CHAPTER 6

Network capability and performance

6 Network capability and performance

Key highlights

- During 2018/19, Powerlink has completed the connection of 11 large-scale solar and wind farm projects, adding 1,423MW of semi-scheduled variable renewable energy (VRE) generation capacity to the grid.
- Generation commitments since the 2018 Transmission Annual Planning Report (TAPR) add 64MW to Queensland's semi-scheduled VRE generation capacity taking the total existing and committed VRE generation capacity to 2,457MW.
- The Central Queensland to Southern Queensland (CQ-SQ) grid section was highly utilised during 2018/19, reflecting higher generation levels in North Queensland (NQ) as a result of recently commissioned VRE generators.
- Committed generation is expected to continue to alter power transfers, particularly during daylight hours, increasing the likelihood of congestion across the Gladstone, CQ-SQ and Queensland/New South Wales (NSW) Interconnector (QNI) grid sections.
- Record peak transmission delivered demands were recorded in the Far North, South West, Moreton and Gold Coast zones, during 2018/19.
- The transmission network has performed reliably during 2018/19, 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
- 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 vary substantially due to output of VRE generation and 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.

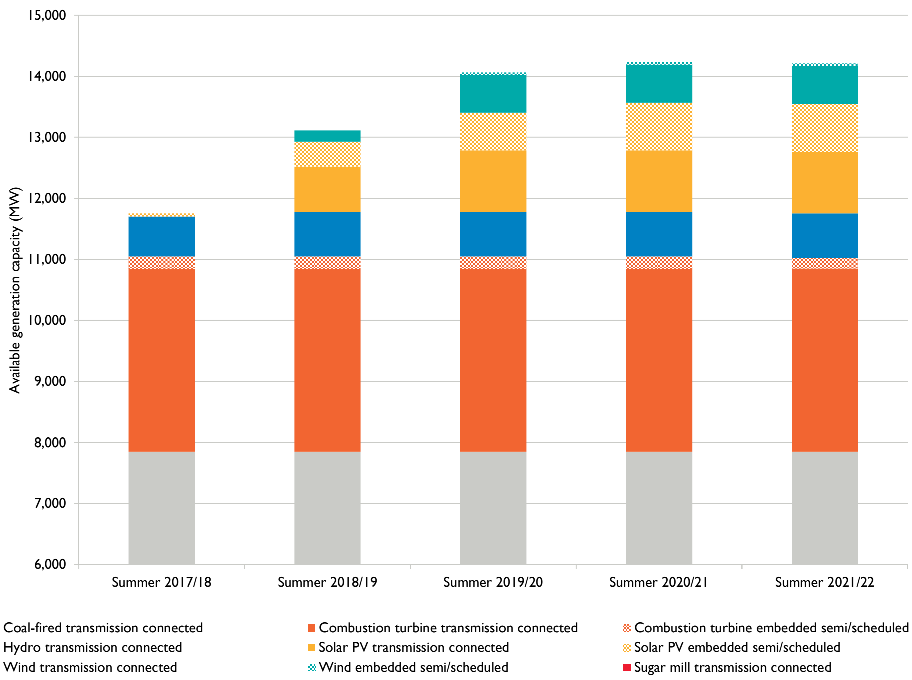
The years referenced in this chapter correspond to the period from April to March of the following year, capturing a full winter and summer period.

6.2 Available generation capacity

Scheduled generation in Queensland is predominantly a combination of coal-fired, gas turbine and hydro-electric generators. In addition during 2018/19, Powerlink has completed connection of 11 large-scale solar and wind farm projects, adding 1,423MW of semi-scheduled VRE generation capacity to the grid.

AEMO's definition of 'committed' from the System Strength Impact Assessment Guidelines[1] (effective 1 July 2018) has been adopted for the purposes of this year's TAPR. During 2018/19, commitments have added 64MW of capacity, taking Queensland's semi-scheduled VRE generation capacity to 2,457MW. Figure 6.1 illustrates the expected changes to available and committed generation capacity in Queensland from summer 2017/18 to summer 2021/22.

Figure 6.1 Summer available generation capacity by energy source



6.2.1 Existing and committed transmission connected and direct connect embedded 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) or connected to direct connect customers.

