CHAPTER 6

Network capability and performance

6 Network capability and performance

Key highlights

- Generation commitments since the 2017 Transmission Annual Planning Report (TAPR) will add 1,912MW to Queensland's semi-scheduled variable renewable energy (VRE) generation capacity taking the total VRE generation capacity to 2,645MW.
- During 2017/18, the Central Queensland to Southern Queensland (CQ-SQ) grid section was highly utilised reflecting higher CQ generator scheduling. The utilisation of this grid section is expected to increase with the connection of further VRE generators in North Queensland (NQ) and Central Queensland (CQ).
- Committed generation is expected to alter power transfers, particularly during daylight hours, increasing the likelihood of congestion across the Gladstone, CQ-SQ and Queensland/New South Wales Interconnector (QNI) grid sections.
- Record peak transmission delivered demands were recorded in the Wide Bay, Surat and Moreton zones, during 2017/18.
- The transmission network has performed reliably during 2017/18, with Queensland grid sections largely unconstrained.

6.1 Introduction

This chapter on network capability and performance provides:

- an outline of existing and committed generation capacity over the next three years
- a summary of network control facilities configured to disconnect load as a consequence of non-credible events
- sample power flows at times of forecast Queensland maximum summer and winter demands under a range of interconnector flows and generation dispatch patterns
- single line diagrams of the existing high voltage (HV) network configuration
- background on factors that influence network capability
- zonal energy transfers for the two most recent years
- historical constraint times and power flow duration curves at key sections of Powerlink Queensland's transmission network
- a qualitative explanation of factors affecting power transfer capability at key sections of Powerlink's transmission network
- historical system normal constraint times and load duration curves at key zones of Powerlink's transmission network
- double circuit transmission lines categorised as vulnerable by the Australian Energy Market Operator (AEMO)
- a summary of the management of high voltages associated with light load conditions.

The capability of Powerlink's transmission network to meet forecast demand is dependent on a number of factors. Queensland's transmission network is predominantly utilised more during summer than winter. During higher summer temperatures, reactive power requirements are greater and transmission plant has lower power carrying capability. Also, higher demands occur in summer as shown in Figure 2.8.

The location and pattern of generation dispatch influences power flows across most of the Queensland network. Future generation dispatch patterns and interconnector flows are uncertain in the deregulated electricity market and will also vary substantially due to the effect of planned or unplanned outages of generation plant. Power flows can also vary substantially with planned or unplanned outages of transmission network elements. Power flows may also be higher at times of local area or zone maximum demands (refer to Table 2.13) and/or when embedded generation output is lower.

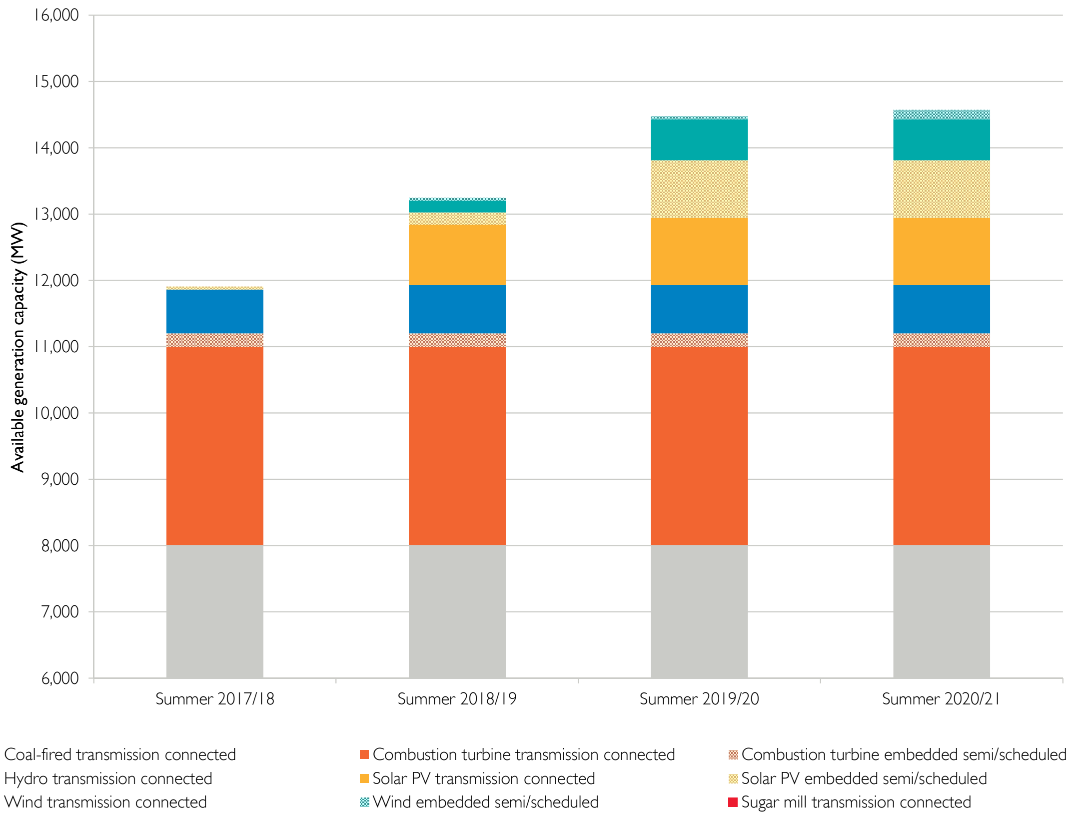
The years referenced in this chapter correspond to the period from April to March of the following year, capturing a full winter and summer period.

6.2 Available generation capacity

Scheduled generation in Queensland is currently a combination of coal-fired, gas turbine and hydro electric generators.

For the purposes of this TAPR, new generators are regarded as reaching committed status (incorporated into future studies) when a Connection and Access Agreement (CAA) has been executed. During 2017/18, commitments have added 1,912MW of capacity, taking Queensland's semi-scheduled VRE generation capacity to 2,645MW. Figure 6.1 illustrates the expected changes to available generation capacity in Queensland from summer 2017/18 to summer 2020/21.

Figure 6.1 Summer available generation capacity by energy source



6.2.1 Existing and committed transmission connected generation

Table 6.1 summarises the available generation capacity of power stations connected, or committed to be connected to Powerlink's transmission network including the non-scheduled generators at Yarwun, Invicta and Koombooloomba.

The semi-scheduled transmission connected solar farms namely, Sun Metals, Haughton, Daydream, Hayman and Lilyvale in addition to the Coopers Gap wind farm have reached committed status since the 2017 TAPR.

In December 2014, Stanwell Corporation withdrew Swanbank E Power Station (PS) from service. Swanbank E was brought back to service in December 2017.

Information in this table has been provided to AEMO by the owners of the generators. Details of registration and generator capacities can be found on AEMO's website. In accordance with clause 5.18A of the NER, Powerlink's Register of Large Generator Connections with information on generators connected to Powerlink's network can be found on Powerlink's website.

Table 6.1 Available generation capacity - existing and committed generators connected to the Powerlink transmission network

Generator	Location	Available generation capacity (MW) (1) Winter 2018	Summer 2018/19	Winter 2019	Summer 2019/20	Winter 2020	Summer 2020/21
Coal-fired							
Stanwell	Stanwell Switchyard	1,460	1,460	1,460	1,460	1,460	1,460
Gladstone	Calliope River	1,680	1,680	1,680	1,680	1,680	1,680
Callide B	Calvale Switchyard	700	700	700	700	700	700
Callide Power Plant	Calvale Switchyard	840	840	840	840	840	840
Tarong North	Tarong Switchyard	443	443	443	443	443	443
Tarong	Tarong Switchyard	1,400	1,400	1,400	1,400	1,400	1,400
Kogan Creek	Kogan Creek PS Switchyard	744	730	744	730	744	730
Millmerran	Millmerran PS Switchyard	852	760	852	760	852	760
Total coal-fired		**8,119**	**8,013**	**8,119**	**8,013**	**8,119**	**8,013**
Combustion turbine							
Townsville 132kV	Townsville GT PS	159	149	159	149	159	148
Mt Stuart (2)	Townsville South	423	398	423	398	423	398
Yarwun (3)	Yarwun	160	155	160	155	160	155
Condamine	Columboola	100	90	100	90	100	90
Braemar 1	Braemar	504	471	504	471	504	471
Braemar 2	Braemar	519	495	519	495	519	495
Darling Downs	Braemar	633	580	633	580	633	580
Oakey (4)	Tangkam	346	282	346	282	346	282
Swanbank E	Swanbank E PS Switchyard	365	365	365	365	365	365
Total combustion turbine		**3,209**	**2,985**	**3,209**	**2,985**	**3,209**	**2,984**
Hydro electric							
Barron Gorge	Kamerunga	66	66	66	66	66	66
Kareeya (including Koombooloomba) (5)	Chalumbin	93	93	93	93	93	93
Wivenhoe (6)	Mt. England	570	570	570	570	570	570
Total hydro electric		**729**	**729**	**729**	**729**	**729**	**729**

Table 6.1 Available generation capacity - existing and committed generators connected to the Powerlink transmission network *(continued)*

Generator	Location	Available generation capacity (MW) (1)					
		Winter 2018	Summer 2018/19	Winter 2019	Summer 2019/20	Winter 2020	Summer 2020/21
Solar PV (7)							
Ross River	Ross		116	116	116	116	116
Sun Metals	Townsville Zinc	107	107	107	107	107	107
Haughton	Haughton River			100	100	100	100
Clare	Clare South	100	100	100	100	100	100
Whitsunday	Strathmore	57	57	57	57	57	57
Hamilton	Strathmore	57	57	57	57	57	57
Daydream	Strathmore		150	150	150	150	150
Hayman	Strathmore		50	50	50	50	50
Rugby Run	Moranbah		65	65	65	65	65
Lilyvale	Lilyvale		100	100	100	100	100
Darling Downs	Braemar	108	108	108	108	108	108
Total solar		**429**	**910**	**1,010**	**1,010**	**1,010**	**1,010**
Wind (7)							
Mt Emerald	Walkamin	180	180	180	180	180	180
Coopers Gap	Coopers Gap			440	440	440	440
Total wind		**180**	**180**	**620**	**620**	**620**	**620**
Sugar mill							
Invicta (5)	Invicta Mill	34	0	34	0	34	0
Total all stations		**12,700**	**12,817**	**13,721**	**13,357**	**13,721**	**13,356**

Notes:

(1) Synchronous generator capacities shown are at the generator terminals and are therefore greater than power station net sent out nominal capacity due to station auxiliary loads and step-up transformer losses. The capacities are nominal as the generator rating depends on ambient conditions. Some additional overload capacity is available at some power stations depending on ambient conditions.

(2) Origin Energy has advised AEMO of its intention to no longer retire Mt Stuart in 2023.

(3) Yarwun is a non-scheduled generator, but is required to comply with some of the obligations of a scheduled generator.

(4) Oakey Power Station is an open-cycle, dual-fuel, gas-fired power station. The generated capacity quoted is based on gas fuel operation.

(5) Koombooloomba and Invicta are transmission connected non-scheduled generators.

(6) Wivenhoe Power Station is shown at full capacity (570MW). However, output can be limited depending on water storage levels in the dam.

(7) VRE generators shown at maximum capacity at the point of connection.

6.2.2 Existing and committed scheduled and semi-scheduled embedded generation

Table 6.2 summarises the available generation capacity of embedded scheduled and semi-scheduled power stations connected, or committed to be connected to Queensland's distribution network.

The semi-scheduled solar farms namely, Cape York, Clermont, Blackwater, Emerald, Aramara, Susan River, Childers, Yarranlea, and Oakey 2 in addition to the Lakeland wind farm and Kennedy Energy Park have reached committed status since the 2017 TAPR.

Information in this table has been provided to AEMO by the owners of the generators. Details of registration and generator capacities can be found on AEMO's website.

Table 6.2 Available generation capacity - existing and committed scheduled or semi-scheduled generators connected to the Energex and Ergon Energy (part of the Energy Queensland Group) distribution networks.

Generator	Location	Available generation capacity (MW)					
		Winter 2018	Summer 2018/19	Winter 2019	Summer 2019/20	Winter 2020	Summer 2020/21
Combustion turbine (1)							
Townsville 66kV	Townsville GT PS	84	84	84	84	84	84
Mackay (2)	Mackay	34	34	34	34	34	34
Barcaldine	Barcaldine	37	34	37	34	37	34
Roma	Roma	68	54	68	54	68	54
Total combustion turbine		**223**	**206**	**223**	**206**	**223**	**206**
Solar PV (3)							
Cape York	Cape York switching station					53	53
Kidston	Kidston	49	49	49	49	49	49
Kennedy Energy Park	Hughenden		15	15	15	15	15
Collinsville	Collinsville North		41	41	41	41	41
Clermont	Clermont			75	75	75	75
Blackwater	Blackwater				150	150	150
Emerald	Emerald			73	73	73	73
Aramara	Aramara			101	101	101	101
Susan River	Maryborough			76	76	76	76
Childers	Isis			56	56	56	56
Yarranlea	Yarranlea			103	103	103	103
Oakey 1	Oakey		25	25	25	25	25
Oakey 2	Oakey		55	55	55	55	55
Total solar		**49**	**185**	**669**	**872**	**872**	**872**
Wind (3)							
Lakeland	Lakeland					100	100
Kennedy Energy Park	Hughenden		43	43	43	43	43
Total wind		**0**	**43**	**43**	**43**	**143**	**143**
Total all stations		**272**	**434**	**935**	**1,121**	**1,238**	**1,221**

Notes:

(1) Synchronous generator capacities shown are at the generator terminals and are therefore greater than power station net sent out nominal capacity due to station auxiliary loads and step-up transformer losses. The capacities are nominal as the generator rating depends on ambient conditions. Some additional overload capacity is available at some power stations depending on ambient conditions.

(2) Stanwell Corporation has advised AEMO of its intention to retire Mackay GT at the end of financial year 2020/21.

(3) VRE generators shown at maximum capacity at the point of connection.

6.3 Network control facilities

Powerlink participated in the inaugural Power System Frequency Risk Review[1] (PSFRR) during 2017/18. The PSFRR is part of the Emergency Frequency Control Schemes rule change[2] which placed an obligation on AEMO to undertake, in collaboration with Transmission Network Service Providers (TNSPs), an integrated, periodic review of power system frequency risks associated with non-credible contingency events.

AEMO published the results of the PSFRR in April 2018. For Queensland, the recommendation involved the expansion of Powerlink's CQ-SQ Special Protection Scheme (SPS). The scheme disconnects one or two highest generating Callide units, depending on CQ-SQ transfer, for the unplanned loss of both Calvale to Halys 275kV feeders. The existing scheme is limited to transfers lower than 1,700MW and relies on the ability to disconnect high output generating units.

The CQ-SQ SPS was commissioned in 2012. CQ-SQ transfers have subsequently increased and are expected to continue increasing with the integration of the committed VRE generation. The CQ-SQ SPS expansion involves extending the scheme to other sites in addition to Callide to access additional large units to disconnect if necessary.

The 2018 PSFRR also identifies a potential need to establish a coordinated Over Frequency Generation Shedding (OFGS) scheme. AEMO and Powerlink will undertake a joint study to consider the risk of major supply disruptions which could lead to an over frequency event.

Powerlink owns other network control facilities which minimise or reduce the consequences of multiple contingency events. Network control facilities owned by Powerlink which may disconnect load following a multiple non-credible contingency event are listed in Table 6.3.

Table 6.3 Powerlink owned network control facilities configured to disconnect load as a consequence of non-credible events during system normal conditions

Scheme	Purpose
Far North Queensland Under Voltage Load Shed (UVLS) scheme	Minimise risk of voltage collapse in Far North Queensland
North Goonyella Under Frequency Load Shed (UFLS) relay	Raise system frequency
Dysart UVLS	Minimise risk of voltage collapse in Dysart area
Eagle Downs UVLS	Minimise risk of voltage collapse in Eagle Downs area
Boyne Island UFLS relay	Raise system frequency
Queensland UFLS Inhibit Scheme	Minimise risk of QNI separation for an UFLS event for moderate to high southern transfers on QNI compared to Queensland demand
Tarong UFLS relay	Raise system frequency
Middle Ridge UFLS relays	Raise system frequency

1 AEMO, 2018 Power System Frequency Risk Review, April 2018.
2 AEMC, Rule Determination National Electricity Amendment (Emergency frequency control schemes) Rule 2017, 30 March 2017.

