provide benefits
- Discussions with asset management and design staff at TransGrid to identify innovations that could provide capability improvements
- A review of the capital portfolio for 2014/15 to 2018/19 to identify projects that have already been identified that meet the requirements for the NCIPAP, and could be moved from forecast capital expenditure in the revenue proposal to the NCIPAP

This work has been done in collaboration with AEMO in its role as national transmission planner and market operator.

The future scenarios considered in developing this plan include those considered in the 2013 National Transmission Network and Development Plan (NTNDP).[7]

2.3 Approach to Ranking Projects

The STPIS requires proposed projects to be ranked in descending order based on the likely benefit of the project to consumers or wholesale market outcomes.

TransGrid and AEMO have taken the following approach to ranking the projects:

- Projects to improve the network capability under system normal or single contingency events have been given priority over other projects, such as those that improve the network capability under multiple contingencies
- Projects with a primary benefit to increase network capability are prioritised over those with other benefits that are higher relative to their network capability benefits
- The payback period is used to rank the projects following the above steps

Under the STPIS, the power of the incentive for a project depends on whether its priority is in the highest 50 per cent of projects or lowest 50 per cent of projects.[8] Therefore, the exact ranking does not materially affect the power of the incentive under the scheme provided projects are correctly allocated to the highest or lowest 50 per cent.

2.3.1 Projects Considered but not Proposed

During the reviews and ranking a number of projects were identified but not considered suitable for inclusion in the plan. These projects are:

- Murraylink runback scheme, which is the responsibility of Murraylink
- Projects to improve the reliability of Directlink, which are the responsibility of Directlink

[7] AEMO, *2013 National Transmission Network Development Plan*, December 2013.
[8] AER, *Final Electricity Transmission Network Service Providers Service Target Performance Incentive Scheme*, December 2012, p14.

- Low-cost options for larger needs that have been considered during option evaluation
- Projects to remediate transmission line low spans, which do not increase the capability of the network
- Mitigation of power swings on the Queensland – New South Wales Interconnector (QNI), which does not meet the cap for the NCIPAP project value
- Projects with a very low likelihood that the capability will be required, which therefore have insufficient economic benefits to be justified at this time

2.4 Consultation with AEMO

The STPIS requires TransGrid to consult with AEMO prior to submitting the plan as to:

1. whether there is potential for co-ordinated projects with other TNSPs
2. whether the proposed priority project improvement targets for its projects will result in a material benefit
3. which projects should be classified as priority projects based on their likely benefit to consumers or wholesale market outcomes, and
4. the ranking of the priority projects.[9]

TransGrid has worked collaboratively with AEMO in the development of this plan, including consultation on these four factors.

2.5 Relationship with Capital and Operating Expenditure

The cost of the projects proposed in this plan will not be included in capital or operating expenditure in TransGrid's revenue proposal.

[9] AER, *Final Electricity Transmission Network Service Providers Service Target Performance Incentive Scheme*, December 2012, p12.

3 Action Plan

TransGrid proposes 28 projects to improve the capability of the network.

The projects are summarised in Table 3.1 and detailed in the following sections.

The total value of the proposed projects is $36.32 million ($2013/14). One per cent of TransGrid's average indicative maximum allowed revenue proposed in the transitional revenue proposal for 2014/15 to 2017/18 is $36.28 million, in the same dollar terms ($2013/14). Therefore, the total value of the proposed projects reaches one per cent of the average indicative maximum allowed revenue for this period.

Table 3.1
Proposed Network Capability Incentive Projects ($2013/14)

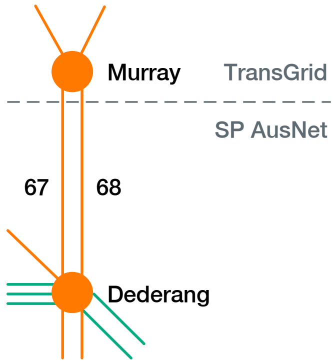
Category	Project	Estimated Cost	Rank
Terminal Equipment Upgrades	67 & 68 Murray – Dederang Switchbays	$360k	2
	81 & 82 Liddell – Newcastle & Tomago Lines	$600k	15
	94E Mt Piper 132 – Wallerawang 132 Switchbays	$50k	9
Protection Changes	976 Line Configuration & Protection Changes	$110k	8
Protection & Metering Upgrades	993 Line Protection & Metering Upgrade	$90k	3
	99P Line Protection & Metering Upgrade	$50k	5
Control Schemes	Extension of Directlink Tripping Scheme	$600k	7
	Northern Reactive Plant Control Scheme	$524k	12
Dynamic Line Ratings & Transmission Line Uprating	Snowy – Yass & Canberra 330kV Lines	$1,400k	11
	65 Murray – Upper Tumut & 66 Murray – Lower Tumut 330kV Lines	$400k	6
	4 & 5 Yass – Marulan, 9 Yass – Canberra, 61 Yass – Bannaby & 39 Bannaby – Sydney West 330kV Lines	$2,600k	13

Category	Project	Estimated Cost	Rank
Dynamic Line Ratings & Transmission Line Uprating (cont'd)	83 Liddell – Muswellbrook, 84 Liddell – Tamworth 330, 85 & 86 Tamworth 330 – Armidale & 88 Muswellbrook – Tamworth 330 330kV Lines	$1,100k	4
	Northern 132kV System	$1,000k	10
	969 Tamworth 330 – Gunnedah 132kV Line	$300k	14
Travelling Wave Fault Location	Western 220kV Network	$877k	25
	Southern 330kV Network	$1,347k	24
	Snowy Lines	$2,211k	17
	Northern 330kV Lines	$1,895k	19
	Far North Coast 132kV System	$890k	20
	North Western 132kV System	$877k	18
Communications	Communications to Albury, ANM & Hume Substations	$4,200k	27
Remote Information	Remote Interrogation of Protection Relays	$1,000k	26
Research Projects	Energy Storage	$4,900k	28
	Behaviour of Residential Solar During System Events	$1,850k	23
Quality of Supply	Point-on-Wave Switching for 132kV Capacitor Banks	$631k	21
	Point-on-Wave Switching for 66kV & Below Capacitor Banks	$4,500k	22
Capacitor Banks	Beryl Capacitor Bank	$1,900k	16
Current Transformer Secondary Ratios	Queensland – New South Wales Interconnector	$55k	1

3.1 Terminal Equipment Upgrades

3.1.1 67 & 68 Murray – Dederang 330kV Switchbays

67 and 68 Lines run from Murray Switching Station to Dederang in Victoria, forming part of the New South Wales to Victoria interconnector. The lines are owned by SP AusNet, with the terminal equipment at Murray Switching Station owned by TransGrid.



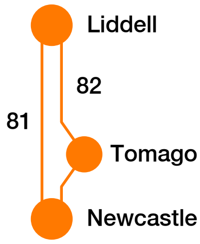
SP AusNet has installed dynamic line ratings on 67 & 68 lines that may provide a rating of up to 1486 MVA under favourable conditions. Some terminal equipment at Murray Switching Station has limitations below this rating.

The replacement of disconnectors and wave traps, and changes to CT ratios and protection settings, would increase the rating of the terminal equipment to the rating that may be achieved using the existing dynamic line rating system under favourable conditions.

Transmission Lines	67 & 68 Murray – Dederang 330kV Lines
Limit and Reason for Limit	The rating of 67 and 68 Lines are presently limited to 1015 MVA by the rating of the wave traps at Murray, with subsequent limitations of 1143 MVA due to disconnectors and 1175 MVA due to metering.
Project	67 & 68 Murray – Dederang Lines Terminal Equipment Upgrade.
Limit Addressed	Constraints on 67 & 68 Lines during system normal and contingency events.
Project Description	Replace wave traps, disconnectors and change CT ratios and protection settings on 67 & 68 line switchbays at Murray.
Capital Cost	$360k
Operating Cost	$0k
Priority Project Improvement Target	Terminal equipment ratings that allow the use of dynamic rating capacity of 1486MVA for 67 & 68 Lines.
Reasons to Undertake the Project	The benefit is avoidance of the market impact due to the present 67 & 68 Line limits. An estimate of this is $477k annually, based on the historical marginal cost of constraints. This provides a payback period of approximately 9 months.

3.1.2 81 & 82 Liddell – Newcastle & Tomago 330kV Switchbays

81 Line runs between Liddell and Newcastle, and 82 Line runs between Liddell and Tomago. The contingency ratings of these lines are presently limited to 1428 MVA by the rating of the high voltage connections at Newcastle and Liddell, and wave traps and metering at Liddell.

