

Arapuni grid reconfiguration

In 2010 Transpower decommissioned the Arapuni-Pakuranga 110 kV circuit to allow construction of the new 400 kV capable line to Auckland. This decommissioning increased generation constraints at Arapuni required to manage post contingency loadings on the Arapuni-Hamilton circuits. A generation runback scheme at Arapuni was installed to allow greater pre-contingency generation at Arapuni.

We have identified that implementing a bus split at Arapuni will further relieve the constraints on generation at Arapuni, increase power transfer capacity into the Upper North Island on the 220 kV network and reduce system losses. This is an interim measure until the new 400 kV capable line to Auckland is commissioned. At this time the need for the split will be reviewed.

We consider the use of a bus split at Arapuni to be an acceptable interim measure similar to the use of special protection schemes for the same purpose. This is discussed in greater detail in our Transmission Code of Practice (<http://www.gridnewzealand.co.nz/n4763,375.html>).

We propose to implement a system split at Arapuni. The split will be normally in place but may be removed during some planned outages or during certain grid emergencies. The system split would be a permanent change in the way the grid is configured so we have applied the net benefit test which Transpower is required to carry out when permanently reconfiguring the grid.

Background

We recently reconfigured the 110 kV bus at Arapuni. This enables us to easily implement a system split at Arapuni and close that split when required. The split has three Arapuni generating units connected to the circuits to Kinleith and five generating units connected to the circuits going to Ongarue, Hangatiki, Hamilton and Bombay.

The bus split relieves constraints on generation at Arapuni power station. The installed capacity at Arapuni is 180 MW. The power station can be constrained back to 100 MW at times of very low generation in the Upper North Island. It should be noted that the bus split will not completely relieve constraints at Arapuni.

The split will also relieve the need for the System Operator to declare grid emergencies to split the system at Kinleith to manage loading on the 110 kV circuits between Tarukenga, Kinleith, Arapuni and Hamilton.

The split does require a minimum amount of generation at Arapuni from the generating units connected to Kinleith. This is to maintain security of supply to Kinleith and Lichfield and to manage voltages.

Net Benefit Test

Section 12.117 of the Electricity Industry Participation Code requires Transpower to demonstrate a net benefit for any permanent reconfiguration of the grid. The following benefits and costs should be estimated where applicable:

- Changes in fuel costs incurred by a generator;
- Direct labour and material costs incurred by Transpower and the designated transmission customers;
- Changes in estimated maintenance costs including Transpower's and any designated transmission customer's costs;
- Any change in the estimation of expected unserved energy;
- Changes in fuel costs of existing assets, committed projects and modelled projects;
- Changes in the value of involuntary demand curtailment;
- Changes in the costs of demand-side management changes in costs resulting from deferral of capital expenditure on modelled projects;
- Changes in costs resulting from differences in the amount of capital expenditure on modelled projects;
- Changes in costs resulting from differences in operations and maintenance expenditure on existing assets, committed projects, and modelled projects;
- Changes in costs for ancillary services;
- Changes in losses, including local losses;
- Changes in subsidies or other benefits provided under or arising pursuant to all applicable laws, regulations and administrative determinations.

Methodology for analysis

Losses and generation fuel costs

We used historic load, generation, capacitor switching and voltage setpoint information for 2010 to estimate reduction in losses and generation fuel costs through implementing the split. Loads were scaled to reflect the 2011 forecast load.

A slack bus was placed at Bunnythorpe to supply the additional load. Constraints on Arapuni generation were met by additional thermal generation at Huntly.

Arapuni generation was varied to determine the maximum generation that would allow a five minute off load time on the Arapuni-Hamilton circuits during a Hamilton-Whakamaru contingency.

The Arapuni split was then opened and Arapuni generation was varied to determine the maximum generation that would allow a five minute off load time on the Arapuni-Hamilton circuit during an Arapuni-Hamilton contingency. The constrained off generation has conservatively been valued at \$20/MWh.