6.4 Sample winter and summer power flows

Powerlink has selected 18 sample scenarios to illustrate possible power flows for forecast Queensland region summer and winter maximum demands. These sample scenarios are for the period winter 2018 to summer 2020/21 and are based on the 50% probability of exceedance (PoE) medium economic outlook demand forecast outlined in Chapter 2. These sample scenarios, included in Appendix C, show possible power flows under a range of import and export conditions on the QNI transmission line. The dispatch assumed is broadly based on historical observed dispatch of generators.

Power flows in Appendix C are based on existing network configuration (illustrated in figures 6.2, 6.3, 6.4 and 6.5) and committed projects (listed in tables 9.1, 9.3 and 9.4), and assume all network elements are available. In providing this information Powerlink has not attempted to predict market outcomes.

Figure 6.2 Existing HV network June 2018 - North Queensland

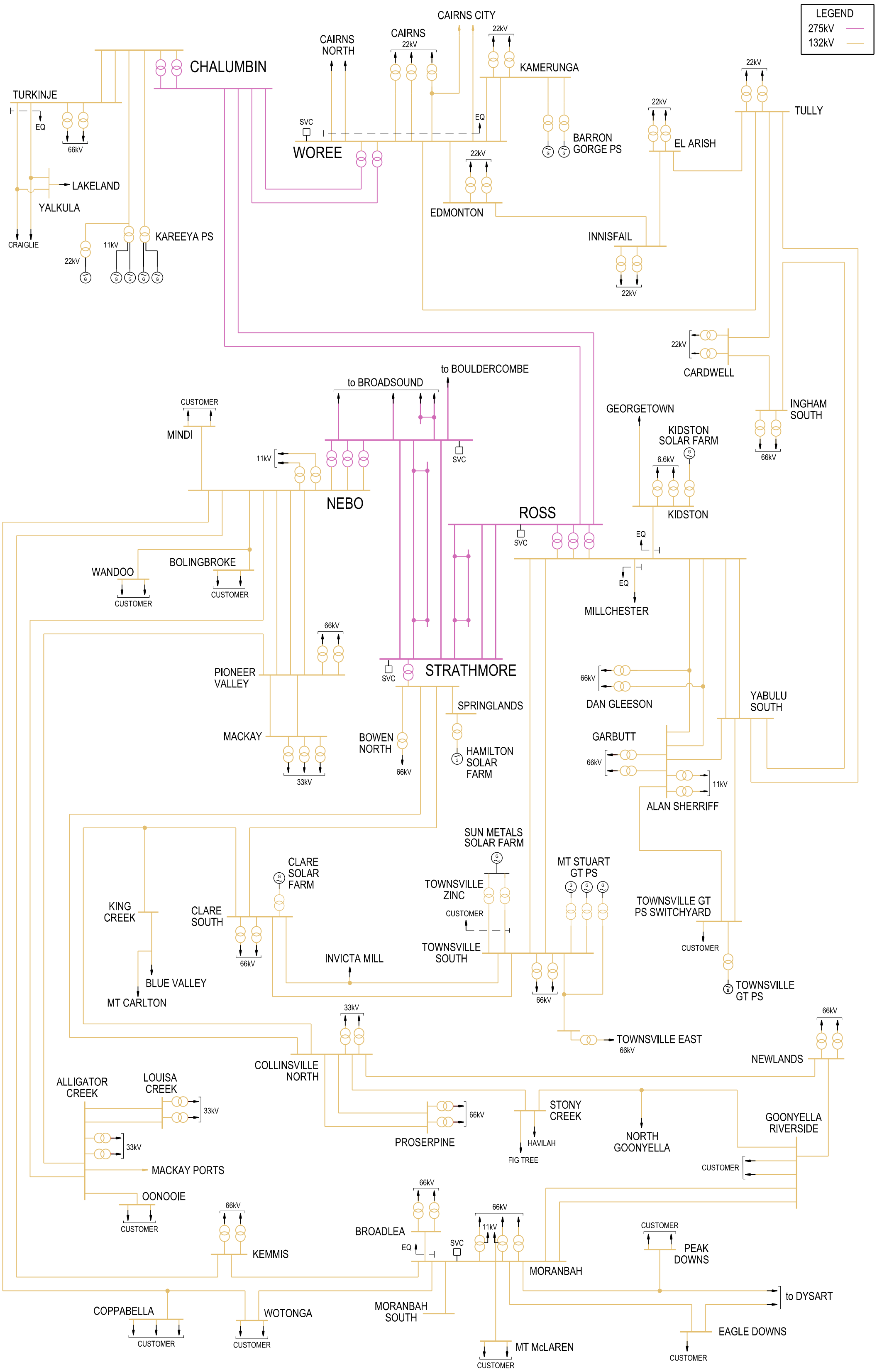


Figure 6.3 Existing HV network June 2018 - Central Queensland

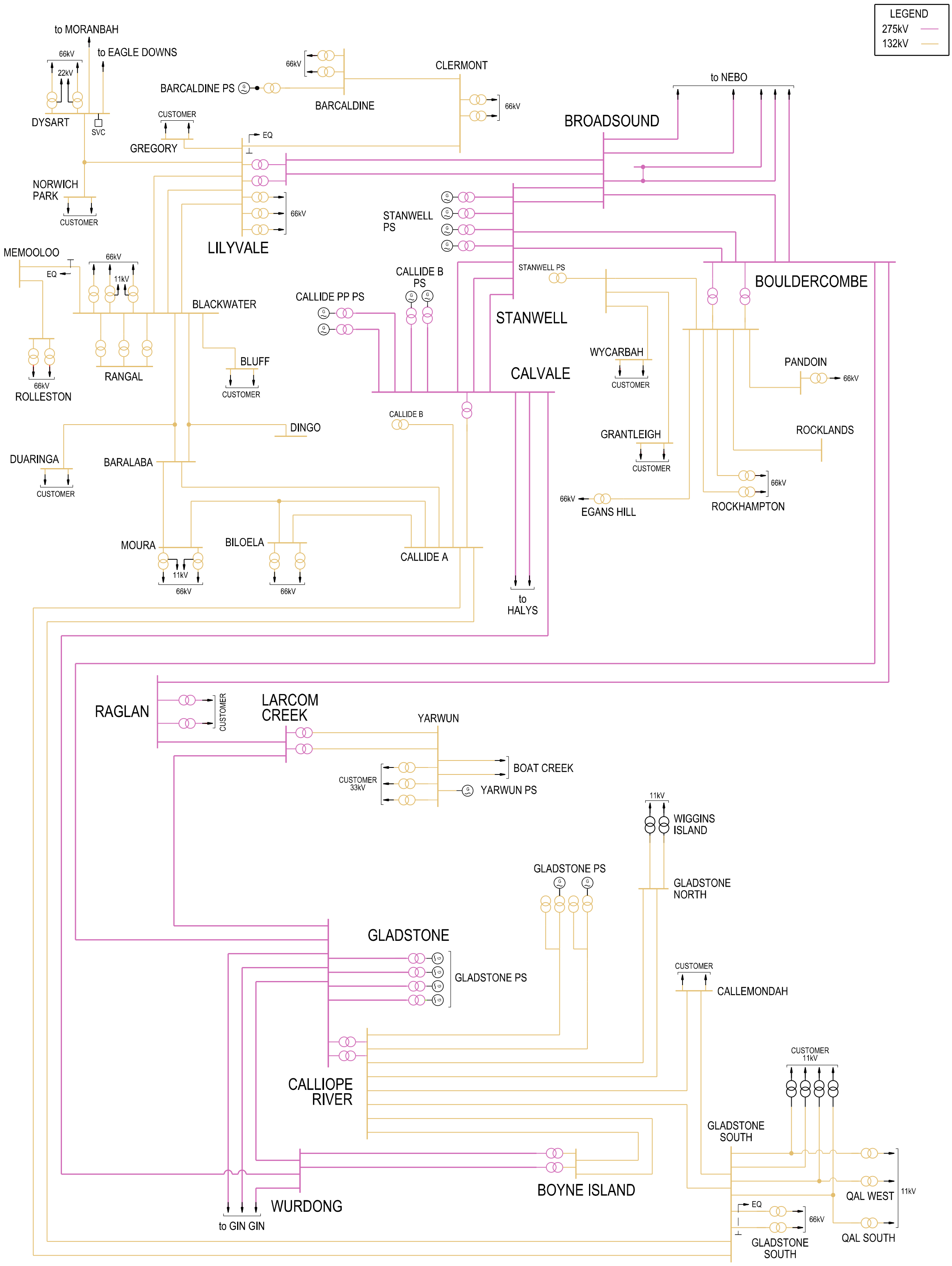


Figure 6.4 Existing HV network June 2018 - South West Queensland

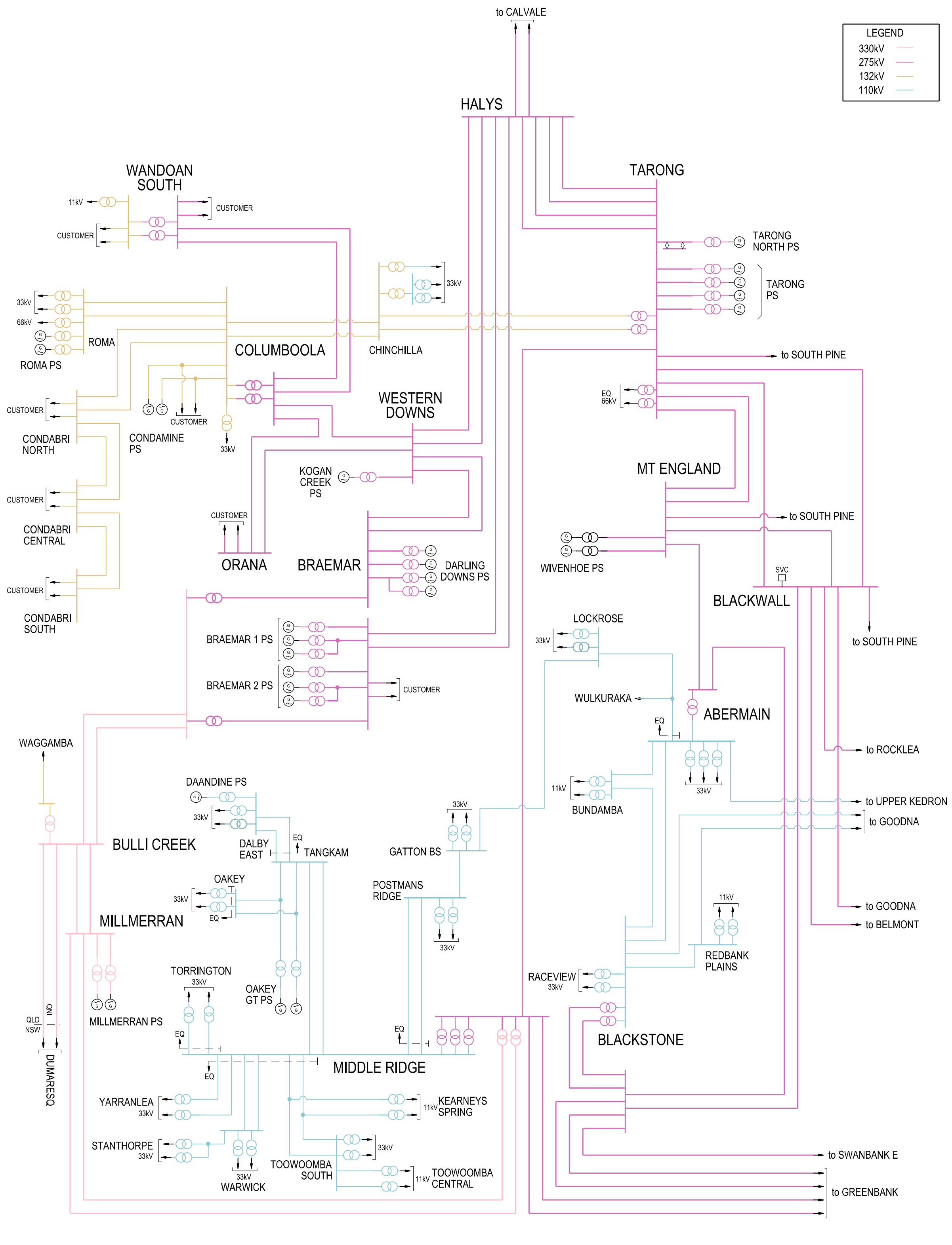
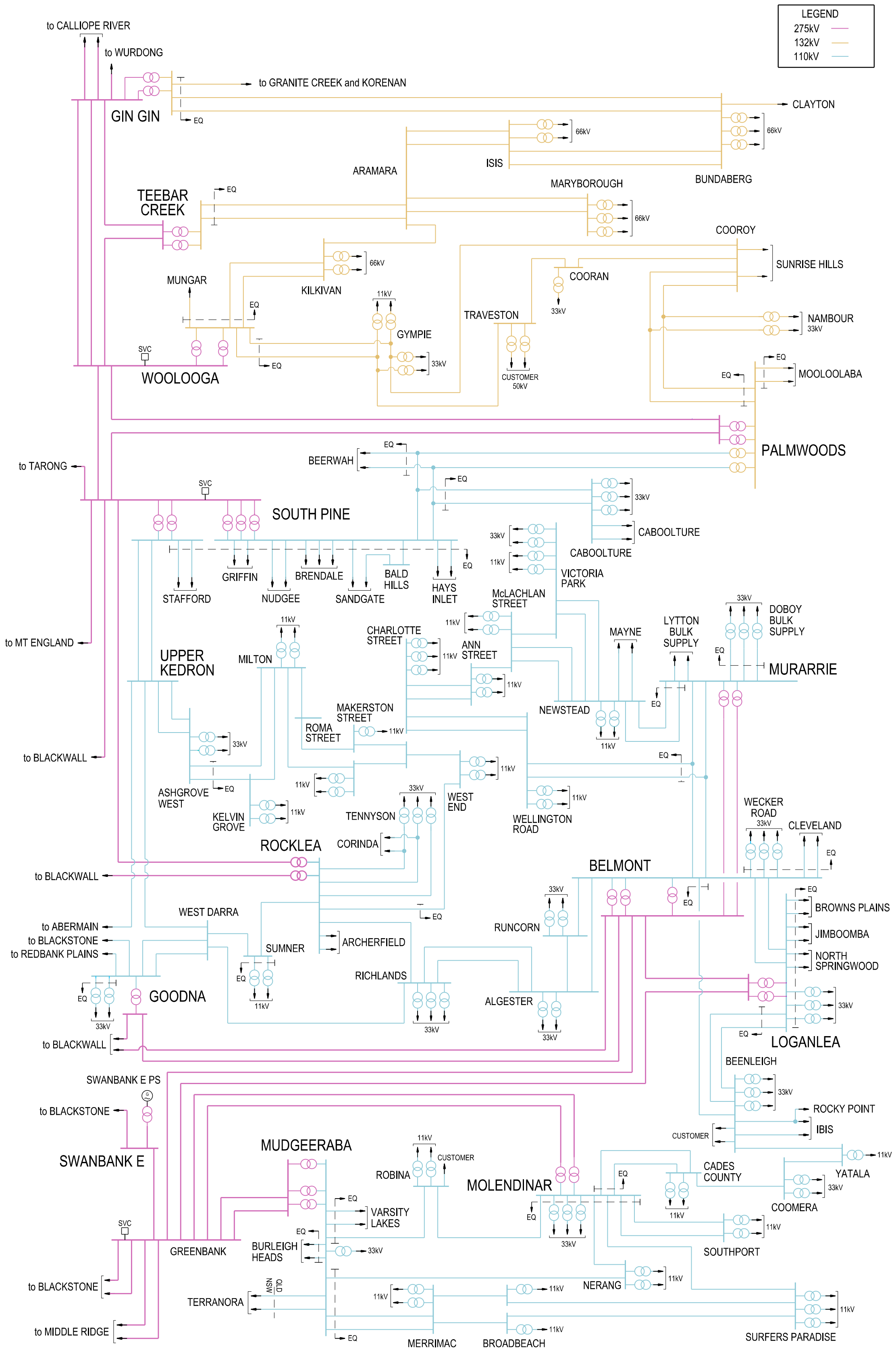


Figure 6.5 Existing HV network June 2018 - South East Queensland



6.5 Transfer capability

6.5.1 Location of grid sections

Powerlink has identified a number of grid sections that allow network capability and forecast limitations to be assessed in a structured manner. Limit equations have been derived for these grid sections to quantify maximum secure power transfer. Maximum power transfer capability may be set by transient stability, voltage stability, thermal plant ratings or protection relay load limits. AEMO has incorporated these limit equations into constraint equations within the National Electricity Market Dispatch Engine (NEMDE). Figure C.2 in Appendix C shows the location of relevant grid sections on the Queensland network.