Semi-scheduled transmission connected solar farms Ross River, Haughton, Whitsunday, Hamilton, Daydream, Hayman, Rugby Run, Lilyvale and Darling Downs in addition to Coopers Gap and Mt Emerald wind farms have been connected since the 2018 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. 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.

1 AEMO, System Strength Impact Assessment Guidelines, June 2018.

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

Generator	Location	Available generation capacity (MW) (1) Winter 2019	Summer 2019/20	Winter 2020	Summer 2020/21	Winter 2021	Summer 2021/22
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	750	713	750	713	750	713
Millmerran	Millmerran PS Switchyard	852	612	852	6120	852	612
Total coal-fired		**8,125**	**7,848**	**8,125**	**7,848**	**8,125**	**7,848**
Combustion turbine							
Townsville 132kV	Townsville GT PS	161	149	159	149	159	149
Mt Stuart	Townsville South	428	400	428	400	428	400
Yarwun (2)	Yarwun	160	155	160	155	160	155
Condamine (3)	Columboola	100	90	100	90	100	90
Braemar 1	Braemar	530	491	530	491	530	501
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	350	365	350	365	350
Total combustion turbine		**3,242**	**2,992**	**3,240**	**2,992**	**3,240**	**3,002**
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 2019	Summer 2019/20	Winter 2020	Summer 2020/21	Winter 2021	Summer 2021/22
Total solar PV (7)							
Ross River	Ross	116	116	116	116	116	116
Sun Metals (3)	Townsville Zinc	107	107	107	107	107	107
Haughton	Haughton River	100	100	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	150
Hayman	Strathmore	50	50	50	50	50	50
Rugby Run	Moranbah	65	65	65	65	65	65
Lilyvale	Lilyvale	100	100	100	100	100	100
Darling Downs	Braemar	108	108	108	108	108	108
Total solar		**1,010**	**1,010**	**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	440	440
Total wind		**620**	**620**	**620**	**620**	**620**	**620**
Sugar mill							
Invicta (5)	Invicta Mill	34	0	34	0	34	0
Total all stations		**13,760**	**13,199**	**13,758**	**13,199**	**13,758**	**13,209**

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

(3) Condamine and Sun Metals are direct connected embedded generators.

(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. Sun Metals and Clare solar farms are fully operational. Other VRE generators may not be at full capacity at the time of publication of the 2019 TAPR.

6.2.2 Existing and committed scheduled and semi-scheduled distribution connected 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.

Semi-scheduled embedded solar farms Collinsville, Clermont, Emerald, Susan River, Childers and Oakey 1 have been connected since the 2018 TAPR.

Semi-scheduled embedded solar farm Warwick has reached committed status since the 2018 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 2019	Summer 2019/20	Winter 2020	Summer 2020/21	Winter 2021	Summer 2021/22
Combustion turbine (1)							
Townsville 66kV	Townsville GT PS	84	84	84	84	84	84
Mackay (2)	Mackay	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**	**172**
Total solar PV (3)							
Cape York	Cape York switching station		48	48	48	48	48
Kidston	Kidston	50	50	50	50	50	50
Kennedy Energy Park	Hughenden	15	15	15	15	15	15
Collinsville	Collinsville North	42	42	42	42	42	42
Clermont	Clermont	75	75	75	75	75	75
Emerald	Emerald	72	72	72	72	72	72
Aramara	Aramara			104	104	104	104
Susan River	Maryborough	75	75	75	75	75	75
Childers	Isis	56	56	56	56	56	56
Yarranlea	Yarranlea	103	103	103	103	103	103
Oakey 1	Oakey	25	25	25	25	25	25
Oakey 2	Oakey	55	55	55	55	55	55
Warwick	Warwick			32	64	64	64
Total solar		**568**	**616**	**720**	**784**	**784**	**784**
Wind (3)							
Kennedy Energy Park	Hughenden	43	43	43	43	43	43
Total all stations		**834**	**865**	**986**	**1,033**	**1,050**	**999**

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[2] (PSFRR) in 2018. The PSFRR, as part of the Emergency Frequency Control Schemes rule change[3], 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 2018 PSFRR Final Report in June 2018. For Queensland, the recommendation involved the expansion of Powerlink's CQ-SQ Special Protection Scheme (SPS). The existing 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 in north and central Queensland. 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.