Losses were calculated for every hour, using the 2010 Arapuni dispatch, with the Arapuni split both open and closed. Losses have also been conservatively valued at \$20/MWh.

Unserviced energy

The probabilities of forced outages on the circuits from Tarukenga to Arapuni were calculated from historic fault records.

Auto-reclose functionality on the line protection relays at Arapuni, Kinleith and Tarukenga will be turned off when the split is in place. This is to prevent line protection relays attempting auto-reclose when the Arapuni generating units on the 'south' bus are out of synchronism with the rest of the power following trippings of both Arapuni-Kinleith circuits or both Kinleith-Lichfield-Tarukenga circuits.

Loss of both Arapuni-Kinleith circuits

The Arapuni-Kinleith circuits do not seem to have any history of double circuit faults in the last twenty years. The circuits average 1.2 trips per year. If we assume that a line patrol takes three hours on average then the risk of the second circuit tripping before the first circuit has been restored is $1.2 \text{ faults per year} \times 3 \text{ hours of risk} / 24 \text{ hours per day} / 365 \text{ days per year} = 0.0004 \text{ per year}$ – which corresponds to a return period of around 2400 years.

The Arapuni-Kinleith circuits do have a history of sequential outages where one circuit is forced out of service followed by the remaining circuit being forced out of service a few minutes later. This occurs about once every five years on average.

The consequence of both Arapuni-Kinleith circuits being out of service at the same time the Arapuni split is in place is the loss of Arapuni 'south' bus generation which would need to be made up from generation elsewhere. It is likely some load at Kinleith will be lost following the tripping of both Arapuni-Kinleith circuits due to a drop in voltage but this loss would occur regardless of whether the Arapuni bus split is in place.

Assuming maximum Arapuni 'south' bus generation at the time when the Arapuni-Kinleith circuits are tripped, additional generation fuel cost to replace the lost generation is \$60/MWh and 0.25 hours to restore connection, the expected costs per year are $0.2 \text{ consecutive trippings per year} \times 68 \text{ MW} \times 0.25 \text{ hours} \times \$60/\text{MWh} = \$204 \text{ per year}$.

Arapuni bus fault with split in place

A bus fault at Arapuni on the south bus (with the split in place) will result in the loss of all south bus generation. This generation will need to be made up from elsewhere. It is likely some load at Kinleith will be lost following the tripping of both Arapuni-Kinleith circuits due to a drop in voltage but this loss would occur regardless of whether the Arapuni bus split is in place.

The probability of a bus fault occurring in a year is around 0.02^1 (50 year return period).

Assuming maximum Arapuni 'south' bus generation at the time of the bus fault, additional generation fuel cost to replace the lost generation is \$60/MWh and 4 hours to restore connection, the expected costs per year are $0.02 \text{ bus trippings per year} \times 68 \text{ MW} \times 4 \text{ hours} \times \$60/\text{MWh} = \$326 \text{ per year}$.

¹ See the System Operator Credible Event Management Review (http://www.systemoperator.co.nz/f2531,21144591/REPORT_-_Credible_Event_Management_Review_For_Consultation.pdf).

Kinleith-Lichfield-Tarukenga circuits

The Kinleith-Lichfield-Tarukenga circuits do not seem to have any history of double circuit faults in the last twenty years. The circuits average 2.3 trips per year. If we assume that a line patrol takes three hours on average then the risk of the second circuit tripping before the first circuit has been restored is $2.3 \text{ faults per year} \times 3 \text{ hours of risk} / 24 \text{ hours per day} / 365 \text{ days per year} = 0.0008 \text{ per year}$ – which corresponds to a return period of around 1250 years.

The Kinleith-Lichfield-Tarukenga circuits do have a history of sequential outages where one circuit is forced out of service followed by the remaining circuit being forced out of service a few minutes later. This occurs about once every twenty years on average.

The consequence of both Kinleith-Lichfield-Tarukenga circuits being out of service at the same time the Arapuni split is in place is:

- Loss of Arapuni 'south' bus generation; and;
- Loss of all load at Kinleith and Lichfield.