6.5.2 Determining transfer capability

Transfer capability across each grid section varies with different system operating conditions. Transfer limits in the NEM are not generally amenable to definition by a single number. Instead, TNSPs define the capability of their network using multi-term equations. These equations quantify the relationship between system operating conditions and transfer capability, and are implemented into NEMDE, following AEMO's due diligence, for optimal dispatch of generation. In Queensland the transfer capability is highly dependent on which generators are in-service and their dispatch level. The limit equations maximise transmission capability available to electricity market participants under prevailing system conditions.

Limit equations derived by Powerlink which are current at the time of publication of this TAPR are provided in Appendix D. Limit equations will change over time with demand, generation and network development and/or network reconfiguration. Such detailed and extensive analysis on limit equations has not been carried out for future network and generation developments for this TAPR. However, expected limit improvements for committed works are incorporated in all future planning. Section 6.6 provides a qualitative description of the main system conditions that affect the capability of each grid section.

6.6 Grid section performance

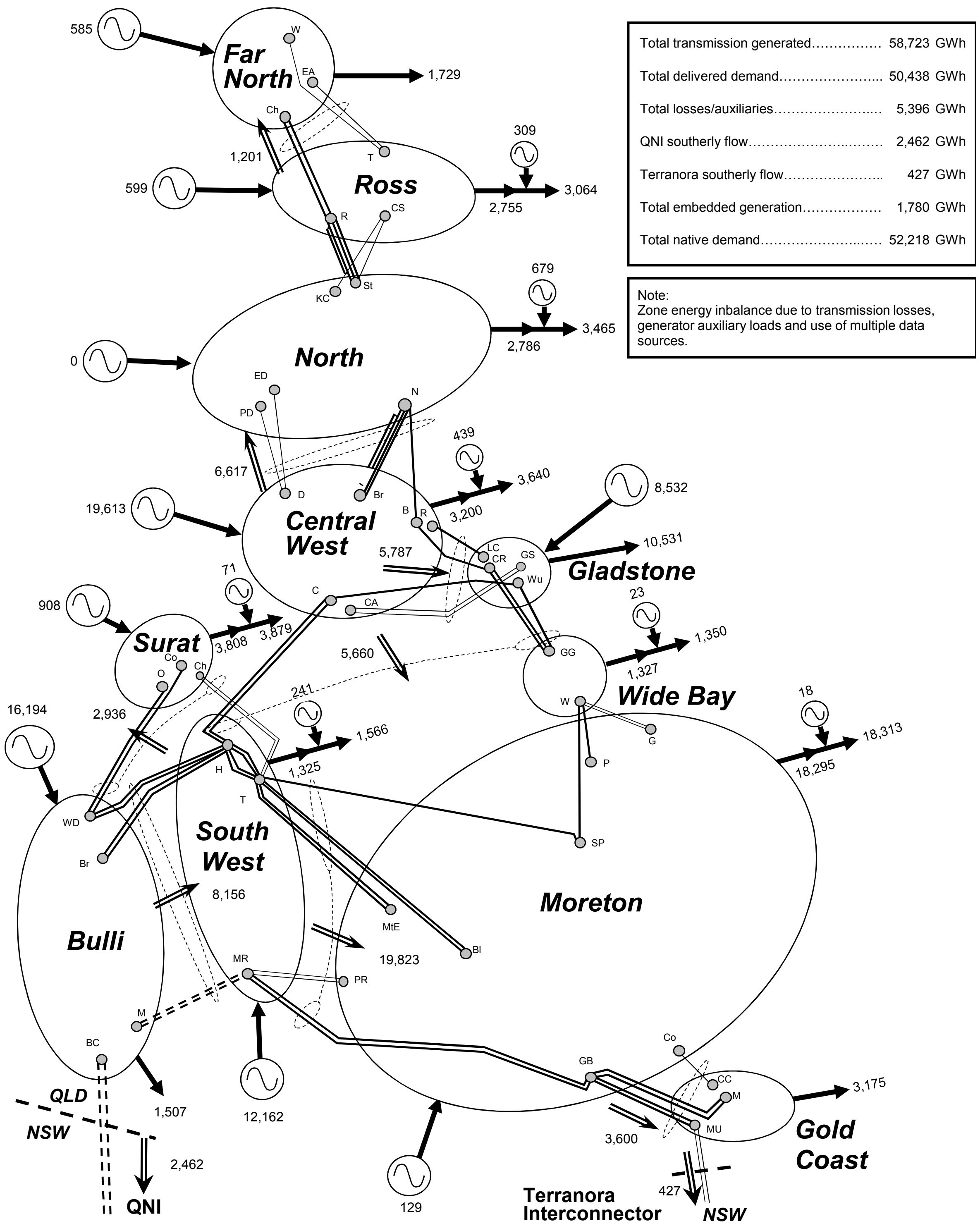
This section is a qualitative summary of system conditions with major effects on transfer capability across key grid sections of the Queensland network.

For each grid section, the time that the relevant constraint equations have bound over the last 10 years is provided. Constraint times can be associated with a combination of generator unavailability, network outages, unfavourable dispatches and/or high loads. Constraint times do not include occurrences of binding constraints associated with network support agreements. Binding constraints whilst network support is dispatched are not classed as congestion. Although high constraint times may not be indicative of the cost of market impact, they serve as a trigger for the analysis of the economics for overcoming the congestion.

Binding constraint information is sourced from AEMO. Historical binding constraint information is not intended to imply a prediction of constraints in the future.

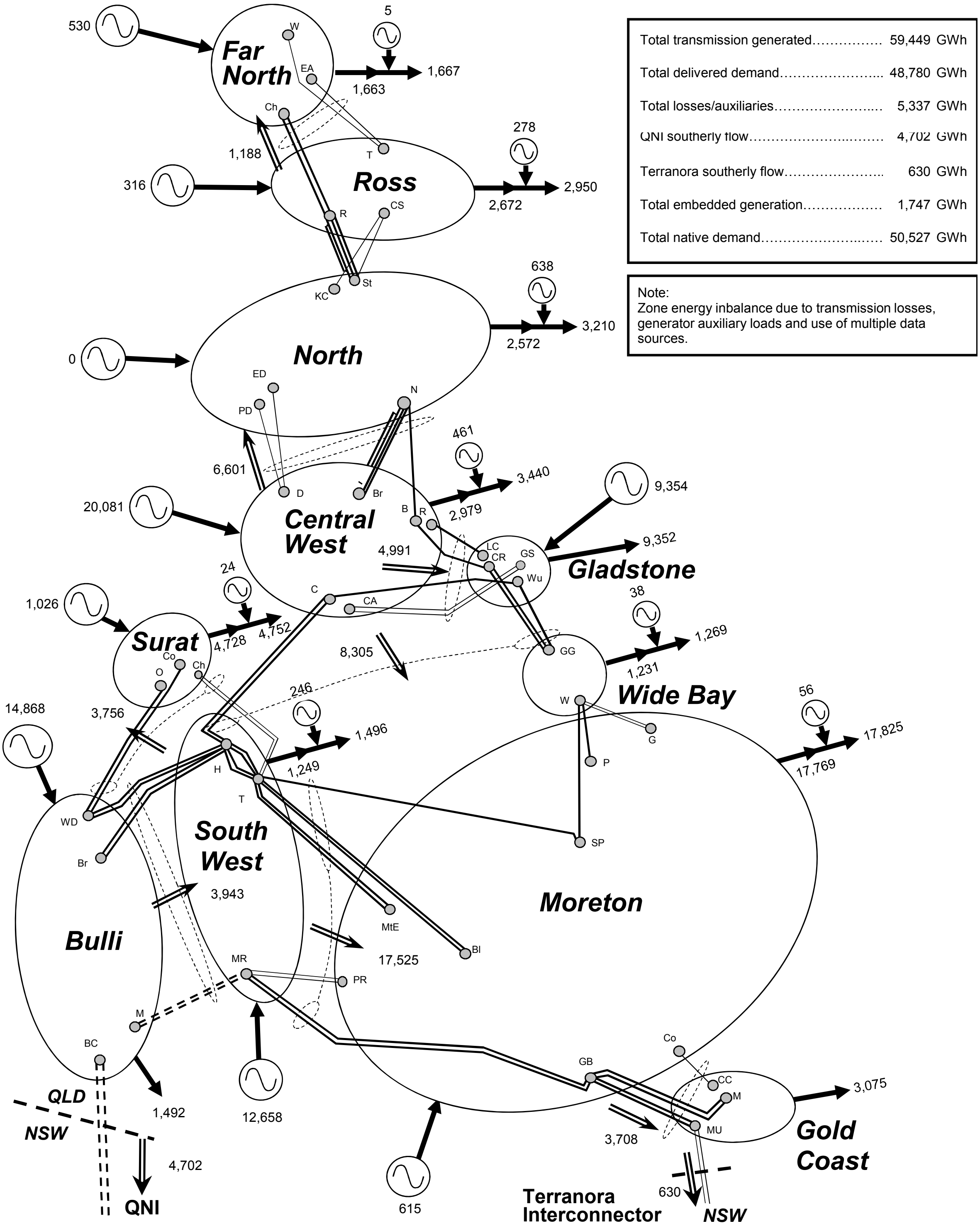
Historical transfer duration curves for the last five years are included for each grid section. Grid section transfers are predominantly affected by load, generation and transfers to neighbouring zones. Figures 6.6 and 6.7 provide 2016 and 2017 zonal energy as generated into the transmission network (refer to Figure C.1 in Appendix C for generators included in each zone) and by major embedded generators, transmission delivered energy to Distribution Network Service Providers (DNSPs) and direct connect customers and grid section energy transfers. Figure 6.8 provides the changes in energy transfers from 2016 to 2017. These figures assist in the explanation of differences between 2016 and 2017 grid section transfer duration curves.

Figure 6.6 2016[3] zonal electrical energy transfers (GWh)



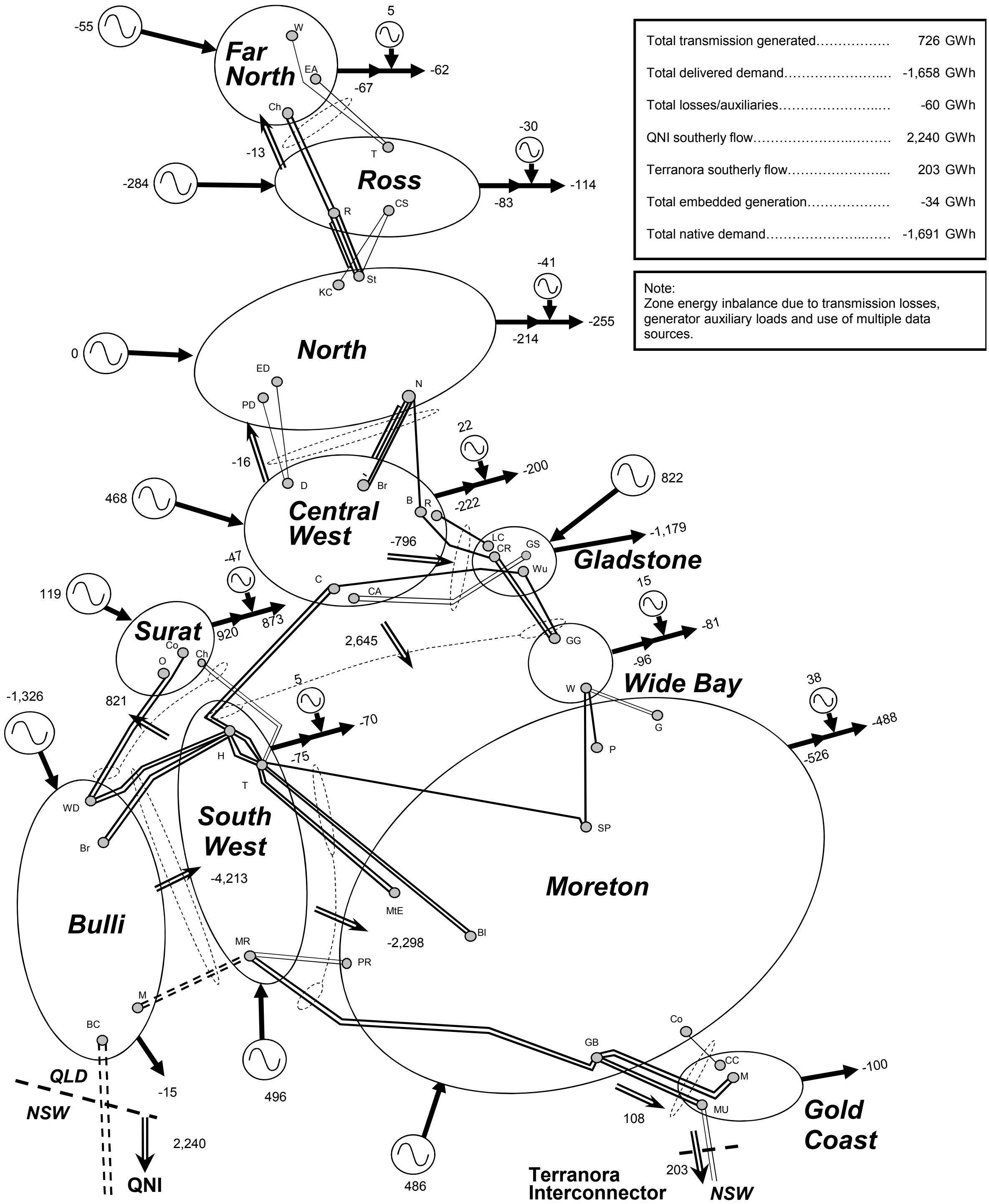
3 Consistent with this chapter, time periods are from April 2016 to March 2017.

Figure 6.7 2017[4] zonal electrical energy transfers (GWh)



[4] Consistent with this chapter, time periods are from April 2017 to March 2018.

Figure 6.8 Change[5] in zonal electrical energy transfers (GWh)



Total transmission generated……………….	726 GWh
Total delivered demand……………………...	-1,658 GWh
Total losses/auxiliaries……………………...	-60 GWh
QNI southerly flow…………………..………	2,240 GWh
Terranora southerly flow…………………...	203 GWh
Total embedded generation………………..	-34 GWh
Total native demand………………….……..	-1,691 GWh

Note:
Zone energy inbalance due to transmission losses, generator auxiliary loads and use of multiple data sources.

5 Consistent with this chapter, time periods for the comparison are from April 2017 to March 2018 and April 2016 to March 2017.

Table C.1 in Appendix C shows power flows across each grid section at time of forecast Queensland region maximum demand, corresponding to the sample generation dispatch shown in figures C.3 to C.20. It also identifies whether the maximum power transfer across each grid section is limited by thermal plant ratings, voltage stability and/or transient stability. Power transfers across all grid sections are forecast to be within transfer capability of the network for these sample generation scenarios. This outlook is based on 50% PoE medium economic outlook demand forecast conditions.

Power flows across grid sections can be higher than shown in figures C.3 to C.20 in Appendix C at times of local area or zone maximum demands. However, transmission capability may also be higher under such conditions depending on how generation or interconnector flow varies to meet higher local demand levels.

6.6.1 Far North Queensland grid section

Maximum power transfer across the Far North Queensland (FNQ) grid section is set by voltage stability associated with an outage of a Ross to Chalumbin 275kV circuit.