Powerlink has initiated discussions with AEMO to modify the scope of the scheme. During expected periods of high VRE generation in north and central Queensland, the disconnection of large synchronous generators would be a destabilising action. Powerlink has commenced a project to investigate an alternative SPS that provides the intended CQ-SQ power transfer coverage and considers subsequent system strength issues following the potential non-credible loss of both Calvale to Halys 275kV feeders. Scope and timeframes will be discussed with AEMO to ensure the delivery of an appropriate scheme.

The 2018 PSFRR also identifies a potential need to establish a coordinated Over Frequency Generation Shedding (OFGS) scheme. AEMO and Powerlink have completed the joint study which considered the risk of major supply disruptions which could lead to an over frequency event. The study concluded that the measures recommended in AEMO's Final Report on the 25 August 2018 Islanding Event[4], which are proposed to be completed by mid-2020, would mitigate the current risk of over-frequency, if implemented. The need for an OFGS will also need to be reviewed as part of the QNI upgrade.

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.

[2] AEMO, 2018 Power System Frequency Risk Review, June 2018.
[3] AEMC, Rule Determination National Electricity Amendment (Emergency frequency control schemes) Rule 2017, 30 March 2017.
[4] AEMO, Final Report – Queensland and South Australia system separation on 25 August 2018, January 2019.

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
Mudgeeraba Emergency Control Scheme (ECS)	Minimise risk of voltage collapse in the Gold Coast zone

6.4 Existing network configuration

Figures 6.2, 6.3, 6.4 and 6.5 illustrate Powerlink's network as of June 2019.