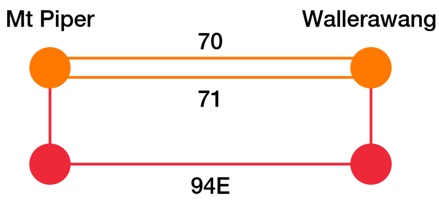


The replacement of high voltage connections on the switchbays at Liddell and Newcastle, and replacement of wave traps and a change to current transformer secondary ratios at Liddell, would increase the rating of the terminal equipment to the thermal rating of the line.

Transmission Lines	81 & 82 Liddell – Newcastle & Tomago 330kV Lines
Limit and Reason for Limit	The ratings of 81 & 82 Lines are presently limited to 1428 MVA by the rating of the high voltage connections at Newcastle and Liddell, and wave traps and current transformer secondary ratios at Liddell.
Project	81 & 82 Liddell – Newcastle & Tomago Lines Terminal Equipment Upgrade.
Limit Addressed	Constraints on 81 & 82 Lines at times of high load.
Project Description	Replace interplant connections on 81 & 82 Line switchbays at Liddell and Newcastle, and replace wave traps and change current transformer secondary ratios at Liddell.
Capital Cost	$600k
Operating Cost	$0k
Priority Project Improvement Target	Full use of contingent capacity of 1646 MVA for 81 & 82 Lines.
Reasons to Undertake the Project	The benefit is avoidance of the market impact due to the present 81 & 82 Line limits. The 2013 NTNDP models a zero carbon price scenario, which considers changes to generation patterns. Under this scenario the power transfer on 81 & 82 lines could increase significantly, with the benefits of an increase to 1646 MVA modelled at $1.4 million per year. This would provide a payback period of approximately 6 months. The project will be scheduled to commence after the expected Federal policy decision on the carbon price in 2014, such that the need can be reviewed against the actual response to the change in policy.

3.1.3 94E Mt Piper 132 – Wallerawang 132 132kV Switchbays

94E Line runs between Mt Piper 132 and Wallerawang 132 Substations in the western generation area. The line provides a low voltage parallel to 70 and 71 Lines.



In the event of multiple contingencies at times of high loads, some interplant connections and CT ratios on 94E Line could impose a limitation below the thermal rating of the line.

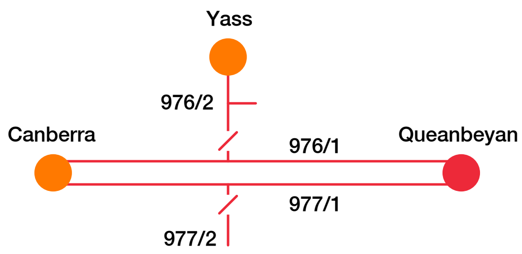
The replacement of interplant connections and change to current transformer secondary ratios would increase the rating of the terminal equipment to the thermal rating of the line.

Transmission Line	94E Mt Piper 132 – Wallerawang 132 132kV Line
Limit and Reason for Limit	The contingency rating of 94E Line is presently limited to 285 MVA by the rating of the high voltage connections and CT ratios at Wallerawang 132.
Project	94E Mt Piper 132 – Wallerawang 132 Line Terminal Equipment Upgrade.
Limit Addressed	Constraints on 94E Line during multiple contingency events at times of high loads.
Project Description	Replace interplant connections and change current transformer secondary ratios on the 94E Line switchbay at Wallerawang 132.
Capital Cost	\$50k
Operating Cost	\$0k
Priority Project Improvement Target	Full use of contingent capacity of 373 MVA for 94E Line.
Reasons to Undertake the Project	The annualised benefit is the is avoidance of the market impact due to the present 94E Line limit. Benefit = $((Rate_{70\text{ or }71\text{ Unplanned Outage}} \times Duration_{70\text{ or }71\text{ Unplanned Outage}}) + (Rate_{\text{Transformer Minor Unplanned Outage}} \times Duration_{\text{Transformer Minor Unplanned Outage}}) + (Rate_{\text{Transformer Major Unplanned Outage}} \times Duration_{\text{Transformer Major Unplanned Outage}})) \times P_{\text{High Load}} \times MW_{\text{Increase}} \times Cost_{\text{Generation Differential}}$ = ((0.18 × 2.2) + (11.9 ×2 × 24.4) + (0.72 × 2 × 504)) × 1.4% × 88MW × \$12/MWh = \$19.3k This provides a payback period of approximately 2½ years.

3.2 Protection Setting Changes

3.2.1 976 Line Configuration and Protection Setting Changes

976 Line supplies Queanbeyan substation from Canberra or Yass substations, and supplies the surrounding townships of Murrumbateman and Spring Flat through tee connections. 977 Line provides a parallel supply from Canberra to Queanbeyan and a tee connection to Spring Flat. Both tees are operated normally open.



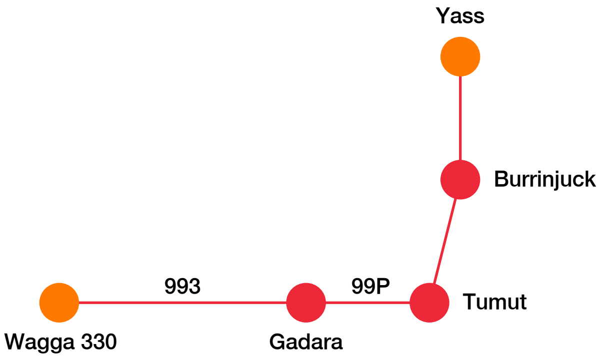
During outages of 976/1 Canberra to Queanbeyan tee or 977 Canberra to Queanbeyan it is currently necessary to secure the Queanbeyan load from Yass via the 976 disconnector. This requires the on-load manual closure of the disconnector at Spring Flat. It is then necessary for Essential Energy to spend significant time reconfiguring its 22kV network in the Murrumbateman area in order to later offload and open the switch.

Transmission Line	976 Canberra – Queanbeyan tee Yass 132kV Line
Limit and Reason for Limit	Queanbeyan load is radial during switching on 976 Line or an outage of 976/1 Line.
Project	Relocation of the 976/1 normally open point from Spring Flat to Yass.
Limit Addressed	Enables firm supply of Queanbeyan load, prevents the need to manually close an on-load disconnector and avoids time consuming load transfers in the Essential Energy network.
Project Description	Install disconnector at Yass substation and change protection settings at Canberra, Yass and Queanbeyan.
Capital Cost	\$110k
Operating Cost	\$0k
Priority Project Improvement Target	Reduced likelihood of loss of supply to Queanbeyan for a second contingency. This includes a reduction in recall times for 976/1 and 976/2 Lines.
Reasons to Undertake the Project	The annualised benefit is the reduction in switching time for planned outages and reduction in risk of loss of supply. Benefit = $(\text{Rate}_{976\ \text{Planned Outage}} \times \text{Cost}_{\text{Switching}}) + (\text{Rate}_{976\ \text{Unplanned Outage}} \times \text{Duration}_{976\ \text{Unplanned Outage}} \times \text{P}_{\text{Prior 977 Planned Outage}} \times \text{MW}_{\text{At Risk}} \times \text{VCR}_{\text{Essential Energy}})$ = (1 × \$5,000) + (0.27 × 2 × 1.1% x 70MW × \$90,710/MWh) = \$42.7k This provides a payback period of approximately 2½ years.

3.3 Protection and Metering Upgrades

3.3.1 993 Line Protection and Metering Upgrade

993 Line is part of the 132kV ring between Wagga 330 and Yass substations that supplies Tumut and Gadara, and connects generation at Burrinjuck.

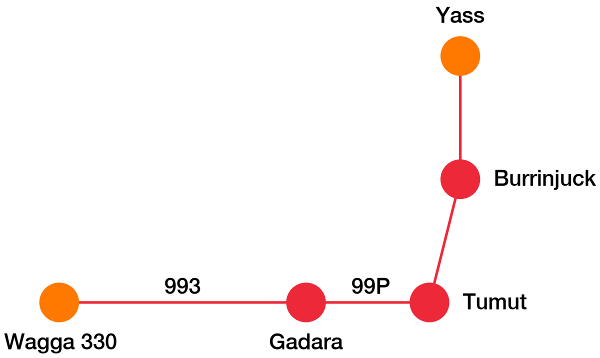


The line is limited to 114 MVA by the panel ammeter at Wagga 330. By removing this limitation the contingency rating of the line will increase to 122 MVA.