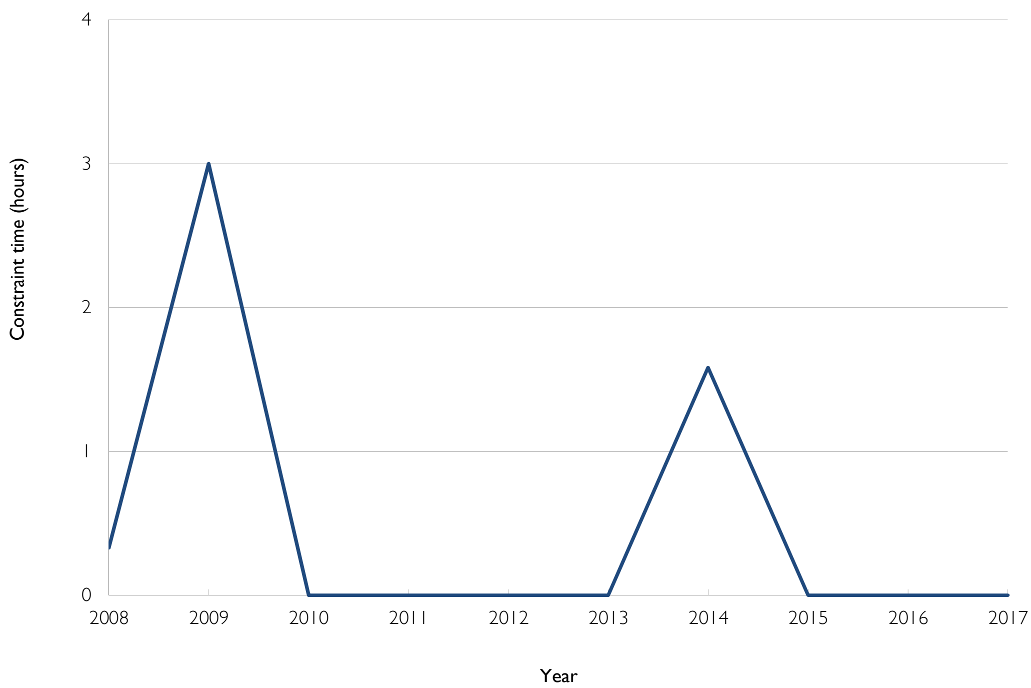
The limit equation in Table D.1 of Appendix D shows that the following variables have a significant effect on transfer capability:

- Far North zone to northern Queensland area[6] demand ratio
- Far North and Ross zones generation.

Local hydro generation reduces transfer capability but allows more demand to be securely supported in the Far North zone. This is because reactive margins increase with additional local generation, allowing further load to be delivered before reaching minimum allowable reactive margins. However, due to its distributed and reactive nature, increases in delivered demand erode reactive margins at greater rates than they were created by the additional local generation. Limiting power transfers are thereby lower with the increased local generation but a greater load can be delivered.

The FNQ grid section did not constrain operation during April 2017 to March 2018. Information pertaining to the historical duration of constrained operation for the FNQ grid section is summarised in Figure 6.9.

Figure 6.9 Historical FNQ grid section constraint times

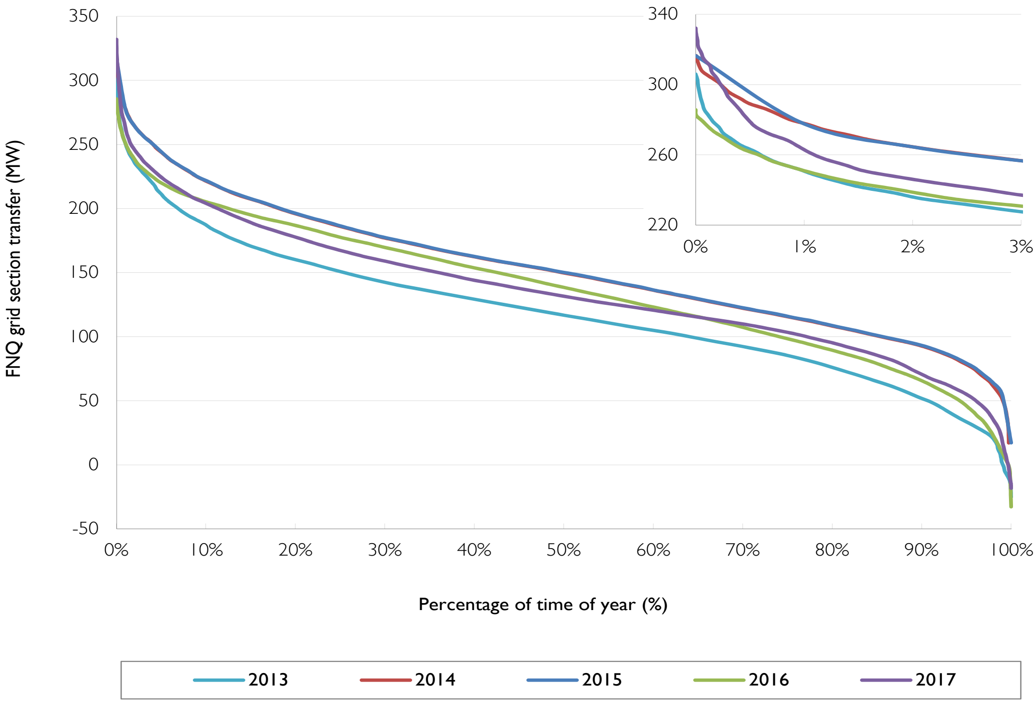


6 Northern Queensland area is defined as the combined demand of the Far North, Ross and North zones.

Constraint durations have reduced over time due to the commissioning of various transmission projects[7]. There have been minimal constraints in this grid section since 2008.

Figure 6.10 provides historical transfer duration curves showing small annual differences in grid section transfer demands and energy. The peak flow and energy delivered to the Far North zone by the transmission network is not only dependant on the Far North zone load, but also generation from the hydro generating power stations at Barron Gorge and Kareeya. These vary depending on rainfall levels in the Far North zone. The hydro generating power stations generated at lower levels during peak load conditions in 2017 compared to 2016. Over the full year, the capacity factor of these power stations decreased nearly on par with reductions in delivered energy in the Far North zone resulting in near equal energy transfers between 2016 and 2017 (refer to figures 6.6, 6.7 and 6.8).

Figure 6.10 Historical FNQ grid section transfer duration curves



No network augmentations are planned to occur as a result of network limitations across this grid section within the five-year outlook period.

6.6.2 Central Queensland to North Queensland grid section

Maximum power transfer across the Central Queensland to North Queensland (CQ-NQ) grid section may be set by thermal ratings associated with an outage of a Stanwell to Broadsound 275kV circuit, under certain prevailing ambient conditions. Power transfers may also be constrained by voltage stability limitations associated with the contingency of the Townsville gas turbine or a Stanwell to Broadsound 275kV circuit.

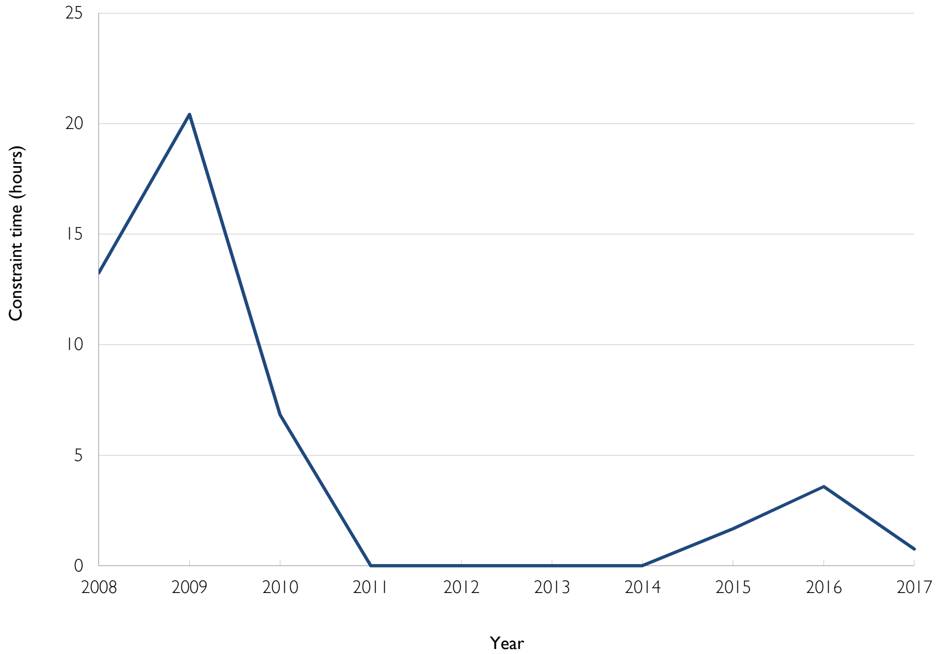
The limit equations in Table D.2 of Appendix D show that the following variables have a significant effect on transfer capability:

- level of Townsville gas turbine generation
- Ross and North zones shunt compensation levels.

Information pertaining to the historical duration of constrained operation for the CQ-NQ grid section is summarised in Figure 6.11. During 2017, the CQ-NQ grid section experienced 0.75 hours of constrained operation. These constraints were associated with planned outages.

[7] For example, the second Woree 275/132kV transformer commissioned in 2007/08.

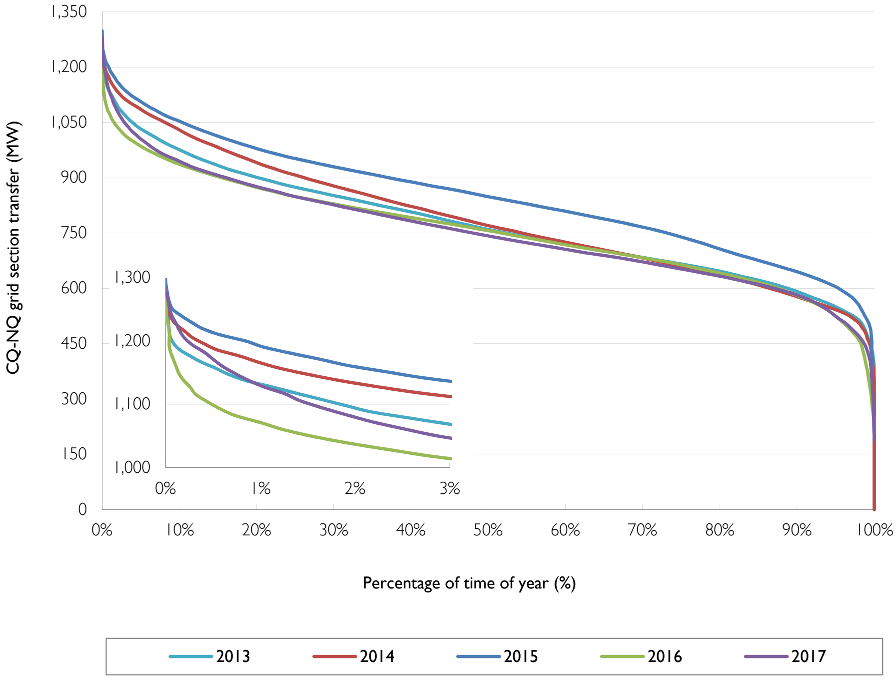
Figure 6.11 Historical CQ-NQ grid section constraint times



Historically, the majority of the constraint times were associated with thermal constraint equations ensuring operation within plant thermal ratings during planned outages. The staged commissioning of double circuit lines from Broadsound to Ross completed in 2010/11 provided increased capacity to this grid section. There have been minimal constraints in this grid section since 2008.

Figure 6.12 provides historical transfer duration curves showing small annual differences in grid section transfer demands and energy. Utilisation of the grid section was approximately equivalent, albeit higher during periods of higher loadings, in 2017 compared to 2016 predominantly due to the lower capacity factor of the generators in Far North and Ross zones balancing the lower delivered energy in the Northern Queensland area (refer to figures 6.6, 6.7 and 6.8).

Figure 6.12 Historical CQ-NQ grid section transfer duration curves



Flooding associated with Tropical Cyclone Debbie caused collapse and damage to 19 towers on one of the paralleled 275kV single circuit lines between Broadsound and Nebo. The transmission line was subsequently returned to service with a large section unparalleled. The system normal capacity of the grid section is not impacted. The damaged towers were rectified in 2017.

The recent commitment of VRE generators (refer to tables 6.1 and 6.2) in north Queensland are expected to reduce CQ-NQ transfers, especially during daylight hours. CQ-NQ transfer duration curves in future years are expected to reflect these new transfer patterns with a downward trend as more energy is supplied locally. The development of large loads in central or northern Queensland (additional to those included in the forecasts), on the other hand, can significantly increase the levels of CQ-NQ transfers. This is discussed in Section 7.2.4.

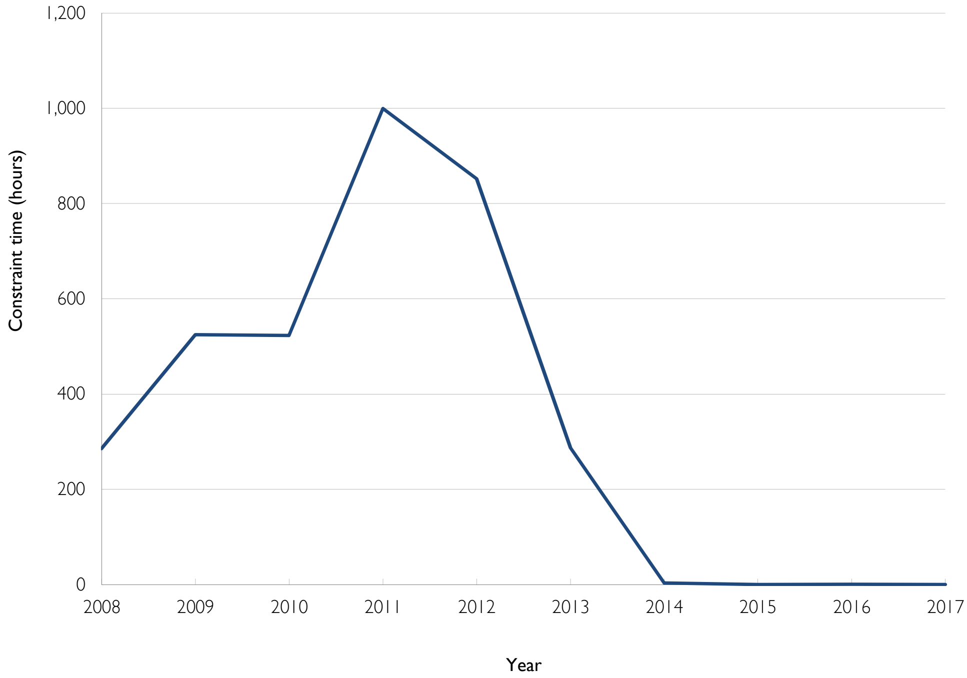
6.6.3 Gladstone grid section

Maximum power transfer across the Gladstone grid section is set by the thermal rating of the Bouldercombe to Raglan, Larcom Creek to Calliope River, Calvale to Wurdong or the Calliope River to Wurdong 275kV circuits, or the Calvale 275/132kV transformer.

If the rating would otherwise be exceeded following a critical contingency, generation is constrained to reduce power transfers. Powerlink makes use of dynamic line ratings and rates the relevant circuits to take account of real time prevailing ambient weather conditions to maximise the available capacity of this grid section and, as a result, reduce market impacts. The appropriate ratings are updated in NEMDE.

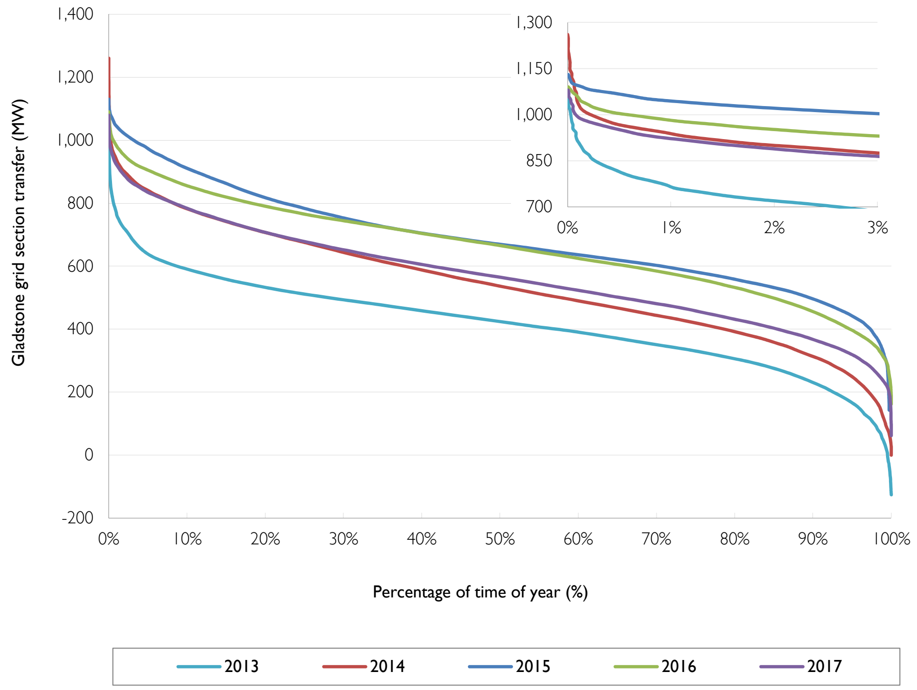
Information pertaining to the historical duration of constrained operation for the Gladstone grid section is summarised in Figure 6.13. During 2017, the Gladstone grid section experienced 0.25 hours of constrained operation.