6 Network capability and performance

Figure 6.2 Existing HV network June 2019 - North Queensland

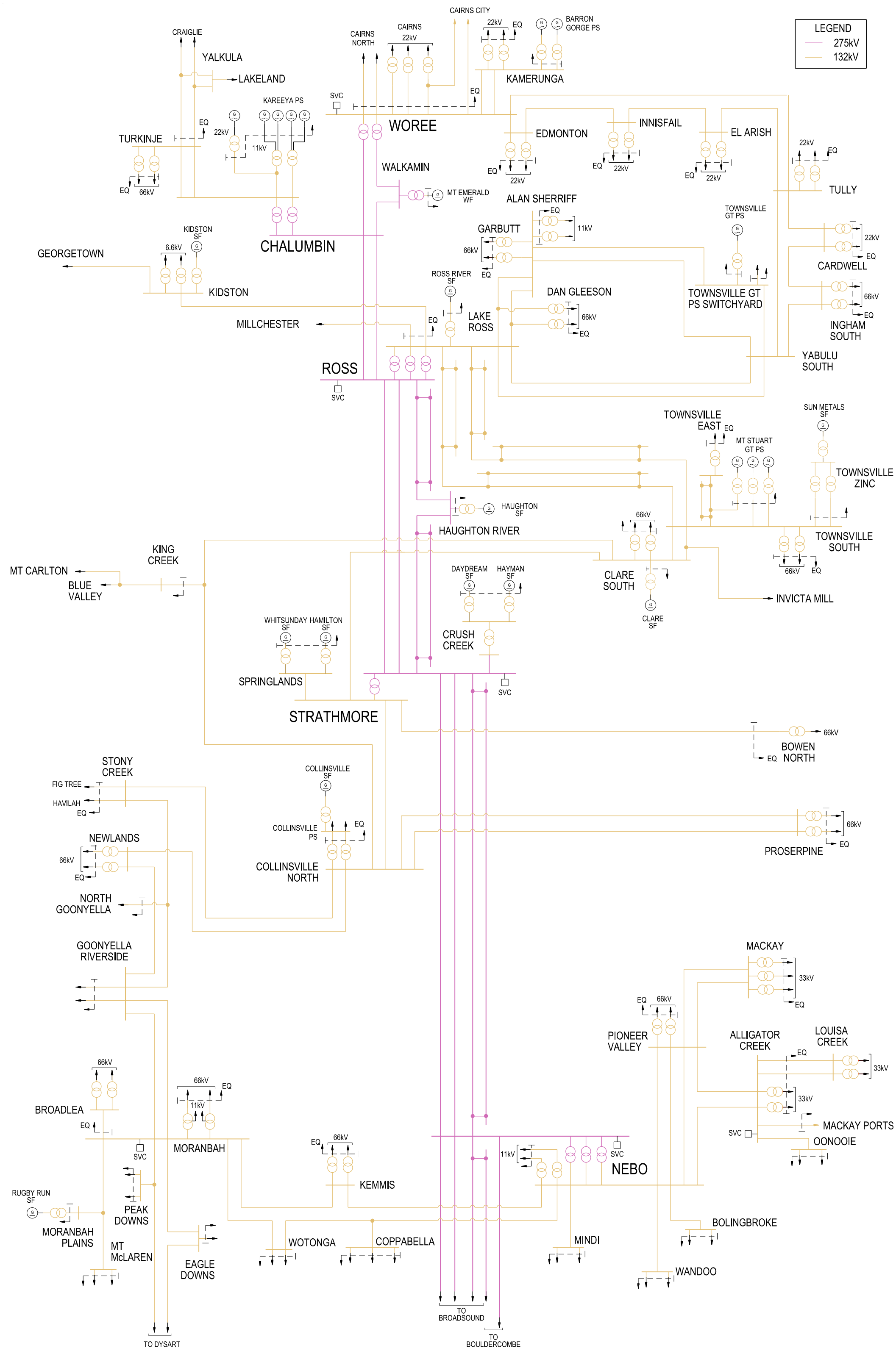