Transmission Line	993 Wagga 330 – Gadara 132kV Line
Limit and Reason for Limit	The line is limited to 114 MVA by the panel ammeter at Wagga 330.
Project	Replace the secondary systems panel for 993 Line at Wagga 330.
Limit Addressed	Constraint on 993 Line during contingency events, which may result in load shedding.
Project Description	Replace the secondary systems panel for 993 Line at Wagga 330 substation.
Capital Cost	\$90k
Operating Cost	\$0k
Priority Project Improvement Target	Full use of contingent capacity of 122 MVA for 993 Line.
Reasons to Undertake the Project	The annualised benefit is the reduction in risk of load shedding in the Gadara and Tumut area following a trip of 970, 992 or 99P Lines at times of high transfer. $\text{Benefit} = \text{Rate}_{\text{970, 992 or 99P Unplanned Outage}} \times \text{Duration}_{\text{970, 992 or 99P Unplanned Outage}} \times P_{\text{High Transfer}} \times MW_{\text{At Risk}} \times VCR_{\text{Essential Energy Large Business}}$ $= 1.45 \times 3.73 \times 0.3\% \times 40\text{MW} \times \$130{,}570/\text{MWh}$ $= \$84.7\text{k}$ This provides a payback period of approximately 1 year.

3.3.2 99P Line Protection and Metering Upgrade

99P Line is part of the 132kV ring between Wagga 330 and Yass substations that supplies Tumut and Gadara, and connects generation at Burrinjuck.



The line is limited to 114 MVA by CT ratios at Gadara and Tumut. By removing this limitation the contingency rating of the line will increase to 128 MVA.

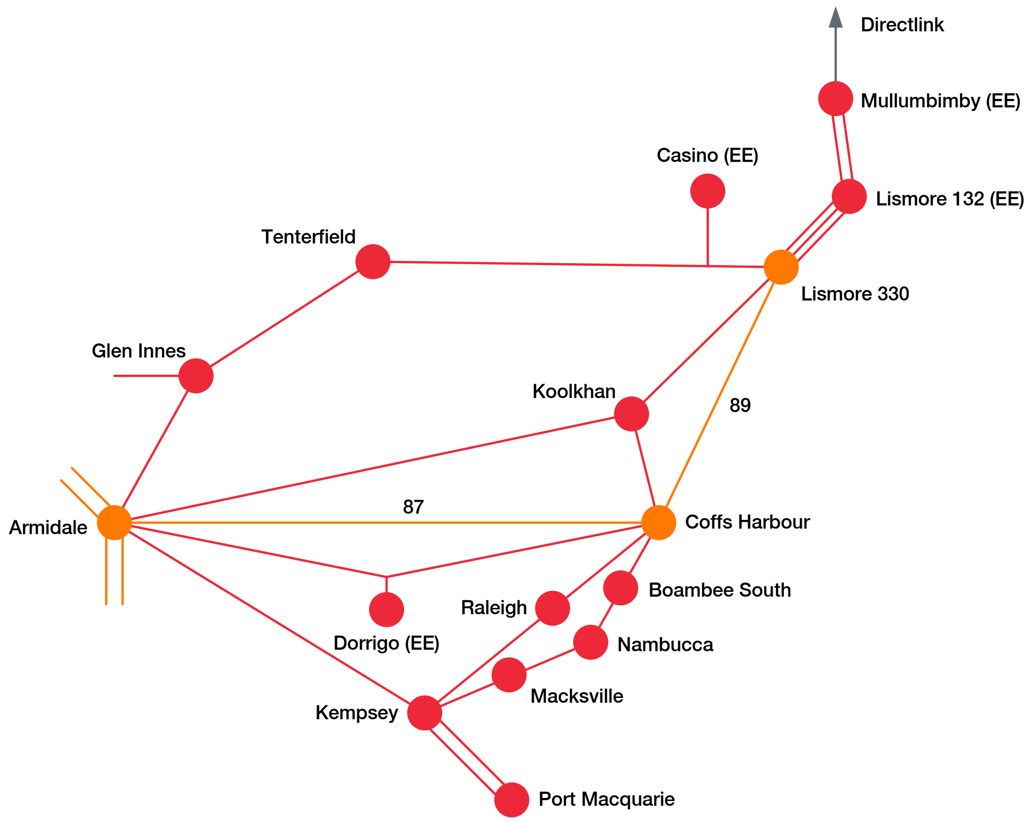
Transmission Line	99P Gadara – Tumut 132kV Line
Limit and Reason for Limit	The line is limited to 114 MVA by CT ratios at Gadara and Tumut.
Project	Change to CT ratios at Gadara.
Limit Addressed	Constraint on 99P Line during contingency events, which may result in load shedding.
Project Description	Change to CT ratios at Gadara. (The change to CT ratios at Tumut will be undertaken as part of the secondary systems replacement project at Tumut.)
Capital Cost	$0k
Operating Cost	$50k
Priority Project Improvement Target	Full use of contingent capacity of 128 MVA for 99P Line.
Reasons to Undertake the Project	The annualised benefit is the reduction in risk of load shedding in the Gadara and Tumut area following a trip of 993 Line at times of high transfer. Benefit = $Rate_{993\ Unplanned\ Outage} \times Duration_{993\ Unplanned\ Outage} \times P_{High\ Transfer} \times MW_{At\ Risk} \times VCR_{Essential\ Energy}$ = 1.18 × 1.82 × 0.3% × 40MW × $130,570/MWh = $33.6k This provides a payback period of approximately 1½ years.

3.4 Control Schemes

3.4.1 Extension of the Directlink Tripping Scheme

TransGrid's Lismore 330/132kV Substation supplies the far north coast of NSW, while also providing a 132kV connection to Directlink via Essential Energy's 132kV network. Directlink is a HVDC interconnection from Mullumbimby to Terranora in NSW, which in turn is connected to the Queensland system. Directlink comprises three modular HVDC systems, each of 60 MW capacity, and is capable of handling an interchange of 180 MW between NSW and Queensland in either direction.

Power flow north on Directlink effectively increases the load on the Lismore 330kV substation and on the transmission system north of Liddell. This additional load may cause loading and voltage problems in TransGrid's network in the event of certain contingencies. The most significant of these are the trip of 87 Armidale to Coffs Harbour Line and the trip of 89 Coffs Harbour to Lismore Line. To cater for these contingencies, an intertrip scheme has been installed to trip Directlink under certain conditions. Without this scheme, it would be necessary to impose market constraints on Directlink via AEMO's dispatch engine.



An emergency control scheme has been installed at Lismore 330kV substation to trip Directlink under specific conditions. This scheme will operate when either CB 872B at Armidale or CB 892 at Lismore is opened, but is blocked if flow south on Directlink is greater than 20 MW.

At present, the Directlink trip scheme is not initiated by the 330kV circuit breaker operations at Coffs Harbour on lines 87 or 89, the status of the 330kV circuit breaker 872A at Armidale, or the status of the Lismore transformers.

For this reason, it is difficult to take prolonged transformer outages at Lismore 330/132kV substation due to the requirement to obtain a suitable outage window. During this outage, market constraints are imposed to prevent thermal overloads or voltage collapse following a contingent trip of the adjacent Lismore transformer. For this reason, it would be beneficial to extend the existing Directlink tripping scheme to include status indication from the in-service Lismore transformer.

It is also necessary to extend the existing scheme to cater for the opening of circuit breaker 872A at Armidale and circuit breakers 872A, 872B and 892A at Coffs Harbour. This additional feature will assist in alleviating constraints during planned outages of the 872B bay associated with Line 87 at Armidale and the 330kV circuit breakers at Coffs Harbour.

Tripping Scheme	Directlink Emergency Tripping Scheme
Limit and Reason for Limit	Export from NSW on Directlink is constrained during outages of transformers at Lismore 330kV Substation, a line bay at Armidale Substation or a line bay at Coffs Harbour Substation.
Project	Extend the Directlink emergency tripping scheme.
Limit Addressed	NSW export on the Directlink interconnector during outages of a transformer at Lismore 330kV Substation, 872B bay at Armidale or a 330kV bay at Coffs Harbour.
Project Description	Extend the Directlink emergency tripping scheme to include the transformers at Lismore 330kV substation, 872B bay at Armidale and 872A, 872B and 892A bays at Coffs Harbour.
Capital Cost	\$600k
Operating Cost	\$0k
Priority Project Improvement Target	Full use of line capacity of the Directlink Interconnector during outages of the Lismore transformers, 872B bay at Armidale or 872A, 872B and 892A bays at Coffs Harbour.
Reasons to Undertake the Project	The upgrade of the emergency tripping scheme enables full use of the capacity the line during plant outages, delivering market benefits. Benefit = $Rate_{\text{Relevant Transformer or CB Outage}} \times Duration_{\text{Outage}} \times P_{\text{Directlink Binding North}} \times P_{\text{Binding Due to Relevant Outage}} \times MW_{\text{At Risk}} \times VCR_{\text{Essential Energy}}$ = 1.5 × 8 × 8.2% × 10%× 40MW × \$90,710/MWh = \$357k This provides a payback period of approximately 2 years.