Figure 6.13 Historical Gladstone grid section constraint times



Power flows across this grid section are highly dependent on the dispatch of generation in Central Queensland and transfers to northern and southern Queensland. Figure 6.14 provides historical transfer duration curves showing a significant decrease in utilisation in 2017 compared to 2016. This reduction in transfer is predominantly associated with a significant increase in net Gladstone zone generation (refer to figures 6.6, 6.7 and 6.8).

Figure 6.14 Historical Gladstone grid section transfer duration curves



The utilisation of the Gladstone grid section is expected to increase if the recently committed generators in the north displace Gladstone zone or southern generators as this incremental power makes its way to the load in the Gladstone and/or southern Queensland zones. A project to increase the design temperature of Bouldercombe to Raglan and Larcom Creek to Calliope River 275kV transmission lines, approved by the AER under the Network Capability Incentive Parameter Action Plan (NCIPAP), will assist in relieving this congestion.

6.6.4 Central Queensland to South Queensland grid section

Maximum power transfer across the CQ-SQ grid section is set by transient or voltage stability following a Calvale to Halys 275kV circuit contingency.

The voltage stability limit is set by insufficient reactive power reserves in the Central West and Gladstone zones following a contingency. More generating units online in these zones increase reactive power support and therefore transfer capability.

The limit equation in Table D.3 of Appendix D shows that the following variables have significant effect on transfer capability:

- number of generating units online in the Central West and Gladstone zones
- level of Gladstone Power Station generation.

The CQ-SQ grid section did not constrain operation during April 2017 to March 2018. Information pertaining to the historical duration of constrained operation for the CQ-SQ grid section is summarised in Figure 6.15.

Figure 6.15 Historical CQ-SQ grid section constraint times

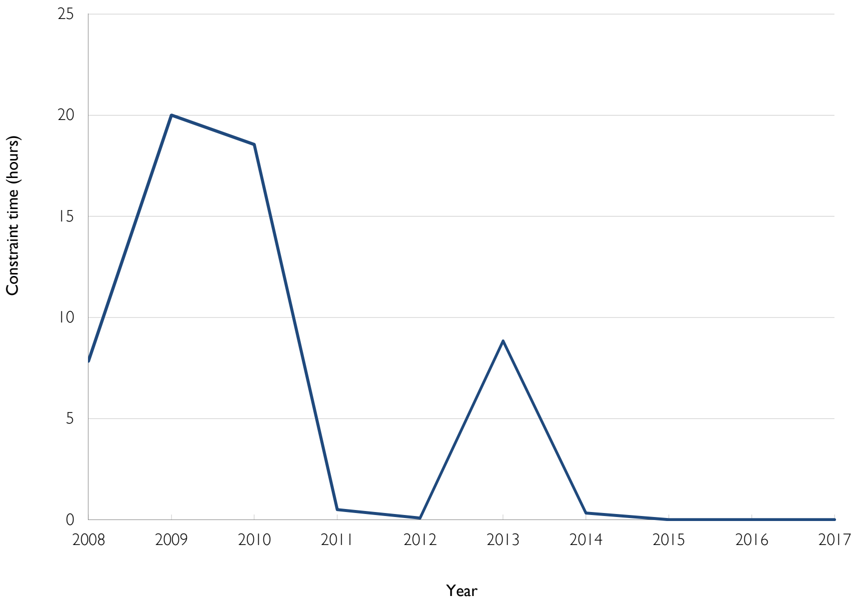
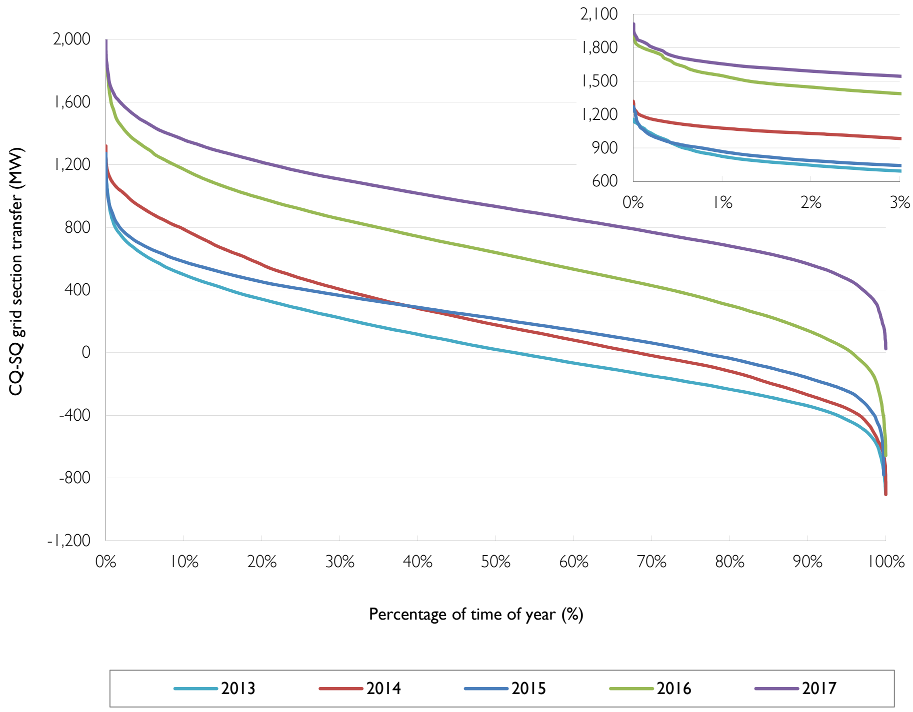


Figure 6.16 provides historical transfer duration curves showing continued increase in utilisation since 2015. This increase in transfer is predominantly due to a significant reduction in generation from the gas fuelled generators in the Bulli zone and higher interconnector transfers sourced predominantly by generation in central and north Queensland (refer to figures 6.6, 6.7 and 6.8). The utilisation of the CQ-SQ grid section is expected to further increase over time if the newly committed generators in the north displace southern generators (refer to Section 5.7.5).

Figure 6.16 Historical CQ-SQ grid section transfer duration curves



The eastern single circuit transmission lines of CQ-SQ traverse a variety of environmental conditions that have resulted in different rates of corrosion resulting in varied risk levels across the transmission lines. Depending on transmission line location, it is expected that sections of lines will be at end of technical service life from the next five to 10 years. This is discussed in Section 5.7.6.

6.6.5 Surat grid section

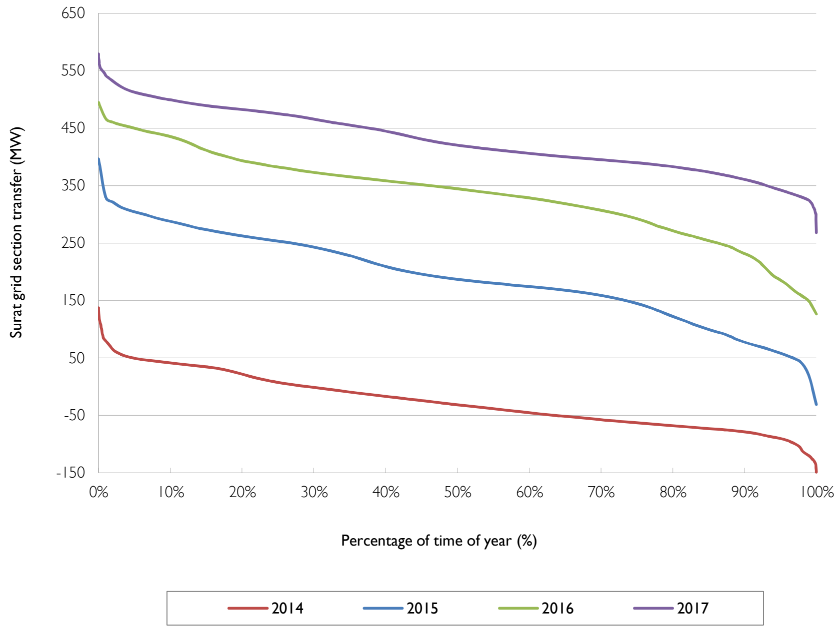
The Surat grid section was introduced in the 2014 TAPR in preparation for the establishment of the Western Downs to Columboola 275kV transmission line[8], Columboola to Wandoan South 275kV transmission line and Wandoan South and Columboola 275kV substations. These network developments were completed in September 2014 and significantly increased the supply capacity to the Surat Basin north west area.

The maximum power transfer across the Surat grid section is set by voltage stability associated with insufficient reactive power reserves in the Surat zone following an outage of a Western Downs to Orana 275kV circuit. More generating units online in the zone increases reactive power support and therefore transfer capability. Local generation reduces transfer capability but allows more demand to be securely supported in the Surat zone. There have been no constraints recorded over the brief history of the Surat grid section.

Figure 6.17 provides the transfer duration curve since the zone's creation. Grid section transfers depict the ramping of coal seam gas (CSG) load. The zone has transformed from a net exporter to a significant net importer of energy.

[8] The Orana Substation is connected to one of the Western Downs to Columboola 275kV transmission lines.

Figure 6.17 Historical Surat grid section transfer duration curve



Network augmentations are not planned to occur as a result of network limitations across this grid section within the five-year outlook period.

The development of large loads in Surat (additional to those included in the forecasts), without corresponding increases in generation, can significantly increase the levels of Surat grid section transfers. This is discussed in Section 7.2.6.

6.6.6 South West Queensland grid section

The South West Queensland (SWQ) grid section defines the capability of the transmission network to transfer power from generating stations located in the Bulli zone and northerly flow on QNI to the rest of Queensland. The grid section is not expected to impose limitations to power transfer under intact system conditions with existing levels of generating capacity.

The SWQ grid section did not constrain operation during April 2017 to March 2018. Information pertaining to the historical duration of constrained operation for the SWQ grid section is summarised in Figure 6.18.

Figure 6.18 Historical SWQ grid section constraint times

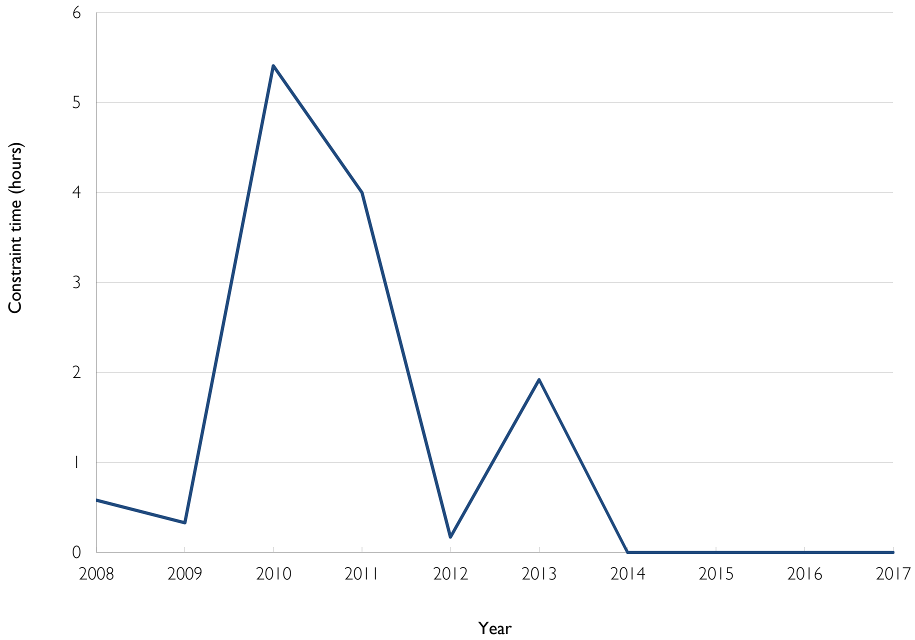
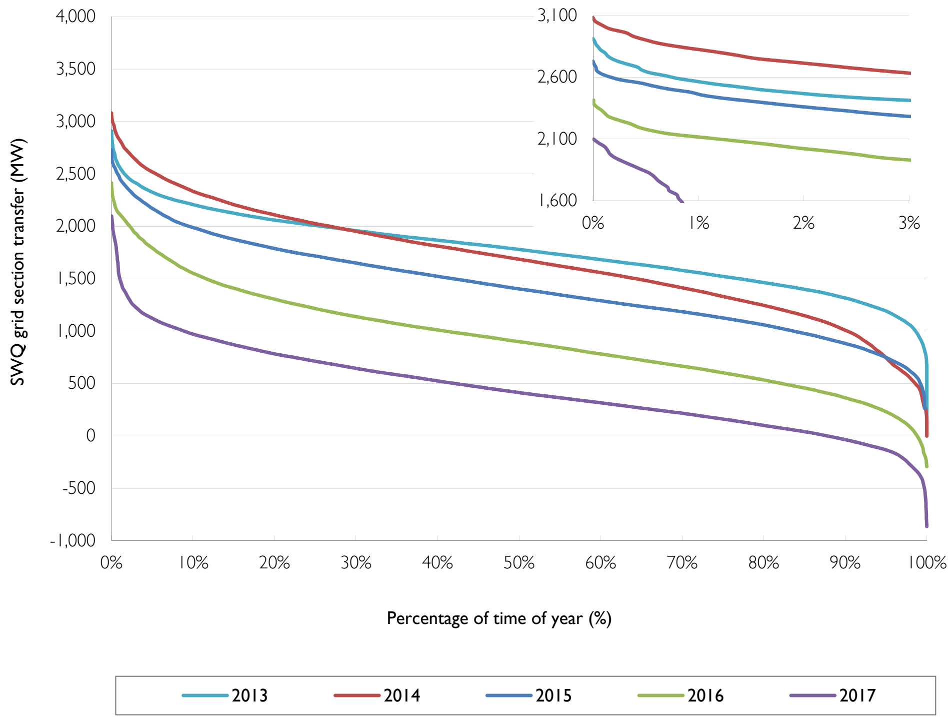


Figure 6.19 provides historical transfer duration curves showing a continued reduction in energy transfer since 2015. Increases in QNI southerly flows, reductions in gas fuelled generation in the Bulli zone, increases in SW zone generation and CQ-SQ transfers (refer to figures 6.6, 6.7 and 6.8) are predominantly responsible for the reduction in SWQ utilisation.

Figure 6.19 Historical SWQ grid section transfer duration curves



Network augmentations are not planned to occur as a result of network limitations across this grid section within the five-year outlook period.

6.6.7 Tarong grid section

Maximum power transfer across the Tarong grid section is set by voltage stability associated with the loss of a Calvale to Halys 275kV circuit. The limitation arises from insufficient reactive power reserves in southern Queensland.