Figure 6.3 Existing HV network June 2019 - Central Queensland

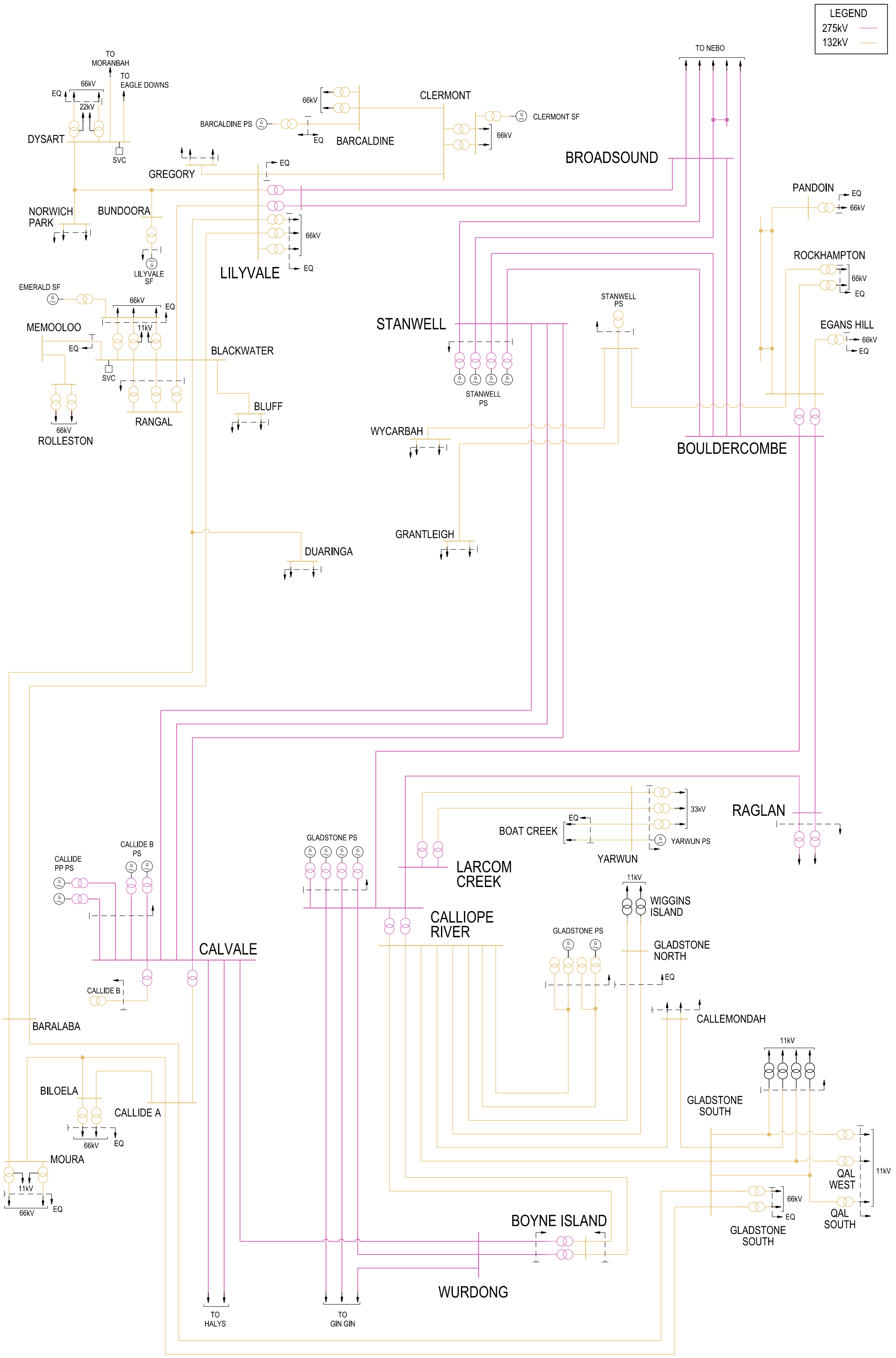