3.4.2 Northern Reactive Plant Control Scheme

There is a need for automatic control of the reactive equipment on the Queensland – New South Wales Interconnector (QNI) to maintain the Armidale SVC at near zero output. Maintaining an SVC output near zero is important for system security and the failure to provide suitable reactive support can impose market constraints.

There is also a need to install emergency switching capability for the reactors at Dumaresq and some reactive equipment at Armidale. Emergency switching capabilities were not applied to some Dumaresq and Armidale reactors when QNI was established. The need for emergency switching settings is highlighted by the event on 13 November 2011 which resulted in all circuit breakers opening at Dumaresq, separating Queensland from the rest of the National Electricity Market. While this event did not result in significant implications for the market, a similar event could result in uncorrected voltage excursions under different operating conditions.

Tripping Scheme	Northern Reactive Plant Control Scheme
Limit and Reason for Limit	Automatic control of the reactive equipment on the Queensland – New South Wales Interconnector (QNI) to maintain the Armidale SVC at near zero output.
Project	Northern reactive plant control scheme.
Limit Addressed	Ensure adequate post-contingent voltage control of the northern area.
Project Description	The installation of a reactive equipment controller with the capability to control reactive equipment at Armidale 330kV Substation. The installation of emergency overvoltage and under voltage controls on reactive equipment at Armidale 330kV Substation and Dumaresq 330kV Switching Station.
Capital Cost	$524k
Operating Cost	$0k
Priority Project Improvement Target	Operating of automatic reactive equipment control at Armidale Substation. Operation of emergency voltage control of QNI reactive equipment at Armidale and Dumaresq Substations.
Reasons to Undertake the Project	The failure to provide suitable reactive support can impose market constraints when the SVC at Armidale is operating at its limit, which on QNI can result in inter-regional price differences. The northern reactive plant control scheme will allow for finer control of the reactive plant in northern NSW, which affects the QNI export voltage limits. On the assumption this will allow, on average, an extra 20 MVAr to be switched in when there the Armidale SVC is generating 20 MVAr or above, the benefits are modelled at $120k per year. This provides a payback period of approximately 4½ years. The installation of a reactive equipment controller would also reduce the need for operator intervention and allow more efficient operation of the transmission system.

3.5 Dynamic Line Ratings & Transmission Line Uprating

In the 2009/10 to 2013/14 regulatory control period TransGrid installed dynamic line ratings on three transmission lines. Dynamic line ratings enable the thermal rating of a line to be determined in real-time depending on ambient conditions, generally temperature and wind speed.

At times this can result in an increase to the line thermal rating above the contingency rating, where favourable conditions exist (for example, sufficient wind speed to improve the cooling of the line compared to normal). At other times, this can result in a decrease to the line thermal rating below the contingency rating (for example, on hot dry days). Dynamic line ratings, therefore, offer benefits only under favourable conditions. However, where these favourable conditions coincide with times of high loads, the benefits are useful in improving the capability of particular network elements.

3.5.1 Snowy – Yass & Canberra 330kV Lines

Transmission Lines	01 Upper Tumut – Canberra 330kV Line 2 Upper Tumut – Yass 330kV Line 3 Lower Tumut – Yass 330kV Line 07 Lower Tumut – Canberra 330kV Line
Limit and Reason for Limit	01 Line contingency rating: 995 MVA. 2 Line contingency rating: 995 MVA. 3 Line contingency rating: 1132 MVA. 07 Line contingency rating: 1132 MVA.
Project	Install dynamic line ratings on these lines.
Limit Addressed	The installation of dynamic line ratings will enable the lines to be operated at higher than their static thermal ratings under favourable conditions.
Project Description	Install dynamic line ratings based on real time ambient temperatures and wind speeds on 01, 2, 3 and 07 Lines.
Capital Cost	$1,400k
Operating Cost	$0k
Priority Project Improvement Target	Improved rating information based on real time ambient temperature and wind speed for these lines, which will allow increased line ratings of approximately 20% at times of favourable conditions.
Reasons to Undertake the Project	The benefit is avoidance of the market impact due to the present 01, 2, 3 & 07 Line limits, under favourable conditions. An estimate of this is $330k annually, based on the historical marginal cost of constraints. This provides a payback period of approximately 4¼ years.

3.5.2 65 Murray – Upper Tumut and 66 Murray – Lower Tumut 330kV Lines

Transmission Lines	65 Murray – Upper Tumut 330kV Line 66 Murray – Lower Tumut 330kV Line
Limit and Reason for Limit	65 Line contingency rating: 715 MVA. 66 Line contingency rating: 715 MVA.
Project	Install dynamic line ratings on these lines.
Limit Addressed	The installation of dynamic line ratings will enable the lines to be operated at higher than their static thermal ratings under favourable conditions.
Project Description	Install dynamic line ratings based on real time ambient temperatures and wind speeds on 65 and 66 Lines.
Capital Cost	$400k
Operating Cost	$0k
Priority Project Improvement Target	Improved rating information based on real time ambient temperature and wind speed for these lines, which will allow increased line ratings of approximately 20% at times of favourable conditions.
Reasons to Undertake the Project	The benefit is avoidance of the market impact due to the present 65 & 66 Line limits, under favourable conditions. An estimate of this is $245k annually, based on the historical marginal cost of constraints. This provides a payback period of approximately 2 years.

3.5.3 4 & 5 Yass – Marulan, 9 Yass – Canberra, 61 Yass – Bannaby and 39 Bannaby – Sydney West 330kV Lines

The power transfer over the system north of Snowy reaches the limit of the network capability at times of high import from the Snowy area, coupled with high generation in the Wagga Wagga area. At times of high NSW load the export from Victoria has traditionally been relatively low.

The development of further wind generation and gas turbine generation in the area will cause the rating of the critical cutset to be reached, which would result in constraints on southern generation. This is likely to result in wind generation being constrained off and thermal generation dispatched in its place.

In addition to the installation of dynamic line ratings, an increase in the rating of 61 Yass – Bannaby 330kV line from 85°C to 100°C by increasing the height of transmission line conductor on certain spans will enable additional power transfer over the system north of Snowy.

Transmission Lines	4 & 5 Yass – Marulan 330kV Lines 9 Yass – Canberra 330kV Line 61 Yass – Bannaby 330kV Line 39 Bannaby – Sydney West 330kV Line
Limit and Reason for Limit	4 Line contingency rating: 880 MVA. 5 Line contingency rating: 880 MVA. 9 Line contingency rating: 995 MVA. 61 Line contingency rating: 995 MVA. 39 Line contingency rating: 995 MVA.
Project	Install dynamic line ratings on these lines and increase the height of transmission line conductor on 61 Line to achieve a maximum operating temperature of 100°C.
Limit Addressed	The installation of dynamic line ratings will enable the lines to be operated at higher than their static thermal ratings under favourable conditions. The increase in maximum operating temperature on 61 Line will enable it to be operated at higher continuous and contingency ratings.
Project Description	Install dynamic line ratings based on real time ambient temperatures and wind speeds on 4, 5, 9, 61 and 39 Lines. Increase the height of transmission line conductor on 61 Line to achieve a maximum operating temperature of 100°C.
Capital Cost	$2,600k
Operating Cost	$0k
Priority Project Improvement Target	Improved rating information based on real time ambient temperature and wind speed for these lines, which will allow increased line ratings of approximately 20% at times of favourable conditions. The increase in maximum operating temperature of 61 Line is expected to achieve an increase in contingency rating of this line of 137 MVA.
Reasons to Undertake the Project	The benefit is avoidance of the market impact due to the present 4, 5, 9, 61 and 39 Line limits, under favourable conditions. Renewable generation developments in Southern NSW, driven by the Renewable Energy Target (RET) are likely to increase the power transfer on 4, 5, 9, 61 and 39 Lines. The benefits of this project are the avoidance of wind generation being constrained off and thermal generation dispatched in its place. This has been modelled at $176k per year, consistent with NTNDP scenarios. This would provide a payback period of approximately 15 years based on current modelling.