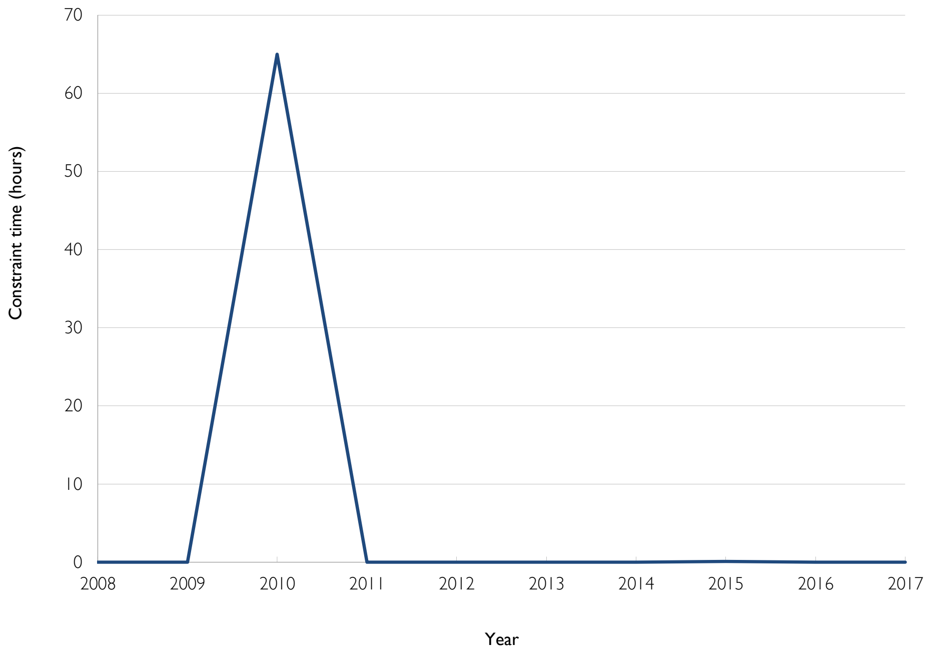
Limit equations in Table D.4 of Appendix D show that the following variables have a significant effect on transfer capability:

- QNI transfer and South West and Bulli zones generation
- level of Moreton zone generation
- Moreton and Gold Coast zones capacitive compensation levels.

Any increase in generation west of this grid section, with a corresponding reduction in generation north of the grid section, reduces the CQ-SQ power flow and increases the Tarong limit. Increasing generation east of the grid section reduces the transfer capability, but increases the overall amount of supportable South East Queensland (SEQ) demand. This is because reactive margins increase with additional local generation, allowing further load to be delivered before reaching minimum allowable reactive margins. However, due to its distributed and reactive nature, increases in delivered demand erode reactive margins at greater rates than they were created by the additional local generation. Limiting power transfers are thereby lower with the increased local generation but a greater load can be delivered.

The Tarong grid section did not constrain during April 2017 to March 2018. Information pertaining to the historical duration of constrained operation for the Tarong grid section is summarised in Figure 6.20.

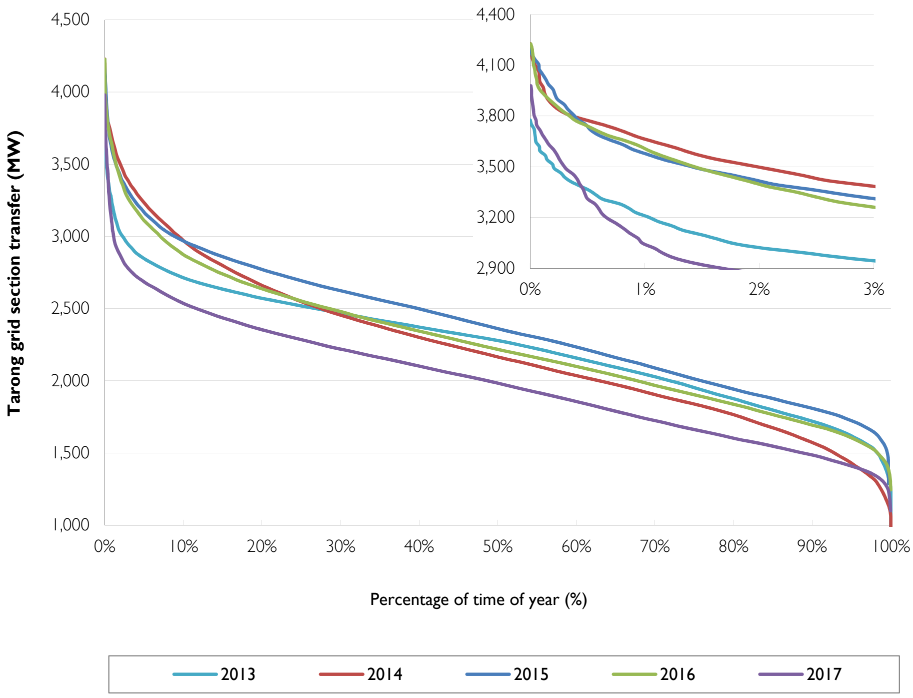
Figure 6.20 Historical Tarong grid section constraint times



Constraint times have been minimal over the last 10 years, with the exception of 2010/11, where constraint times are associated with line outages as a result of severe weather events in January 2011.

Figure 6.21 provides historical transfer duration curves showing small annual differences in grid section transfer demands. The increase in transfer between 2014 and 2015 is predominantly attributed to Swanbank E being removed from service in December 2014. Swanbank E was brought back into service in December 2017. The 2017 trace reflects lower delivered south east Queensland demands as a result of overall mild conditions, Swanbank E generation and greater transfers from CQ generators (refer to figures 6.6, 6.7 and 6.8).

Figure 6.21 Historical Tarong grid section transfer duration curves



Network augmentations are not planned to occur as a result of network limitations across this grid section within the five-year outlook period.

6.6.8 Gold Coast grid section

Maximum power transfer across the Gold Coast grid section is set by voltage stability associated with the loss of a Greenbank to Molendinar 275kV circuit, or Greenbank to Mudgeeraba 275kV circuit.

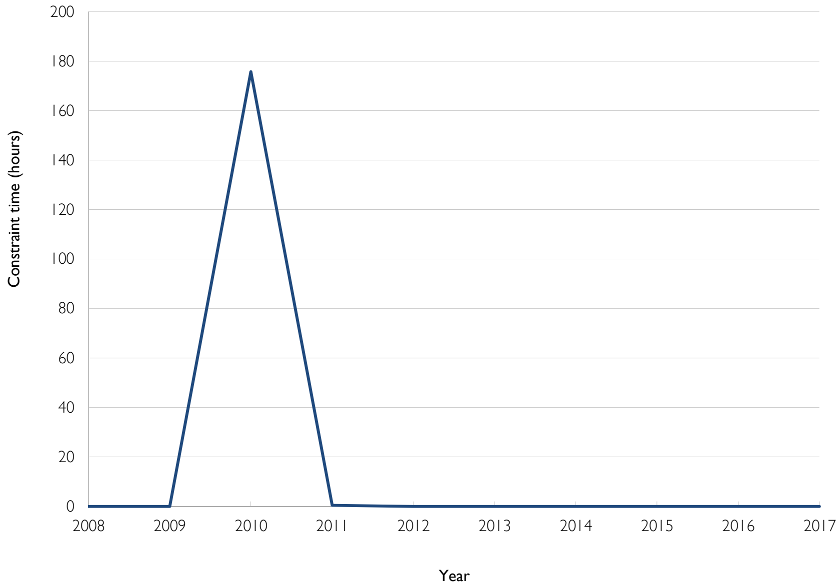
The limit equation in Table D.5 of Appendix D shows that the following variables have a significant effect on transfer capability:

- number of generating units online in Moreton zone
- level of Terranora Interconnector transmission line transfer
- Moreton and Gold Coast zones capacitive compensation levels
- Moreton zone to the Gold Coast zone demand ratio.

Reducing southerly flow on Terranora Interconnector reduces transfer capability, but increases the overall amount of supportable Gold Coast demand. This is because reactive margins increase with reductions in southerly Terranora Interconnector flow, allowing further load to be delivered before reaching minimum allowable reactive margins. However, due to its distributed and reactive nature, increases in delivered demand erode reactive margins at greater rates than they were created by the reduction in Terranora Interconnector southerly transfer. Limiting power transfers are thereby lower with reduced Terranora Interconnector southerly transfer but a greater load can be delivered.

The Gold Coast grid section did not constrain operation during April 2017 to March 2018. Information pertaining to the historical duration of constrained operation for the Gold Coast grid section is summarised in Figure 6.22.

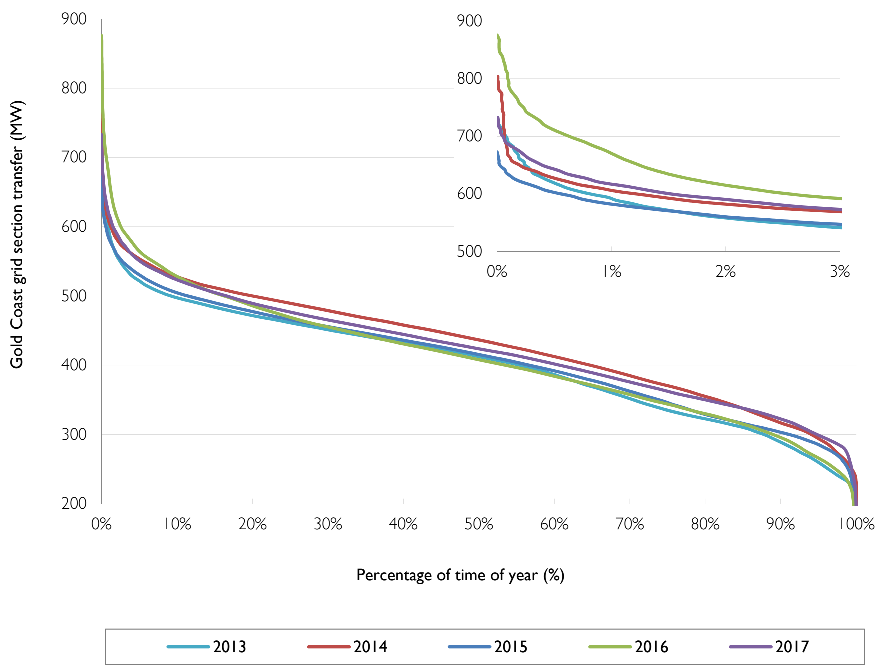
Figure 6.22 Historical Gold Coast grid section constraint times



Constraint times have been minimal since 2007, with the exception of 2010 where constraint times are associated with the planned outage of one of the 275kV Greenbank to Mudgeeraba feeders.

Figure 6.23 provides historical transfer duration curves showing changes in grid section transfer demands and energy in line with changes in transfer to northern New South Wales (NSW) and changes in Gold Coast loads. Gold Coast zone demand was lower in 2017 compared to 2016 (refer to figures 6.6, 6.7 and 6.8).

Figure 6.23 Historical Gold Coast grid section transfer duration curves



The condition of two 275/110kV transformers at Mudgeeraba Substation requires action within the five-year outlook. One of the transformers was replaced in 2017. This is discussed in Section 5.7.10.

6.6.9 QNI and Terranora Interconnector

The transfer capability across QNI is limited by voltage stability, transient stability, oscillatory stability, and line thermal rating considerations. The capability across QNI at any particular time is dependent on a number of factors, including demand levels, generation dispatch, status and availability of transmission equipment, and operating conditions of the network.

AEMO publish an annual NEM Constraint Report which includes a chapter examining each of the NEM interconnectors, including QNI and Terranora Interconnector. Information pertaining to the historical duration of constrained operation for QNI and Terranora Interconnector is contained in these Annual NEM Constraint Reports. The NEM Constraint Report can be found on AEMO's website.

For intact system operation, the southerly transfer capability of QNI is most likely to be set by the following:

- transient stability associated with transmission faults near the Queensland border
- transient stability associated with the trip of a smelter potline load in Queensland
- transient stability associated with transmission faults in the Hunter Valley in NSW
- transient stability associated with a fault on the Hazelwood to South Morang 500kV transmission line in Victoria
- thermal capacity of the 330kV transmission network between Armidale and Liddell in NSW
- oscillatory stability upper limit of 1,200MW.

For intact system operation, the combined northerly transfer capability of QNI and Terranora Interconnector is most likely to be set by the following:

- transient and voltage stability associated with transmission line faults in NSW
- transient stability and voltage stability associated with loss of the largest generating unit in Queensland
- thermal capacity of the 330kV and 132kV transmission network within northern NSW
- oscillatory stability upper limit of 700MW.

AEMO's 2016 National Transmission Network Development Plan (NTNDP) indicated net positive market benefits in increasing the capability of QNI from 2026/27. The ISP Consultation Paper[9] recommended that Powerlink and TransGrid initiate a RIT-T to increase interconnector capacity between and reduce the likelihood of reserve deficit in either region. Powerlink and TransGrid are currently in preparation to undertake this RIT-T. This is discussed further in Section 5.7.12.

6.7 Zone performance

This section presents, where applicable, a summary of:

- the capability of the transmission network to deliver 2017 loads
- historical zonal transmission delivered loads
- intra-zonal system normal constraints
- double circuit transmission lines categorised as vulnerable by AEMO
- Powerlink's management of high voltages associated with light load conditions.

[9] AEMO, Integrated System Plan Consultation, December 2017.

Double circuit transmission lines that experience a lightning trip of all phases of both circuits are categorised by AEMO as vulnerable. A double circuit transmission line in the vulnerable list is eligible to be reclassified as a credible contingency event during a lightning storm if a cloud to ground lightning strike is detected close to the line. A double circuit transmission line will remain on the vulnerable list until it is demonstrated that the asset characteristics have been improved to make the likelihood of a double circuit lightning trip no longer reasonably likely to occur or until the Lightning Trip Time Window (LTTW) expires from the last double circuit lightning trip. The LTTW is three years for a single double circuit trip event or five years where multiple double circuit trip events have occurred during the LTTW.

Zonal transmission delivered energy, in general, has been lower in 2017 compared to 2016. This is predominantly due to mild winter conditions in 2017 (refer to Section 2.4). Additionally, Queensland continues to lead Australia in the capacity of installed rooftop photovoltaic (PV), reaching 2,000MW in February 2018.

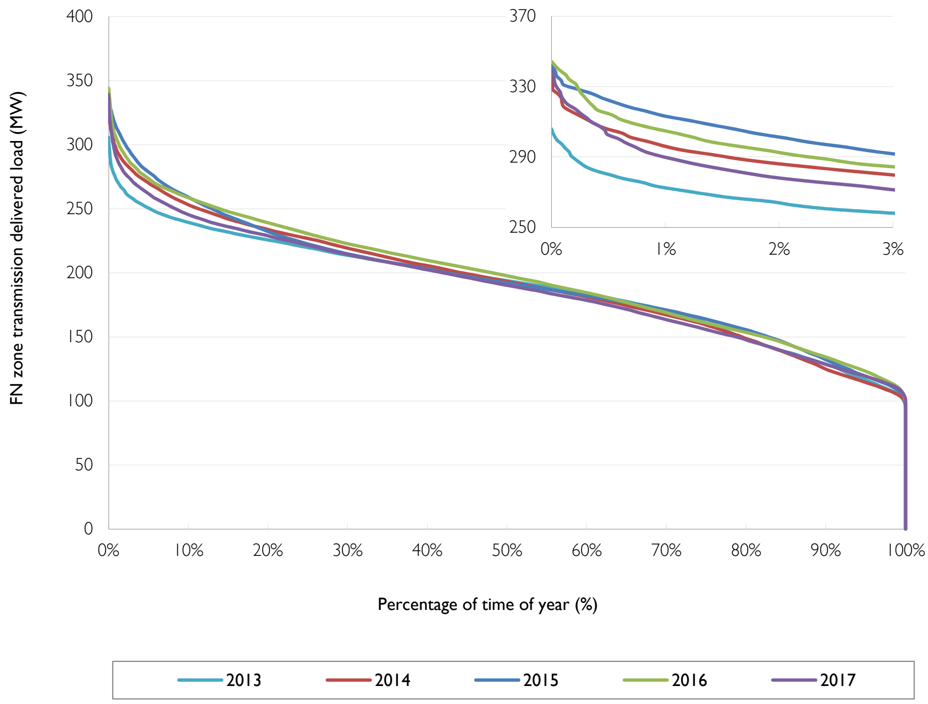
6.7.1 Far North zone

The Far North zone experienced no load loss for a single network element outage during 2017.

The Far North zone includes the-scheduled embedded generator Lakeland Solar and Storage as defined in Figure 2.4. This embedded generator provided approximately 5GWh during 2017.

Figure 6.24 provides historical transmission delivered load duration curves for the Far North zone. Energy delivered from the transmission network has reduced by 3.9% between 2016 and 2017. The maximum transmission delivered demand in the zone was 339MW, which is below the highest maximum demand over the last five years of 344MW set in 2016.