Figure 6.4 Existing HV network June 2019 - South West Queensland

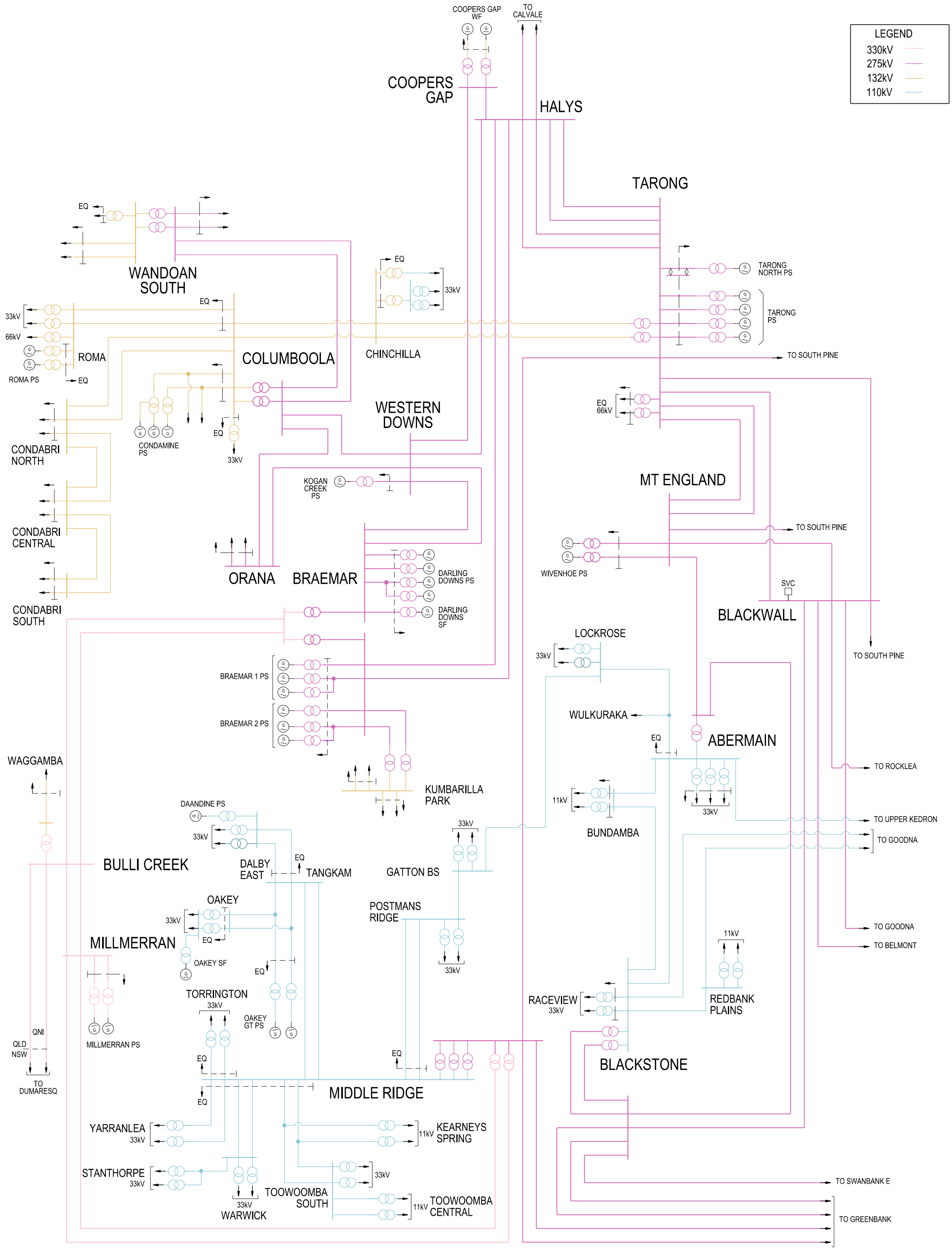
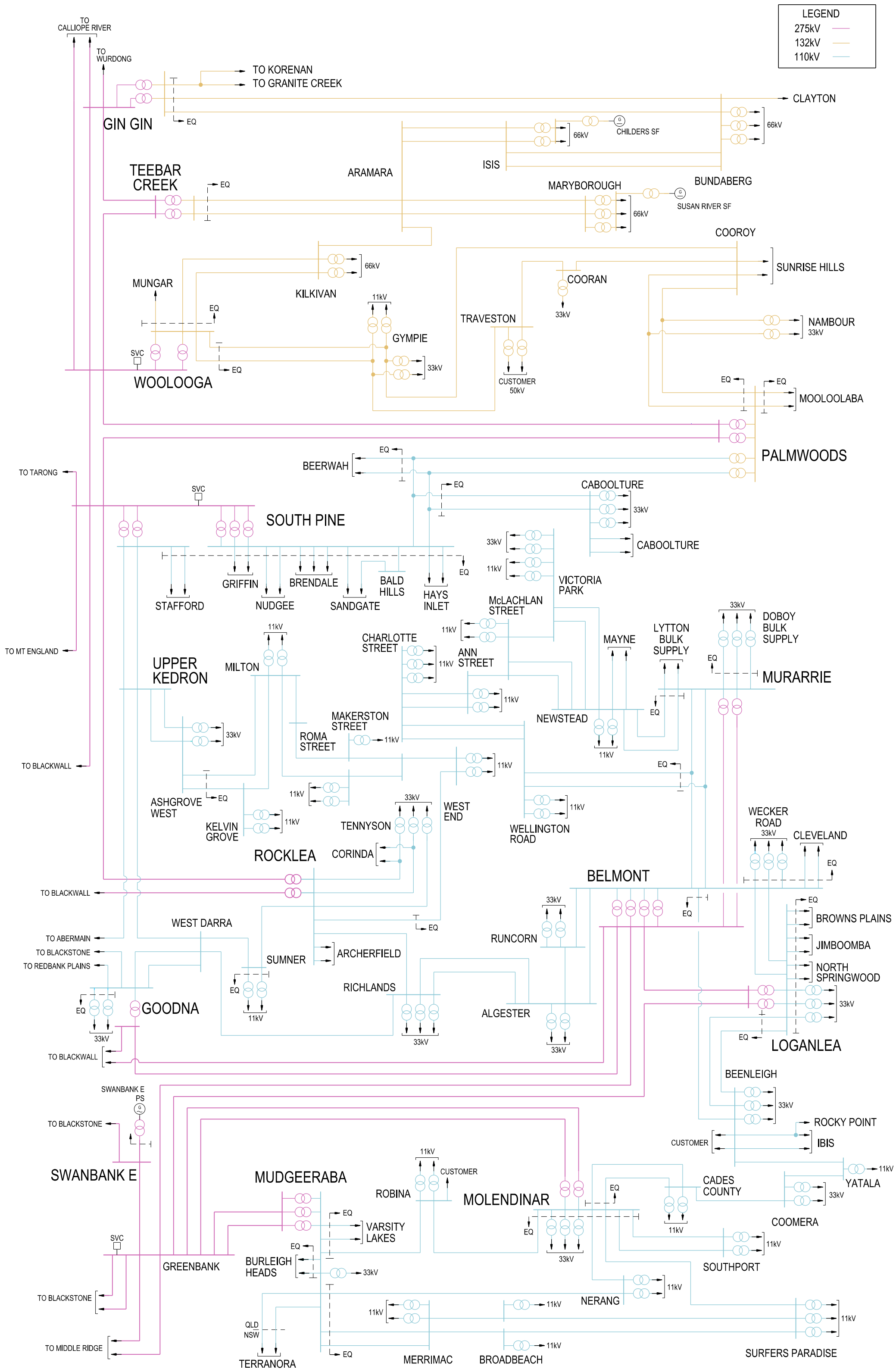