3.5.4 83 Liddell – Muswellbrook, 84 Liddell – Tamworth 330 and 88 Muswellbrook – Tamworth 330 330kV Lines

Transmission Lines	83 Liddell – Muswellbrook 330kV Line 84 Liddell – Tamworth 330 330kV Line 85 Tamworth 330 – Armidale 330kV Line 86 Tamworth 330 – Armidale 330kV Line 88 Muswellbrook – Tamworth 330 330kV Line
Limit and Reason for Limit	83 Line contingency rating: 1160 MVA. 84 Line contingency rating: 983 MVA. 85 Line contingency rating: 983 MVA. 86 Line contingency rating: 989 MVA. 88 Line contingency rating: 983 MVA.
Project	Install dynamic line ratings on these lines.
Limit Addressed	The installation of dynamic line ratings will enable the lines to be operated at higher than their static thermal ratings under favourable conditions.
Project Description	Install dynamic line ratings based on real time ambient temperatures and wind speeds on 83, 84, 85, 86 and 88 Lines.
Capital Cost	$1,100k
Operating Cost	$0k
Priority Project Improvement Target	Improved rating information based on real time ambient temperature and wind speed for these lines, which will allow increased line ratings of approximately 20% at times of favourable conditions.
Reasons to Undertake the Project	The benefit is avoidance of the market impact due to the present 83, 84, 85, 86 & 88 Line limits, under favourable conditions. This is likely to increase given future demand projections from Queensland LNG industrial load, which will increase the time QNI is binding northwards. Market benefit calculations based on the 2013 NTNDP scenarios indicate gross benefits of approximately $8 million for a rating improvement of equivalent to that of dynamic line ratings. Assuming that favourable conditions occur 10% of the time, the benefit for the project is: Benefit = Gross Market Benefit x $P_{\text{Favourable Conditions}}$ = $8,000k x 10% = $800k This provides a payback period of approximately 1½ years.

3.5.5 Northern 132kV System

Transmission Lines	967 Lismore – Koolkhan 132kV Line 96R Glen Innes – Tenterfield 132kV Line 96T Armidale – Glen Innes 132kV Line 966 Armidale – Koolkhan 132kV Line
Limit and Reason for Limit	967 Line contingency rating: 136 MVA. 96R Line contingency rating: 136 MVA. 96T Line contingency rating: 136 MVA. 966 Line contingency rating: 121 MVA.
Project	Install dynamic line ratings on these lines.
Limit Addressed	The installation of dynamic line ratings will enable the lines to be operated at higher than their static thermal ratings under favourable conditions.
Project Description	Install dynamic line ratings based on real time ambient temperatures and wind speeds on 967, 96R, 96T and 966 Lines.
Capital Cost	$1,000k
Operating Cost	$0k
Priority Project Improvement Target	Improved rating information based on real time ambient temperature and wind speed for these lines, which will allow increased line ratings of approximately 20% at times of favourable conditions.
Reasons to Undertake the Project	The benefit is avoidance of the market impact due to the present line limits, under favourable conditions. $\text{Benefit} = \text{Cost}_{\text{Average Inter-regional Price Difference}} \times \text{Duration}_{\text{Outages Not Covered by Directlink Tripping Scheme}} \times \text{MW}_{\text{Constrained on Directlink}}$ $= \$20 \times 360 \times 50\text{MW}$ $= \$360\text{k}$ This provides a payback period of approximately 3 years.

3.5.6 969 Tamworth 330 – Gunnedah 132kV Line

Transmission Line	969 Tamworth 330 - Gunnedah 132kV Line
Limit and Reason for Limit	Contingency rating: 82 MVA.
Project	Install dynamic line ratings on this line.
Limit Addressed	The installation of dynamic line ratings will enable the line to be operated at higher than its static thermal rating under favourable conditions.
Project Description	Install dynamic line ratings based on real time ambient temperatures and wind speeds on 969 Line.
Capital Cost	$300k
Operating Cost	$0k
Priority Project Improvement Target	Improved rating information based on real time ambient temperature and wind speed for this line, which will allow increased line ratings of approximately 20% at times of favourable conditions.
Reasons to Undertake the Project	An increase in capacity on 969 Line allows the deferral of the construction of a second transmission line between Tamworth and Gunnedah. The revenue impact of the second transmission line will be approximately $4.5 million per year, therefore the installation of dynamic line rating would provide a payback period of approximately 1 month. The second Tamworth to Gunnedah transmission line has been assigned a range of probability weighted commissioning dates under various scenarios in the capital expenditure forecasts in the transitional revenue proposal, reflecting the likelihood of deferral of this project.

3.6 Travelling Wave Fault Location

Travelling wave fault location provides improved accuracy of faults on the network compared to distance to fault measurements from protection relays, which have particular measurement difficulties for certain types of faults.

The main benefit of accurate fault location is to reduce the time taken to patrol and locate faults. This enables quicker commencement of repairs for sustained faults, assessment of potential damage from transient faults and detection of external impacts such as fire starts. This improves the capability of the network by reducing the duration of unplanned outages, and allowing faster response to minimise the external impacts of a fault.

3.6.1 Western 220kV Network

Transmission Lines	X5/1 Darlington Point – Balranald 220kV Line X5/3 Balranald – Buronga 220kV Line X2 Buronga – Broken Hill 220kV Line
Limit and Reason for Limit	Travel and inspection time to locate faults.
Project	Installation of travelling wave fault locators on western 220kV network.
Limit Addressed	Response time to locate, inspect and if required, repair faults is reduced and time taken to restore transmission line to service is reduced.
Project Description	Install travelling wave fault locators on the western 220kV network.
Capital Cost	$877k
Operating Cost	$0k
Priority Project Improvement Target	Commissioning of the travelling wave fault locators on the above lines.
Reasons to Undertake the Project	The benefits of travelling wave fault locators are described above. The benefit can be calculated as: $\text{Benefit} = \text{Benefit}_{\text{Sustained Faults}} + \text{Benefit}_{\text{Transient Faults}} + \text{Benefit}_{\text{Fire Detection}}$ $((\text{Rate}_{\text{Sustained Fault}} \times \text{Time}_{\text{Patrol}} \times \text{Cost}_{\text{Constraint}} \times \text{MW}_{\text{Constrained}}) + \text{Cost}_{\text{Patrol}}) + (\text{Rate}_{\text{Transient Fault}} \times \text{Time}_{\text{Patrol}} \times \text{Cost}_{\text{Hourly Rate}}) + (\text{Cost}_{\text{Major Fire}} \times \text{P}_{\text{Major Fire Potential}} \times \text{Number}_{\text{Fire Starts}})$ $= (0.5 \times 5 \times \$10 \times 50\text{MW} + \$8{,}000) + (0.5 \times 8 \text{ hrs} \times \$160/\text{hr}) + (\$291.3\text{m} \times 10\% \times (0.8 * 1 \text{ line} / 200 \text{ lines}))$ $= \$126\text{k}$ This provides a payback period of approximately 7 years.

3.6.2 Southern 330kV Network

Transmission Lines	63 Darlington Point – Wagga 330 330kV Line 51 Wagga 330 – Lower Tumut 330kV Line
Limit and Reason for Limit	Travel and inspection time to locate faults.
Project	Installation of travelling wave fault locators on southern 330kV lines.
Limit Addressed	Response time to locate, inspect and if required, repair sustained faults reduced and time taken to restore transmission line to service is reduced.
Project Description	Install travelling wave fault locators on 63 and 51 Lines.
Capital Cost	$1,347k
Operating Cost	$0k
Priority Project Improvement Target	Commissioning of the travelling wave fault locators on the above lines.
Reasons to Undertake the Project	The benefits of travelling wave fault locators are described above. The benefit can be calculated as: $Benefit = Benefit_{Sustained\ Faults} + Benefit_{Transient\ Faults} + Benefit_{Fire\ Detection}$ $((Rate_{Sustained\ Fault} \times Time_{Patrol} \times Cost_{Constraint} \times MW_{Constrained}) + Cost_{Patrol}) + (Rate_{Transient\ Fault} \times Time_{Patrol} \times Cost_{Hourly\ Rate}) + (Cost_{Major\ Fire} \times P_{Major\ Fire\ Potential} \times Number_{Fire\ Starts})$ = (0.5 × 5 × $10 × 50MW + $8,000) + (0.5 × 8 hrs × $160/hr) + ($291.3m × 10% × (0.8 * 2 lines / 200 lines)) = $243k This provides a payback period of approximately 6 years.