The loss of load and generation may be smaller if the Arapuni and Kinleith generation and Kinleith load can successfully form an island.

The cost of both Kinleith-Lichfield-Tarukenga circuits tripping when the split is in place is:

- The loss of generation at Arapuni on the south bus which would need to be made up from generation elsewhere; and;
- Energy not served at Kinleith and Lichfield.

It is assumed that following the tripping of both circuits, supply to Kinleith and the Arapuni south bus can be restored quickly by closing the Arapuni bus split.

Assuming maximum Arapuni 'south' bus generation at the time when the Arapuni-Kinleith circuits are tripped, additional generation fuel cost to replace the lost generation is \$60/MWh and 0.5 hours to restore connection, the costs per year are $0.05 \text{ consecutive trippings per year} \times 68 \text{ MW} \times 0.5 \text{ hours} \times \$60/\text{MWh} = \$102 \text{ per year}$.

Assuming load reduction of 80 MW at Kinleith following the loss of the Arapuni 'south' bus generation, 0.5 hours to restore connection, a VOLL of \$20,000/MWh, the energy not served costs are $0.05 \text{ consecutive faults per year} \times 80 \text{ MW} \times 0.5 \text{ hours} \times \$20,000/\text{MWh} = \$40,000 \text{ per year}$.

The load reduction at Lichfield is not considered as this load will be lost regardless of whether the 110 kV bus at Arapuni is split if both Kinleith-Lichfield-Tarukenga circuits are tripped.

Costs

The applicable costs for this cost benefit analysis are shown in the Table below.

Cost	Value (\$M)	Comment
the direct labour and material costs incurred by Transpower and the designated transmission customers	0.1	This is the cost of physically reconfiguring the Arapuni 110 kV bus.
any increase in the estimation of expected unserved energy	0.04	
Changes in generator fuel cost	0.006	
Total	0.156	

Benefits

The applicable costs for this cost benefit analysis are shown in the Table below.

Benefit	Value (\$M)	Comment
any reduction in fuel costs incurred by a generator	\$3+	The split allows more than 149,000 MWh additional output to be generated from Arapuni power station over a year. The average reduction in fuel cost (fuel cost of generation that would otherwise be required less the Arapuni fuel cost) is assumed to be at least \$20/MWh.
changes in losses, including local losses:	0.04	Reduction in losses over a year is 1951 MWh.
Total	3+	

Other costs and benefits

Two to three generating units are required to be generating on the south bus at Arapuni when the bus split is in place. The units are required to manage loading of Kinleith Tarukenga circuit 1, maintain voltages at Kinleith within an acceptable range following the outage of one of the Kinleith-Tarukenga circuits and to ensure that there is sufficient fault current for protection relays at Arapuni to operate correctly. Around 60 MW of generation on the south bus is required at peak times.

Concern has been expressed at the need for this south bus generation. It is perceived that the bus split has required this generation to be “constrained on” and that competition in the area has been reduced.

The Arapuni bus split increases the capacity of the 220 kV network to transfer power into the Upper North Island. At peak times, the bus split can reduce reliance on regional generation by up to 370 MW.

While 60 MW of generation is “constrained on” at Arapuni, the bus split reduces the amount of generation “constrained on” in the Upper North Island by 370 MW. In terms of competition, the bus split is very likely to improve net competition in New Zealand.

Discussion and Conclusions

The amount of analysis conducted for the net benefit should be commensurate with the value of the investment. In this case the value of the investment is around \$100,000 (the cost of reconfiguring the Arapuni bus). What we need to show is that the benefits are likely to be at least an order of magnitude greater than the cost.

There are some caveats on this analysis:

- The net benefit test should be reviewed following the commissioning of the new 400 kV-capable line to Auckland;
- The hydrology of the Waikato River is not considered, generation at Karapiro and upstream may vary with the constraints at Arapuni.

The net benefit test for implementing a system split at Arapuni is positive (\$3M+ benefits per year versus \$0.16M cost).