Figure 6.5 Existing HV network June 2019 - South East Queensland



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), Table C.2 provides definitions and 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 National Electricity Market (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

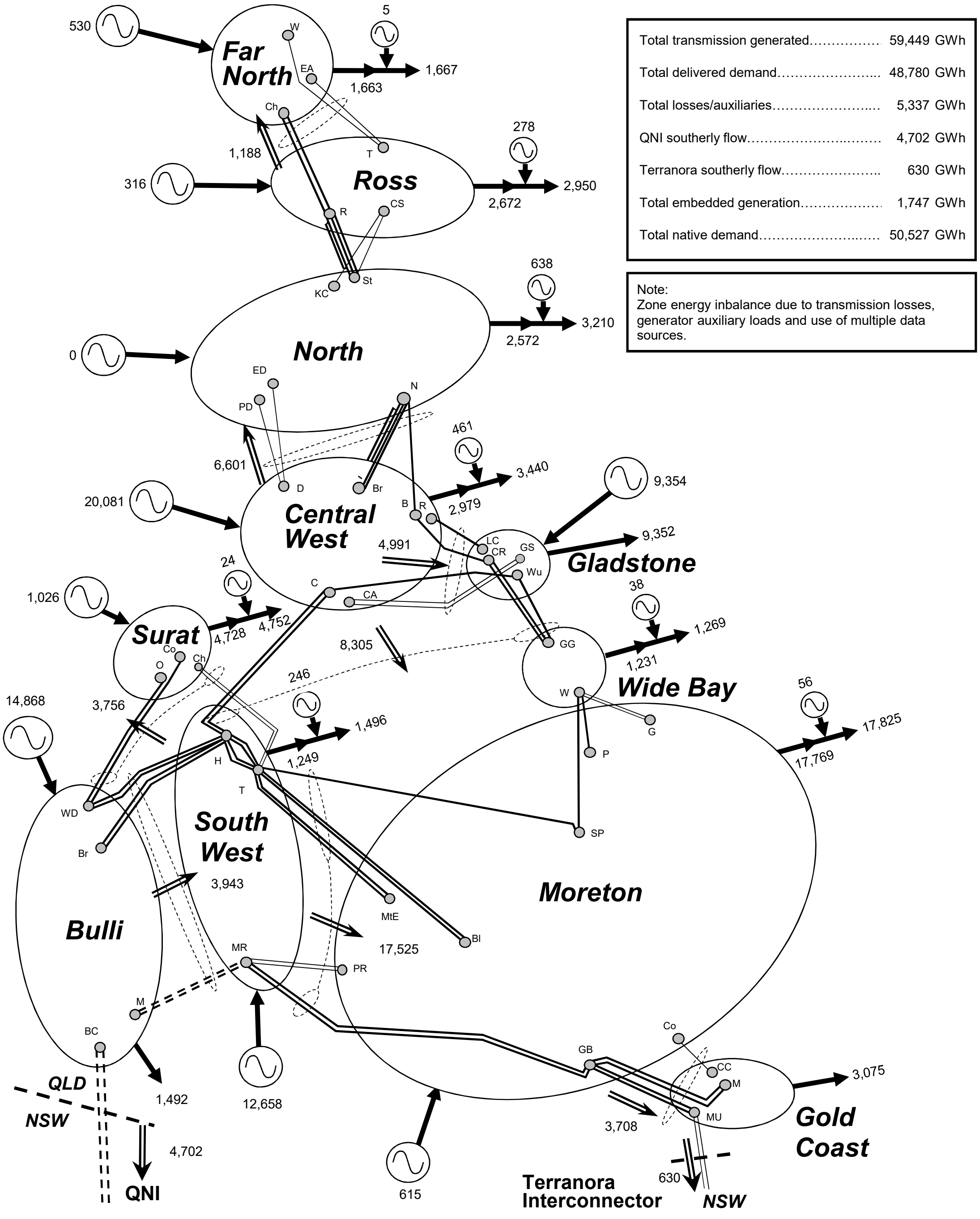
This section is a qualitative summary of system conditions with major effects on transfer capability across key grid sections of the Queensland network.

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.