3.6.3 Snowy Lines

Transmission Lines	01 Upper Tumut – Canberra 330kV Line 2 Upper Tumut – Yass 330kV Line 3 Lower Tumut – Yass 330kV Line 07 Lower Tumut – Canberra 330kV Line 64 Lower Tumut – Upper Tumut 330kV Line 65 Murray – Upper Tumut 330kV Line 66 Murray – Lower Tumut 330kV Line 97G Murray – Guthega 132kV Line
Limit and Reason for Limit	Travel and inspection time to locate faults. This can be particularly challenging in the terrain in the Snowy mountains.
Project	Installation of travelling wave fault locators on Snowy lines.
Limit Addressed	Response time to locate, inspect and if required, repair sustained faults reduced and time taken to restore transmission line to service is reduced.
Project Description	Install travelling wave fault locators on Snowy lines.
Capital Cost	$2,211k
Operating Cost	$0k
Priority Project Improvement Target	Commissioning of the travelling wave fault locators on the above lines.
Reasons to Undertake the Project	The benefits of travelling wave fault locators are described above. The benefit can be calculated as: $\text{Benefit} = \text{Benefit}_{\text{Sustained Faults}} + \text{Benefit}_{\text{Transient Faults}} + \text{Benefit}_{\text{Fire Detection}}$ $((\text{Rate}_{\text{Sustained Fault}} \times \text{Time}_{\text{Patrol}} \times \text{Cost}_{\text{Constraint}} \times \text{MW}_{\text{Constrained}}) + \text{Cost}_{\text{Patrol}}) + (\text{Rate}_{\text{Transient Fault}} \times \text{Time}_{\text{Patrol}} \times \text{Cost}_{\text{Hourly Rate}}) + (\text{Cost}_{\text{Major Fire}} \times \text{P}_{\text{Major Fire Potential}} \times \text{Number}_{\text{Fire Starts}})$ = (0.5 × 5 × $10 × 50MW + $8,000) + (0.5 × 8 hrs × $160/hr) + ($291.3m × 20% × (0.8 * 8 lines / 200 lines)) = $1,864k This provides a payback period of approximately 1¼ years.

3.6.4 Northern 330kV Lines

Transmission Lines	83 Liddell – Muswellbrook 330kV Line 84 Liddell – Tamworth 330kV Line 88 Muswellbrook – Tamworth 330kV Line 85 & 86 Tamworth – Armidale 330kV Lines 8C & 8E Armidale – Dumaresq 330kV Lines
Limit and Reason for Limit	Travel and inspection time to locate faults.
Project	Installation of travelling wave fault locators on northern 330kV lines.
Limit Addressed	Response time to locate, inspect and if required, repair sustained faults reduced and time taken to restore transmission line to service is reduced.
Project Description	Install travelling wave fault locators on the above lines.
Capital Cost	$1,895k
Operating Cost	$0k
Priority Project Improvement Target	Commissioning of the travelling wave fault locators on the above lines.
Reasons to Undertake the Project	The benefits of travelling wave fault locators are described above. The benefit can be calculated as: $Benefit = Benefit_{Sustained\ Faults} + Benefit_{Transient\ Faults} + Benefit_{Fire\ Detection}$ $((Rate_{Sustained\ Fault} \times Time_{Patrol} \times Cost_{Constraint} \times MW_{Constrained}) + Cost_{Patrol}) + (Rate_{Transient\ Fault} \times Time_{Patrol} \times Cost_{Hourly\ Rate}) + (Cost_{Major\ Fire} \times P_{Major\ Fire\ Potential} \times Number_{Fire\ Starts})$ = (0.5 × 5 × $10 × 50MW + $8,000) + (0.5 × 8 hrs × $160/hr) + ($291.3m × 10% × (0.8 * 7 lines / 200 lines)) = $826k This provides a payback period of approximately 2¼ years.

3.6.5 Far North Coast 330kV and 132kV System

Transmission Lines	87 Armidale – Coffs Harbour 330kV Line 89 Coffs Harbour – Lismore 330kV Line 96C Armidale – Coffs Harbour 132kV Line
Limit and Reason for Limit	Travel and inspection time to locate faults.
Project	Installation of travelling wave fault locators on far north coast 330kV and 132kV lines.
Limit Addressed	Response time to locate, inspect and if required, repair sustained faults reduced and time taken to restore transmission line to service is reduced.
Project Description	Install travelling wave fault locators on the above lines.
Capital Cost	$890k
Operating Cost	$0k
Priority Project Improvement Target	Commissioning of the travelling wave fault locators on the above lines.
Reasons to Undertake the Project	The benefits of travelling wave fault locators are described above. The benefit can be calculated as: $Benefit = Benefit_{Sustained\ Faults} + Benefit_{Transient\ Faults} + Benefit_{Fire\ Detection}$ $((Rate_{Sustained\ Fault} \times Time_{Patrol} \times Cost_{Constraint} \times MW_{Constrained}) + Cost_{Patrol}) + (Rate_{Transient\ Fault} \times Time_{Patrol} \times Cost_{Hourly\ Rate}) + (Cost_{Major\ Fire} \times P_{Major\ Fire\ Potential} \times Number_{Fire\ Starts})$ = (0.5 × 5 × $10 × 50MW + $8,000) + (0.5 × 8 hrs × $160/hr) + ($291.3m × 10% × (0.8 * 3 lines / 200 lines)) = $350k This provides a payback period of approximately 2½ years.

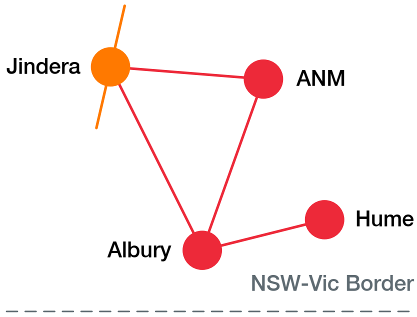
3.6.6 North Western 132kV System

Transmission Lines	968 Tamworth – Narrabri 132kV Line 969 Tamworth – Gunnedah 132kV Line 9U3 Gunnedah – Narrabri 132kV Line 96M Narrabri – Moree 132kV Line
Limit and Reason for Limit	Travel and inspection time to locate sustained faults.
Project	Installation of travelling wave fault locators on north western 132kV lines.
Limit Addressed	Response time to locate, inspect and if required, repair sustained faults reduced and time taken to restore transmission line to service is reduced.
Project Description	Install travelling wave fault locators on the above lines.
Capital Cost	$877k
Operating Cost	$0k
Priority Project Improvement Target	Commissioning of the travelling wave fault locators on the above lines.
Reasons to Undertake the Project	The benefits of travelling wave fault locators are described above. The benefit can be calculated as: $Benefit = Benefit_{Sustained\ Faults} + Benefit_{Transient\ Faults} + Benefit_{Fire\ Detection}$ $((Rate_{Sustained\ Fault} \times Time_{Patrol} \times Cost_{Constraint} \times MW_{Constrained}) + Cost_{Patrol}) + (Rate_{Transient\ Fault} \times Time_{Patrol} \times Cost_{Hourly\ Rate}) + (Cost_{Major\ Fire} \times P_{Major\ Fire\ Potential} \times Number_{Fire\ Starts})$ = (0.5 × 5 × $10 × 50MW + $8,000) + (0.5 × 8 hrs × $160/hr) + ($291.3m × 10% × (0.8 * 4 lines / 200 lines)) = $476k This provides a payback period of approximately 2 years.

3.7 Communication

3.7.1 Communication to Albury, ANM and Hume 132kV Substations

Albury 132kV substation was commissioned in 1958, ANM 132kV substation in 1981, and Hume in 1957. The communication links to these sites are presently slow and do not support the connection of SCADA or advanced protection schemes.



This project is to install high bandwidth, high speed communication infrastructure to connect these substations to the main network to permit modern SCADA and protection signalling controls to be commissioned, which would improve the reliability of supply by enabling a faster response to unplanned events.

The provision of broadband communications services would also permit the establishment of facilities such as the substation secure data network, asset management services like condition monitoring, security functions such as surveillance video and corporate data services, which result in operational efficiencies.