Figure 6.24 Historical Far North zone transmission delivered load duration curves



As a result of double circuit outages associated with lightning strikes, AEMO has included Chalumbin to Turkinje 132kV in the vulnerable list. This double circuit tripped due to lightning in January 2016.

High voltages associated with light load conditions are managed with existing reactive sources. The need for voltage control devices increased with the reinforcements of the Strathmore to Ross 275kV double circuit transmission line and the replacement of the coastal 132kV transmission lines between Yabulu South and Woree substations. Powerlink relocated a 275kV reactor from Braemar to Chalumbin Substation in April 2013. Generation developments in the Braemar area resulted in underutilisation of the reactor, making it possible to redeploy. No additional reactive sources are required in the Far North zone within the five-year outlook period for the control of high voltages.

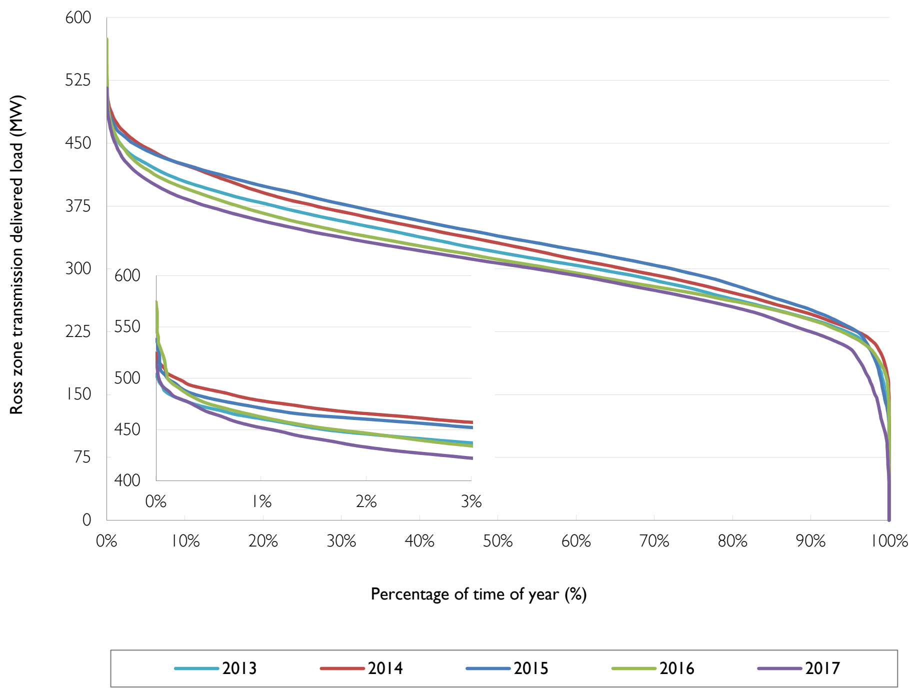
6.7.2 Ross zone

The Ross zone experienced no load loss for a single network element outage during 2017.

The Ross zone includes the scheduled embedded Townsville Power Station 66kV component, semi-scheduled embedded Kidston Solar Farm and the significant non-scheduled embedded generator at Pioneer Mill as defined in Figure 2.4. These embedded generators provided approximately 278GWh during 2017.

Figure 6.25 provides historical transmission delivered load duration curves for the Ross zone. Energy delivered from the transmission network has reduced by 3.0% between 2016 and 2017. The peak transmission delivered demand in the zone was 516MW which is below the highest maximum demand over the last five years of 574MW set in 2016.

Figure 6.25 Historical Ross zone transmission delivered load duration curves



As a result of double circuit outages associated with lightning strikes, AEMO has included the Ross to Chalumbin 275kV double circuit transmission line in the vulnerable list. This double circuit tripped due to lightning in January 2015.

High voltages associated with light load conditions are managed with existing reactive sources. Two tertiary connected reactors at Ross Substation were replaced by a bus reactor in August 2015.

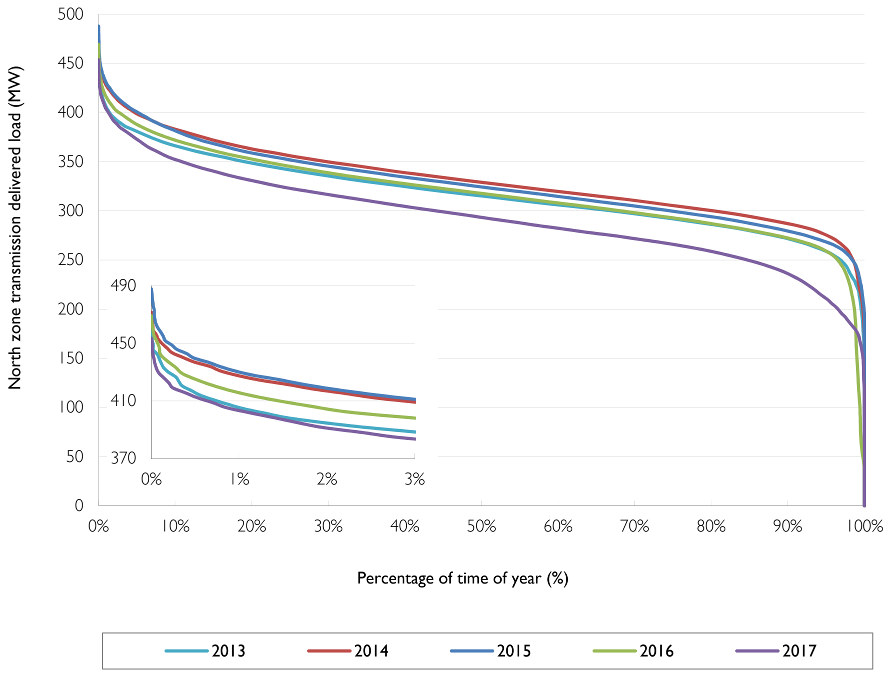
6.7.3 North zone

The North zone experienced no load loss for a single network element outage during 2017.

The North zone includes the scheduled embedded Mackay generator and significant non-scheduled embedded generators Moranbah North, Moranbah and Racecourse Mill as defined in Figure 2.4. These embedded generators provided approximately 638GWh during 2017.

Figure 6.26 provides historical transmission delivered load duration curves for the North zone. Energy delivered from the transmission network has reduced by 7.7% between 2016 and 2017. The peak transmission delivered demand in the zone was 454MW, which is below the highest maximum demand over the last five years of 488MW set in 2015.

Figure 6.26 Historical North zone transmission delivered load duration curves



As a result of double circuit outages associated with lightning strikes, AEMO includes the following double circuits in the North zone in the vulnerable list:

- Collinsville North to Proserpine 132kV double circuit transmission line, last tripped February 2018
- Collinsville North to Stony Creek and Collinsville North to Newlands 132kV double circuit transmission line, last tripped February 2016
- Goonyella to North Goonyella and Goonyella to Newlands 132kV double circuit transmission line, last tripped February 2018
- Moranbah to Goonyella Riverside 132kV double circuit transmission line, last tripped December 2014.

High voltages associated with light load conditions are managed with existing reactive sources. A Braemar 275kV reactor was relocated to replace two transformer tertiary connected reactors decommissioned due to condition at Nebo Substation in August 2013. Generation developments in the Braemar area resulted in underutilisation of the reactor, making it possible to redeploy. No additional reactive sources are required in the North zone within the five-year outlook period for the control of high voltages.

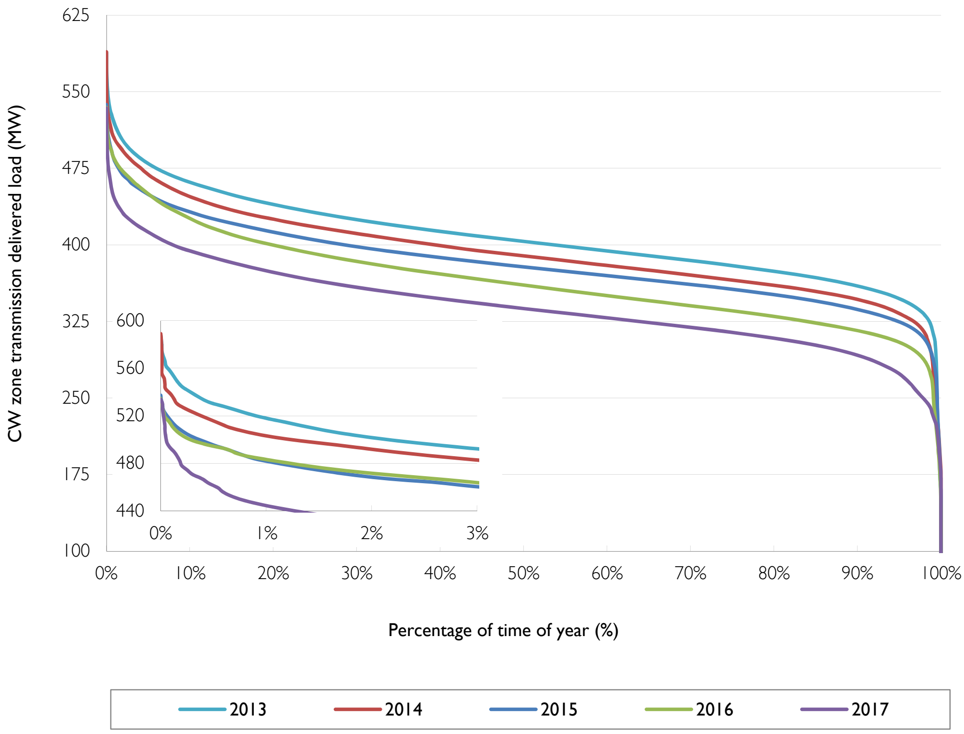
6.7.4 Central West zone

The Central West zone experienced no load loss for a single network element outage during 2017.

The Central West zone includes the scheduled embedded Barcaldine generator and significant non-scheduled embedded generators Barcaldine Solar Farm, German Creek and Oaky Creek as defined in Figure 2.4. These embedded generators provided approximately 461GWh during 2017.

Figure 6.27 provides historical transmission delivered load duration curves for the Central West zone. Energy delivered from the transmission network has reduced by 6.9% between 2016 and 2017. The peak transmission delivered demand in the zone was 534MW, which is below the highest maximum demand over the last five years of 589MW set in 2014.

Figure 6.27 Historical Central West zone transmission delivered load duration curves



As a result of double circuit outages associated with lightning strikes, AEMO includes the Bouldercombe to Rockhampton and Bouldercombe to Egans Hill 132kV double circuit transmission line in the vulnerable list. This double circuit tripped due to lightning in February 2016.

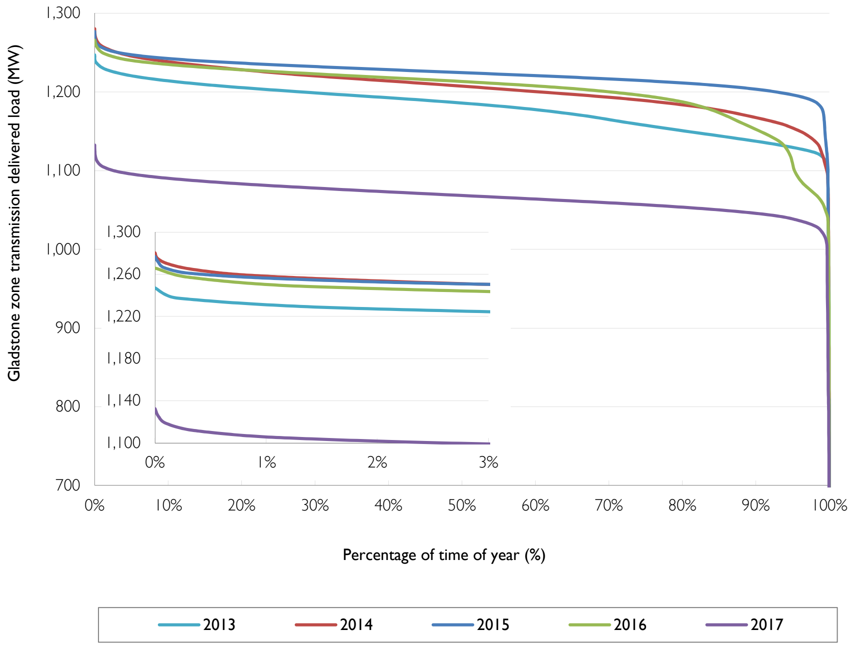
6.7.5 Gladstone zone

The Gladstone zone experienced no load loss for a single network element outage during 2017.

The Gladstone zone contains no scheduled, semi-scheduled or significant non-scheduled embedded generators as defined in Figure 2.4.

Figure 6.28 provides historical transmission delivered load duration curves for the Gladstone zone. Energy delivered from the transmission network has reduced by 11.2% between 2016 and 2017 predominantly due reductions to production of aluminium by BSL. The peak transmission delivered demand in the zone was 1,133MW, which is below the highest maximum demand over the last five years of 1,280MW set in 2014.

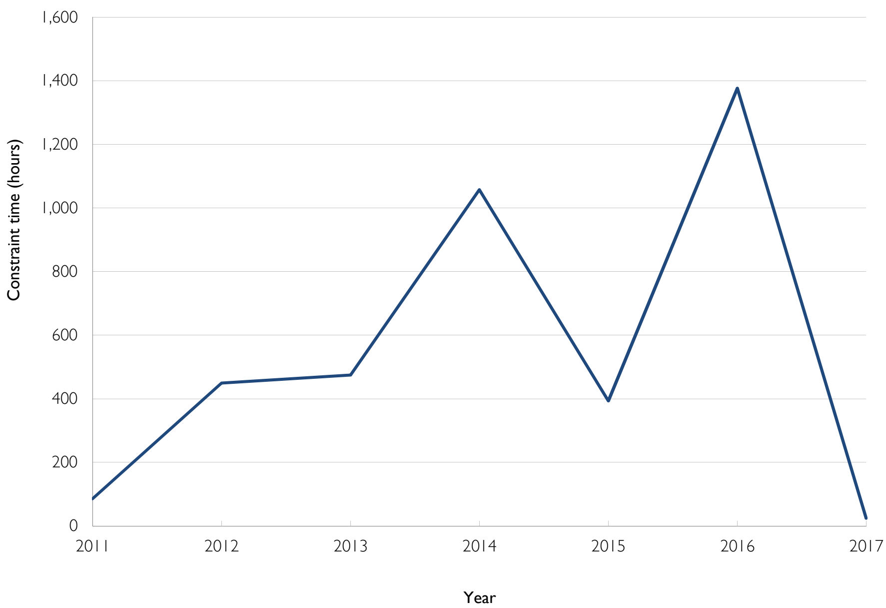
Figure 6.28 Historical Gladstone zone transmission delivered load duration curves



Constraints occur within the Gladstone zone under intact network conditions. These constraints are associated with maintaining power flows within the continuous current rating of a 132kV feeder bushing within BSL's substation. The constraint limits generation from Gladstone Power Station, mainly from the units connected at 132kV. AEMO identifies this constraint by constraint identifier Q>NIL_BI_FB. This constraint was implemented in AEMO's market system from September 2011.

Information pertaining to the historical duration of constrained operation due to this constraint is summarised in Figure 6.29. The trend prior to 2017 was reflective of the operation of the two 132kV connected Gladstone Power Station units. Although, Gladstone 132kV units ran at highest capacity factors in the last decade, due to the BSL's reduced production the constraint only bound 25 hours during 2017.