Connection Points	Albury, ANM and Hume 132kV Substations
Limit and Reason for Limit	The communication links to these sites are presently slow and do not support the connection of SCADA or advanced protection schemes.
Project	Installation of suitable speed and bandwidth communications for SCADA to Albury, ANM and Hume substations.
Limit Addressed	At present the connection of SCADA and other advanced protection schemes to these substations is constrained by the lack of communications to the site.
Project Description	Installation of suitable bandwidth communications for SCADA to Albury, ANM and Hume substations.
Capital Cost	$4,200k
Operating Cost	$0k
Priority Project Improvement Target	Commissioning of the communication link to Albury, ANM and Hume substations.
Reasons to Undertake the Project	The benefits of suitable bandwidth communications to Albury, ANM and Hume are calculated as follows. $\text{Benefit} = \text{Benefit}_{\text{Reliability}} + \text{Benefit}_{\text{Remote Secondary Systems Maintenance}} + \text{Benefit}_{\text{Work Scheduling Access}} + \text{Benefit}_{\text{Future Remote Interrogation Capability}}$ $= (\text{Load}_{\text{At Risk}} \times \text{Rate}_{\text{Incidents}} \times \text{VCR}_{\text{Essential Energy}}) + (\text{Duration}_{\text{Travelling Time Avoided}} \times \text{Cost}_{\text{Hourly Rate}}) + (\text{Duration}_{\text{Work Scheduling Time Avoided}} \times \text{Cost}_{\text{Hourly Rate}}) + \text{Benefit}_{\text{Future Remote Interrogation Capability}}$ $= (11.8\text{ MWh} \times 0.2 \times \$90{,}710) + (6\text{ days} \times 8\text{ hrs/day} \times \$160\text{/hr}) + (48\text{ hrs} \times \$130\text{/hr}) + \$7{,}000$ $= \$235\text{k}$ The benefit calculation has not considered the option value benefits of enabling modern protection signalling controls and improved data for planning analysis and energy management system analysis. This project provides a payback period of less than 18 years, which is further improved by the option value benefits identified.

3.8 Remote Information Capability

3.8.1 Remote Interrogation of Protection Relays

Modern protection relays have the ability to store extensive information on faults including protection flags, waveforms and other information. This information is used for fault location and investigation. Presently this information can be read by staff attending site after the fault and manually interrogating the relays.

TransGrid's system operators respond to multiple system events each week. The current system provides a limited amount of information for these trips and system operators use their knowledge of the system to make the most appropriate decision.

TransGrid has installed a pilot trial at one substation of a remote interrogation system through which protection flags, waveforms and other information can be remotely interrogated, allowing faster response and either being better able to identify the nature of the event and select the most appropriate staff to attend site, or avoiding the need to send staff outside of normal hours.

TransGrid has, on average, approximately 580 forced outages each year on its network including forced outage operations due to faults on customer feeders. Of these, approximately 12 each year require detailed investigation as system incidents and provision of information to AEMO. Additionally, design engineers provide assistance to field staff when commissioning or troubleshooting protection relays, and sometimes require remote information in the course of this assistance.

There are 13 substations that have secondary systems ready for remote interrogation. This project is to commission production servers and extend the pilot trial to the 13 substations that are ready for remote interrogation. Other substations will be added to the system as the secondary systems are replaced.

Connection Points	Holroyd, Rookwood Road, Griffith, Wallerawang, Tomago, Williamsdale, Bannaby, Glen Innes, Wagga North, Uranquinty, Wollar, Mt Piper 500kV and Bayswater Substations
Limit and Reason for Limit	Protection relay fault information is presently stored at site, requiring a site visit to interrogate.
Project	Install remote interrogation of protection relays at 13 substations.
Limit Addressed	Protection relay fault information is presently stored at site, requiring a site visit to interrogate.
Project Description	Install remote interrogation of protection relays at 13 substations and commission production servers.
Capital Cost	$1,000k
Operating Cost	$0k
Priority Project Improvement Target	Remote interrogation of protection relay information from 13 substations operational.
Reasons to Undertake the Project	The benefits of this project are better scheduling of staff to read protection flags and download waveforms, and more efficient provision of remote support. This benefit is calculated as: Benefit = (13 / 94) × ((580 flag readings × 2 hrs × $130/hr) + (24 waveform downloads × 5 hrs × $160/hr) + (50 enquiries × 5 hrs × $160/hr)) = $29k The information retrieved from protection relays during system events will also contribute to the provision of more accurate information to improve the accuracy of voltage and transient stability constraints and potentially improve inter-regional transfer limits, together with fault recorder installations. Benefit = (13 / 94) × ($Duration_{Binding}$ × $P_{Exporting}$ × $Price_{Differential}$ × Rating Improvement) = (13 / 94) × ((12% × 2 × 24 × 365) × 58% × $30 × 10MW) = $51k These benefits together provide a payback period of approximately 13 years.

3.9 Research Projects

3.9.1 Energy Storage

The New South Wales electricity transmission network has increasing connections of intermittent generation, such as wind and solar farms. One of the characteristics of these types of generation is uncertainty around forecasts of generation output.

Energy storage technologies have developed rapidly in recent years and are increasingly being used internationally to help smooth the output of intermittent generation. As these are emerging technologies, they are currently the subject of several research projects internationally to better understand their application to transmission networks.

This project is to install a pilot energy storage trial on the load side of constraints. The benefit of this concept in network capability is the ability to discharge the energy storage device at times of high load, thereby reducing the constraint. The pilot installation would be a relatively small installation to trial and evaluate the concept. This project differs from many other current research projects as the focus at a grid level is to investigate the feasibility of control schemes that could improve market outcomes, either by tracking intermittent generation or otherwise reducing constraints.

During its consumer engagement forums TransGrid sought the views of electricity consumers on their level of support for expenditure on research, particularly into technologies that may be used to reduce network investment in the future such as energy storage. There was widespread support for research to pursue the development of these types of technologies.

TransGrid intends to share the knowledge acquired from this project more broadly throughout the industry.

Connection Points	Sydney Area
Limit and Reason for Limit	Unpredictability of intermittent generation and constraints between generation areas and load centres at times of high load.
Project	Install a pilot energy storage device in the Sydney area.
Limit Addressed	The trial of an energy storage device will enable its evaluation for future, larger scale application on the network.
Project Description	Install a pilot energy storage device in the Sydney area.
Capital Cost	$4,900k
Operating Cost	$0k
Priority Project Improvement Target	Installation and commissioning of an energy storage device to trial the concept.
Reasons to Undertake the Project	The benefit of this concept in network capability is the ability to discharge the energy storage device at times of high load, thereby reducing the constraint. The benefit of the pilot installation would to trial and evaluate the concept for potentially more widespread use.

3.9.2 Behaviour of Residential Solar During System Events

The National Electricity Market now has over 1000 MW of residential solar generation installed, an amount larger than the largest generating unit.

To date, there has been limited experience of the behaviour of this distributed solar generation during system events, during which there may be fluctuations in voltage or frequency. In particular, there are certain conditions under which inverters associated with panel installations may trip, removing some distributed generation from the system. This has the potential to exacerbate some system events.

This project is to enable research into the behaviour of residential solar installations during system events, as it affects transmission networks in aspects such as system security and stability.

The project is to install additional high speed monitoring in areas with significant penetration of residential solar installations, such that the monitors will capture detailed high speed records of the behaviour of residential solar in aggregate during system events. These records will be made available to AEMO for review. The project will also install fault recorders at connection points that are representative of various load types, to improve the data available for the calculation of load indices.

Connection Points	Various Representative Connection Points
Limit and Reason for Limit	Potential behaviour of residential solar generation during system events, that could exacerbate the effect of some system events.
Project	Install high speed monitors on connection points with significant penetration of residential solar installations, and fault recorders at locations representative of various load types.
Limit Addressed	The records provided by the high speed monitors will provide information to further analyse the behaviour of residential solar generation during system events. The records provided by fault recorders will improve the data available for the calculation of load indices.
Project Description	Install high speed monitors on connection points with significant penetration of residential solar installations, and fault recorders at locations representative of various load types.
Capital Cost	$1,850k
Operating Cost	$0k
Priority Project Improvement Target	Installation and commissioning of high speed monitors and fault recorders at various representative connection points.
Reasons to Undertake the Project	To enable research into the behaviour of residential solar installations during system events, as it affects transmission networks in aspects such as system security and stability. The data provided by the monitors will assist in the development of load indices, which can provide more accurate information to improve the accuracy of voltage and transient stability constraints and potentially improve inter-regional transfer limits. Benefit = ($Duration_{Binding} \times P_{Exporting} \times Price_{Differential} \times$ Rating Improvement) = ((12% × 2 × 24 × 365) × 58% × $30 × 10MW) = $366k This provides a payback period of approximately 5 years.

3.10 Quality of Supply Projects

3.10.1 Point-on-Wave Switching for 132kV Capacitor Banks

Transmission networks have capacitor banks installed for voltage regulation, power factor improvement and as part of filter banks to remove harmonics. This is to meet various requirements for system quality of supply, as specified in the National Electricity Rules.

Historically, capacitor banks were switched using standard circuit breakers with no point-on-wave closing control of the poles. This type of switching of capacitor banks can generate transient disturbances and there has been reported damage to plant and equipment by consumers from transient disturbances.

TransGrid now installs point-on-wave circuit breakers on new capacitor banks or when replacing capacitor bank circuit breakers to address the abovementioned quality of supply issues. These are in place for the majority of capacitor banks on TransGrid's network.

There are benefits for the quality of supply to consumers by installing point-on-wave switching on 3 existing 132kV capacitor banks on which it has not yet been installed.

Connection Points	3 Capacitor Banks
Limit and Reason for Limit	Transient distortion of supply voltage.
Project	Replace standard circuit breakers with point-on-wave circuit breakers.
Limit Addressed	Transient distortion of supply voltage.
Project Description	Replace standard circuit breakers with point-on-wave circuit breakers.
Capital Cost	$631k
Operating Cost	$0k
Priority Project Improvement Target	Installation of point-on-wave switching on 3 capacitor banks.
Reasons to Undertake the Project	Reduction of transient disturbances which can affect consumers' plant and equipment. The actual economic impact of transient disturbances is not recorded, however distribution network service providers in New South Wales and the Australian Capital Territory receive around 1000 valid complaints each year regarding supply voltage and quality matters, including transient disturbances. Assuming an average value of customer reliability for NSW of $94,990/MWh, one disturbance per year of a moderate sized load block of 20MW for one hour would have an economic impact of $1.9 million. The benefit of avoiding this supply quality impact would provide payback period of approximately 3 years across both this project and the point-on-wave switching for 66kV & below capacitor banks.

3.10.2 Point-on-Wave Switching for 66kV & Below Capacitor Banks

Transmission networks have capacitor banks installed for voltage regulation, power factor improvement and as part of filter banks to remove harmonics. This is to meet various requirements for system quality of supply, as specified in the National Electricity Rules.

Historically, capacitor banks were switched using standard circuit breakers with no point-on-wave closing control of the poles. This type of switching of capacitor banks can generate transient disturbances and there has been reported damage to plant and equipment by consumers from transient disturbances.

TransGrid now installs point-on-wave circuit breakers on new capacitor banks or when replacing capacitor bank circuit breakers to address the abovementioned quality of supply issues. These are in place for the majority of capacitor banks on TransGrid's network.

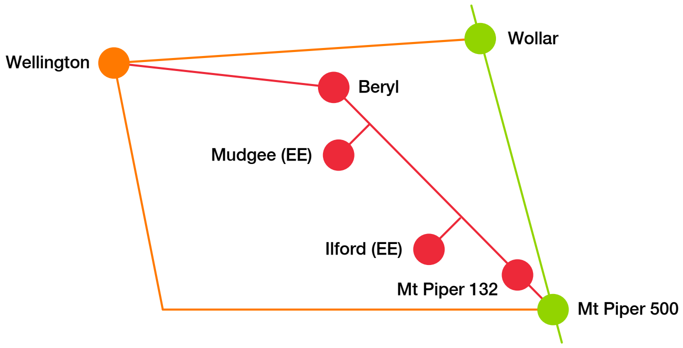
There are benefits for the quality of supply to consumers by installing point-on-wave switching on 24 existing 66kV and below capacitor banks on which it has not yet been installed.

Connection Points	24 Capacitor Banks
Limit and Reason for Limit	Transient distortion of supply voltage.
Project	Replace standard circuit breakers with point-on-wave circuit breakers.
Limit Addressed	Transient distortion of supply voltage.
Project Description	Replace standard circuit breakers with point-on-wave circuit breakers.
Capital Cost	$4,500k
Operating Cost	$0k
Priority Project Improvement Target	Installation of point-on-wave switching on 24 capacitor banks.
Reasons to Undertake the Project	Reduction of transient disturbances which can affect consumers' plant and equipment. The actual economic impact of transient disturbances is not recorded, however distribution network service providers in New South Wales and the Australian Capital Territory receive around 1000 valid complaints each year regarding supply voltage and quality matters, including transient disturbances. Assuming an average value of customer reliability for NSW of $94,990/MWh, one disturbance per year of a moderate sized load block of 20MW for one hour would have an economic impact of $1.9 million. The benefit of avoiding this supply quality impact would provide payback period of approximately 3 years across both this project and the point-on-wave switching for 132kV capacitor banks.

3.11 Capacitor Banks

3.11.1 Beryl 132kV Substation

Beryl 132kV Substation, together with Essential Energy substations at Mudgee and Ilford, is supplied via 132kV transmission lines from Wellington and Mt Piper 500 substations.



The load at Beryl is expected to grow primarily from expansion of mining in the Ulan area. In the long term a new 330/132kV substation to provide additional capacity to Beryl is the most likely network solution. However, planning studies have indicated that at current projections of growth in mining loads, an additional capacitor bank at the existing Beryl 132kV Substation could defer the need for the new substation.

Connection Points	Beryl 132kV Substation
Limit and Reason for Limit	The current capacity available to the Beryl and Mudgee area is approximately 91 MW.
Project	Install a new capacitor bank at Beryl 132kV Substation.
Limit Addressed	The installation of a capacitor bank at Beryl 132kV substation would increase the capacity available at the substation, deferring the construction of an additional supply to Beryl.
Project Description	Install a new capacitor bank at Beryl 132kV Substation.
Capital Cost	$1,900k
Operating Cost	$0k
Priority Project Improvement Target	The installation of a capacitor bank at Beryl substation would increase the total capacity available to the area by 6 MW in 2016. This additional capacity will reduce with load growth over time due to voltage constraints.
Reasons to Undertake the Project	Deferral of the additional supply will avoid approximately $3.5 million per year in costs, therefore the installation of a capacitor bank would provide a payback period of approximately 6 months. The additional supply to Beryl has been assigned a range of probability weighted commissioning dates under various scenarios in the capital expenditure forecasts in the transitional revenue proposal, reflecting a range of potential demand scenarios and the likelihood of deferral of this project.

3.12 Current Transformer Secondary Ratio Changes

3.12.1 Queensland – New South Wales Interconnector

A recent review of the oscillatory stability limit on the Queensland – New South Wales Interconnector has resulted in an increase of the southbound transfer limit from 1078MW to 1200MW. The system normal rating of the four transmission lines above is 1097MVA, due to current transformer secondary ratios.

A change to current transformer secondary ratios would enable use of full line thermal capacity of 1200MVA for 8C and 8E 330kV Armidale – Dumaresq circuits and 8L and 8M Dumaresq – Bulli Creek circuits during system normal conditions, subject to other constraints such as thermal constraints.

The increase to this limit would reduce the extent of binding constraints on the interconnector and enable more effective interstate competition between generators during times of high interstate transfer.

Transmission Lines	8C & 8E Armidale – Dumaresq 330kV Lines 8L & 8M Dumaresq – Bulli Creek 330kV Lines
Limit and Reason for Limit	A review of the oscillatory stability limit on the Queensland – New South Wales Interconnector has resulted in an increase of the southbound transfer limit from 1078MW to 1200MW. The system normal rating of the four transmission lines above is 1097MVA, due to current transformer secondary ratios.
Project	Current transformer secondary ratio changes on QNI lines.
Limit Addressed	Current transformer secondary ratios on 8C, 8E, 8L and 8M Lines
Project Description	Changes to current transformer secondary ratios on 8C, 8E, 8L and 8M lines
Capital Cost	$0k
Operating Cost	$55k
Priority Project Improvement Target	Full use of line thermal capacity of 1200MVA for 8C and 8E 330kV Armidale – Dumaresq circuits and 8L and 8M Dumaresq – Bulli Creek circuits during system normal conditions.
Reasons to Undertake the Project	The annualised benefit is the is avoidance of the market impact due to the present line limits. This is estimated based on inter-regional price differences between New South Wales and Queensland when New South Wales is importing. Benefit = $\text{Cost}_{\text{Average Inter-retional Price Difference}} \times \text{Duration}_{\text{Inter-regional Price Difference}} \times \text{MW}_{\text{Increase}}$ = \$11.08 × 86 × 103MW = \$98k This provides a payback period of approximately 6 months.