Figure 6.29 Historical Q>NIL_BI_FB constraint times



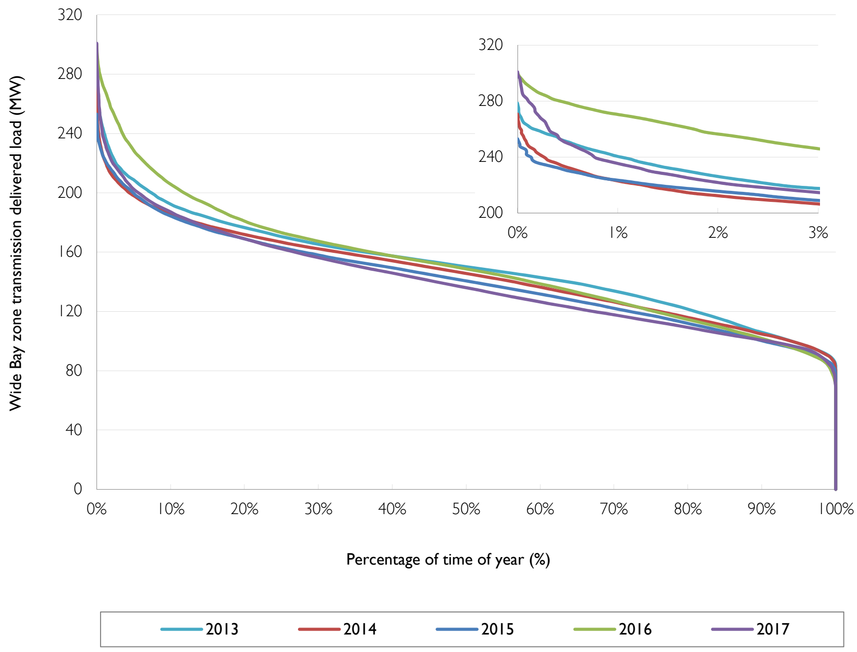
6.7.6 Wide Bay zone

The Wide Bay zone experienced no load loss for a single network element outage during 2017.

The Wide Bay zone includes the non-scheduled embedded Isis Central Sugar Mill and Sunshine Coast Solar Farm as defined in Figure 2.4. These embedded generators provided approximately 38GWh during 2017.

Figure 6.30 provides historical transmission delivered load duration curves for the Wide Bay zone. Energy delivered from the transmission network reduced by 7.2% between 2016 and 2017 predominantly due to summer 2016/17 being hot and long lasting (refer to Section 2.1). The peak transmission delivered demand in the zone was 301MW, which is the highest maximum demand over the last five years.

Figure 6.30 Historical Wide Bay zone transmission delivered load duration curves



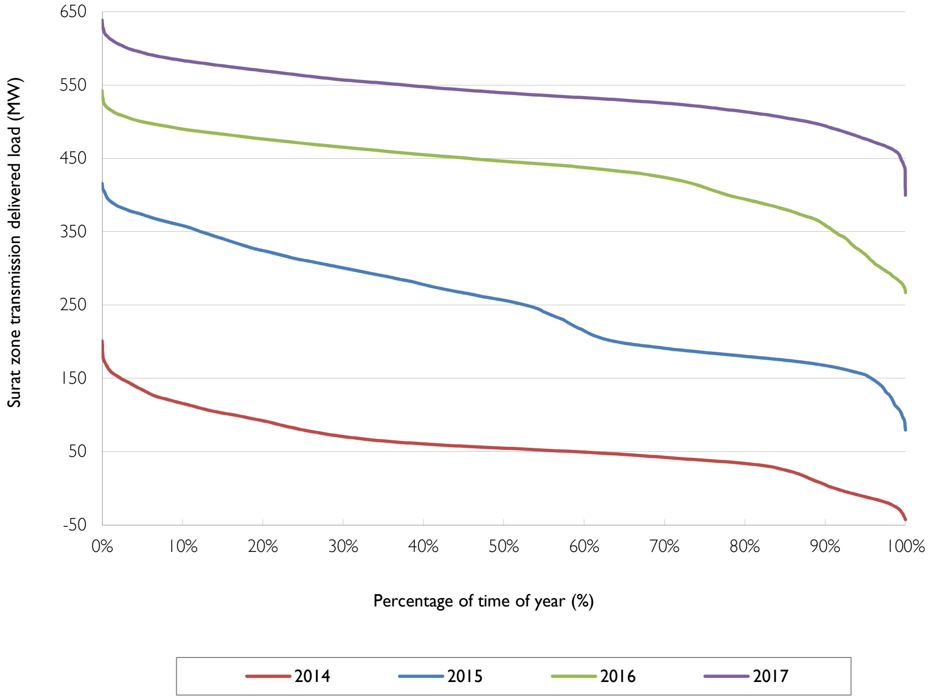
6.7.7 Surat zone

The Surat zone experienced no load loss for a single network element outage during 2017.

The Surat zone includes the scheduled embedded Roma generator as defined in Figure 2.4. This embedded generator provided approximately 24GWh during 2017.

The Surat zone was introduced in the 2014 TAPR, Figure 6.31 provides transmission delivered load duration curve since its introduction. The curves reflect the ramping of CSG load in the zone.

Figure 6.31 Historical Surat zone transmission delivered load duration curves



As a result of double circuit outages associated with lightning strikes, AEMO includes the following double circuits in the Surat zone in the vulnerable list:

- Chinchilla to Columboola 132kV double circuit transmission line, last tripped October 2015
- Tarong to Chinchilla 132kV double circuit transmission line, last tripped February 2018.

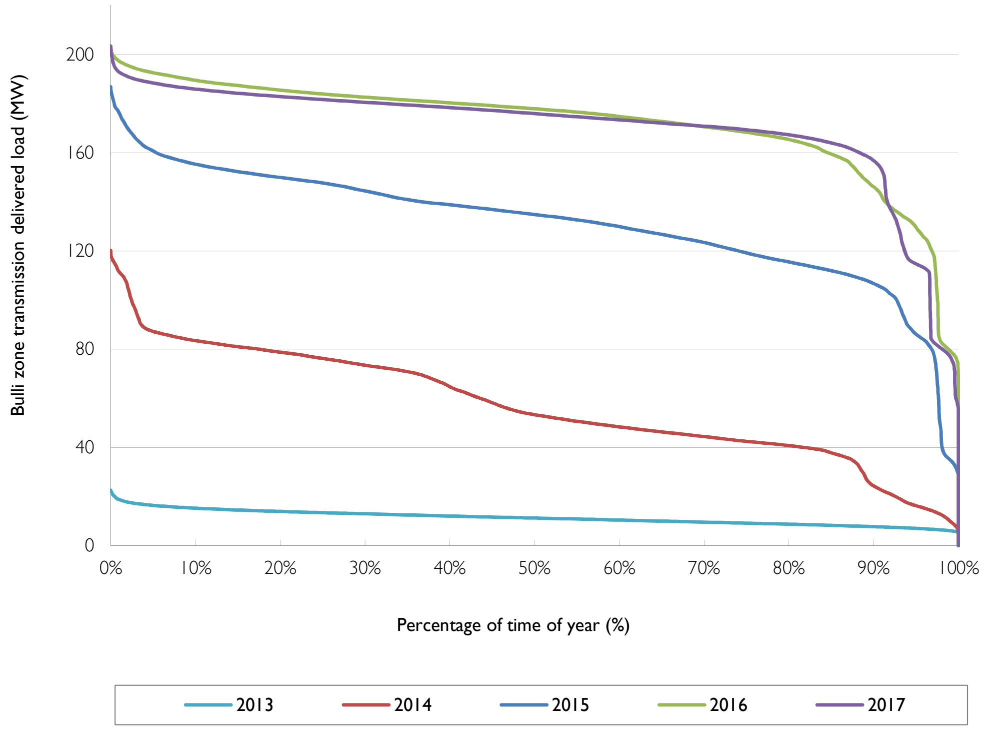
6.7.8 Bulli zone

The Bulli zone experienced no load loss for a single network element outage during 2017.

The Bulli zone contains no scheduled, semi-scheduled or significant non-scheduled embedded generators as defined in Figure 2.4.

Figure 6.32 provides historical transmission delivered load duration curves for the Bulli zone. Energy delivered from the transmission network has reduced by approximately 1.0% between 2016 and 2017. The peak transmission delivered demand in the zone was 204MW. The CSG load in the zone has now reached expected demand levels.

Figure 6.32 Historical Bulli zone transmission delivered load duration curves



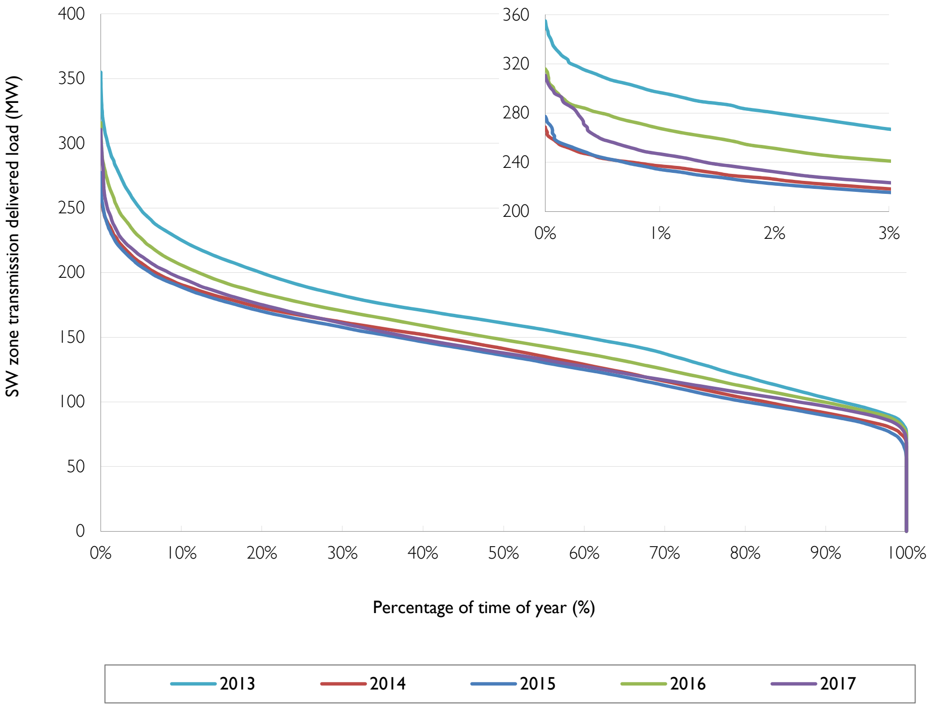
6.7.9 South West zone

The South West zone experienced no load loss for a single network element outage during 2017.

The South West zone includes the significant non-scheduled embedded Daandine Power Station as defined in Figure 2.4. This embedded generator provided approximately 246GWh during 2017.

Figure 6.33 provides historical transmission delivered load duration curves for the South West zone. Energy delivered from the transmission network has reduced by 5.7% between 2016 and 2017. The peak transmission delivered demand in the zone was 311MW.

Figure 6.33 Historical South West zone transmission delivered load duration curves

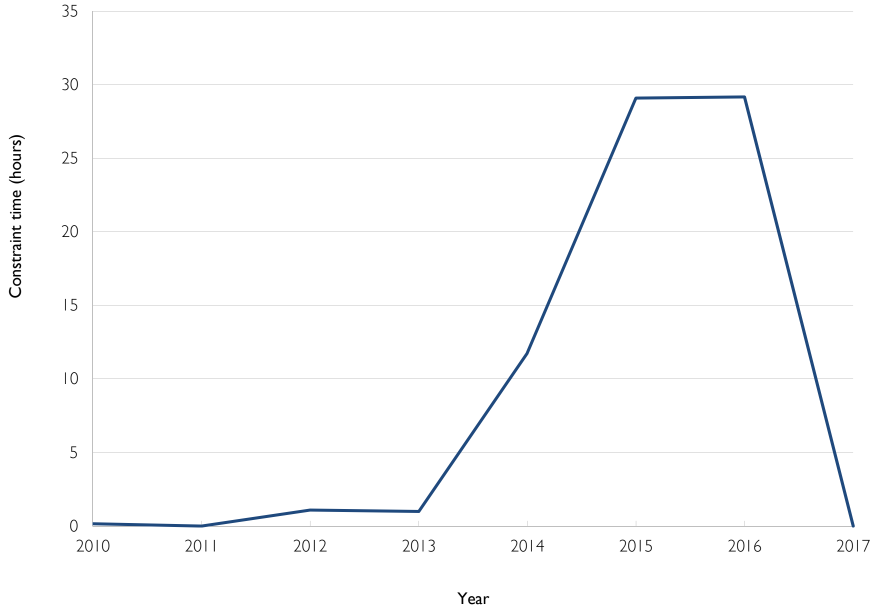


Constraints occur within the South West zone under intact network conditions. These constraints are associated with maintaining power flows of the 110kV transmission lines between Tangkam and Middle Ridge substations within the feeder's thermal ratings at times of high Oakey Power Station generation. Powerlink maximises the allowable generation from Oakey Power Station by applying dynamic line ratings to take account of real time prevailing ambient weather conditions. AEMO identifies these constraints with identifiers Q>NIL_MRTA_A and Q>NIL_MRTA_B. These constraints were implemented in AEMO's market system from April 2010. No constraints were recorded against this constraint in 2017. Oakey's production reduced significantly over 2017, in line with other gas fired generators in South West Queensland.

Energy Infrastructure Investments (EII) has advised AEMO of its intention to retire Daandine Power Station in June 2022.

Information pertaining to the historical duration of constrained operation due to these constraints is summarised in Figure 6.34.

Figure 6.34 Historical Q>NIL_MRTA_A and Q>NIL_MRTA_B constraint times



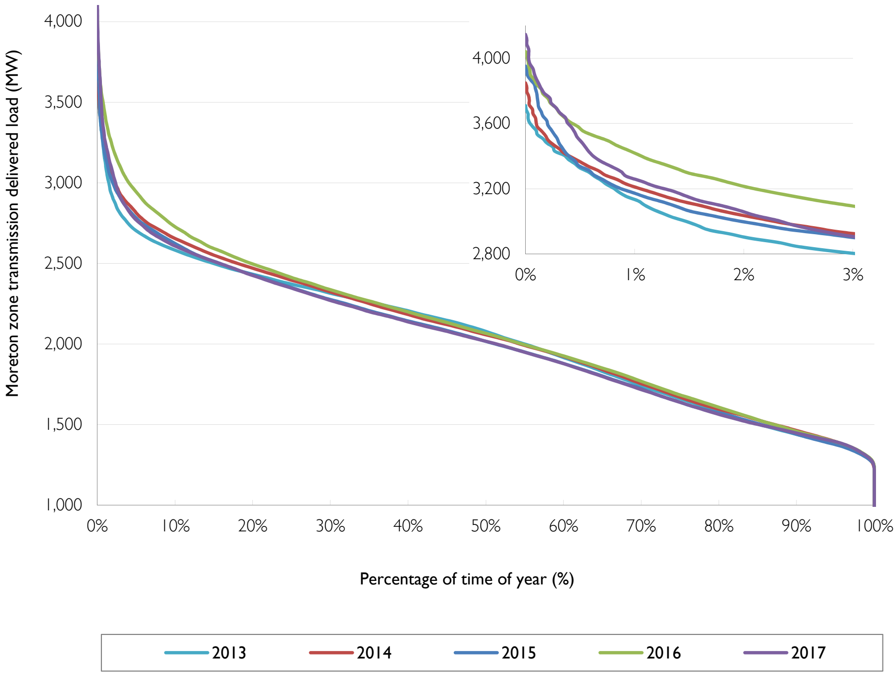
6.7.10 Moreton zone

The Moreton zone experienced no load loss for a single network element outage during 2017.

The Moreton zone includes the significant non-scheduled embedded generators Bromelton and Rocky Point as defined in Figure 2.4. These embedded generators provided approximately 56GWh during 2017.

Figure 6.35 provides historical transmission delivered load duration curves for the Moreton zone. Energy delivered from the transmission network has reduced by 2.9% between 2016 and 2017. The peak transmission delivered demand in the zone was 4,145MW, which is the highest ever maximum demand for the zone.

Figure 6.35 Historical Moreton zone transmission delivered load duration curves



High voltages associated with light load conditions are managed with existing reactive sources. Powerlink and AEMO have an agreed procedure to manage voltage controlling equipment in SEQ. The agreed procedure uses voltage control of dynamic reactive plant in conjunction with Energy Management System (EMS) online tools prior to resorting to network switching operations. No additional reactive sources are forecast in the Moreton zone within the five-year outlook period for the control of high voltages.

6.7.11 Gold Coast zone

The Gold Coast zone experienced no load loss for a single network element outage during 2017.

The Gold Coast zone contains no scheduled, semi-scheduled or significant non-scheduled embedded generators as defined in Figure 2.4.

Figure 6.36 provides historical transmission delivered load duration curves for the Gold Coast zone. Energy delivered from the transmission network has reduced by 3.2% between 2016 and 2017. The peak transmission delivered demand in the zone was 718MW which is below the highest maximum demand over the last five years of 727MW, set in 2016.

Figure 6.36 Historical Gold Coast zone transmission delivered load duration curves