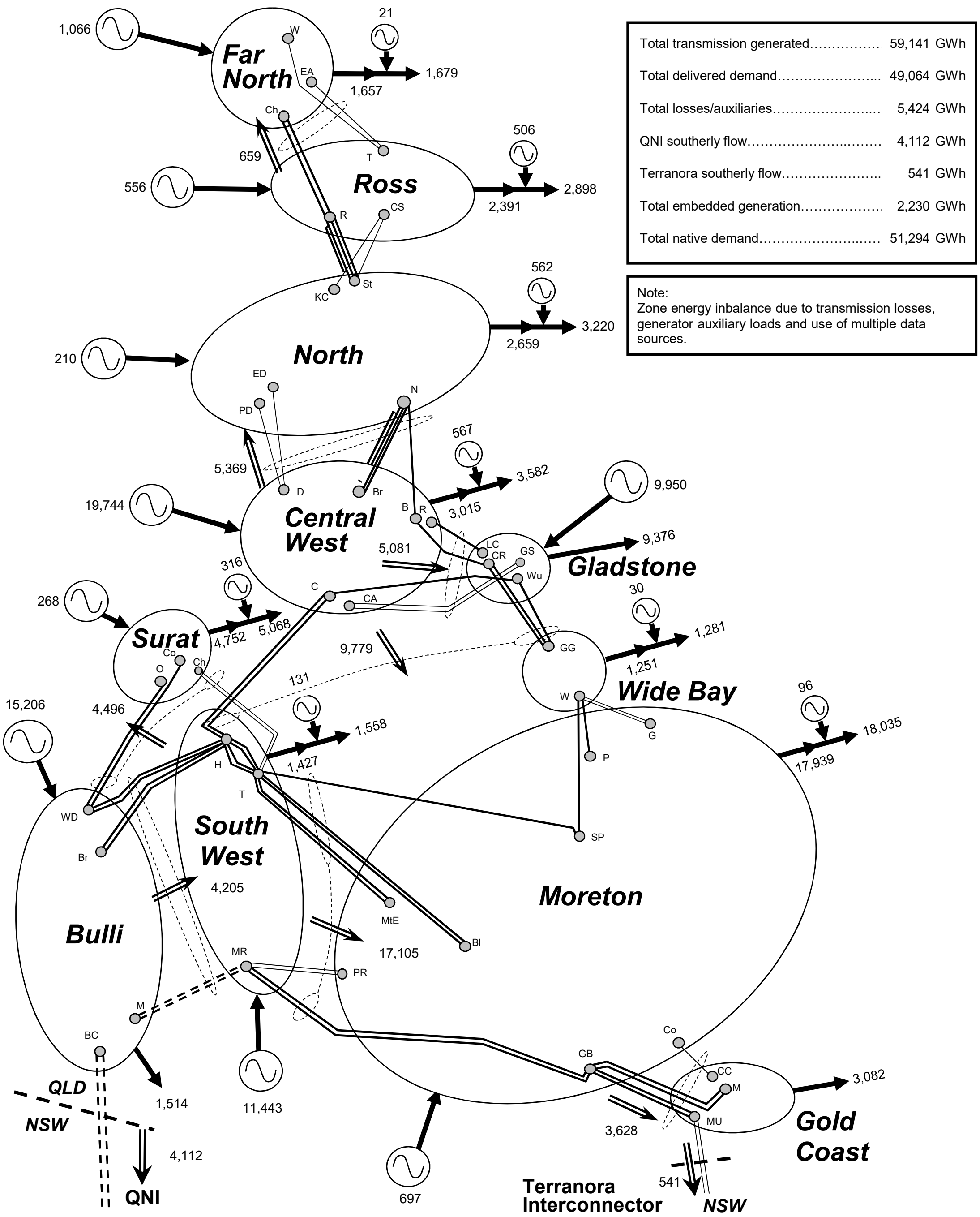
Historical transfer duration curves for the last five years are included for each grid section. Grid section transfers are predominantly affected by load, generation and transfers to neighbouring zones. Figures 6.6 and 6.7 provide 2017 and 2018 zonal energy as generated into the transmission network (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 2017 to 2018. These figures assist in the explanation of differences between 2017 and 2018 grid section transfer duration curves.

Figure 6.6 2017[5] zonal electrical energy transfers (GWh)



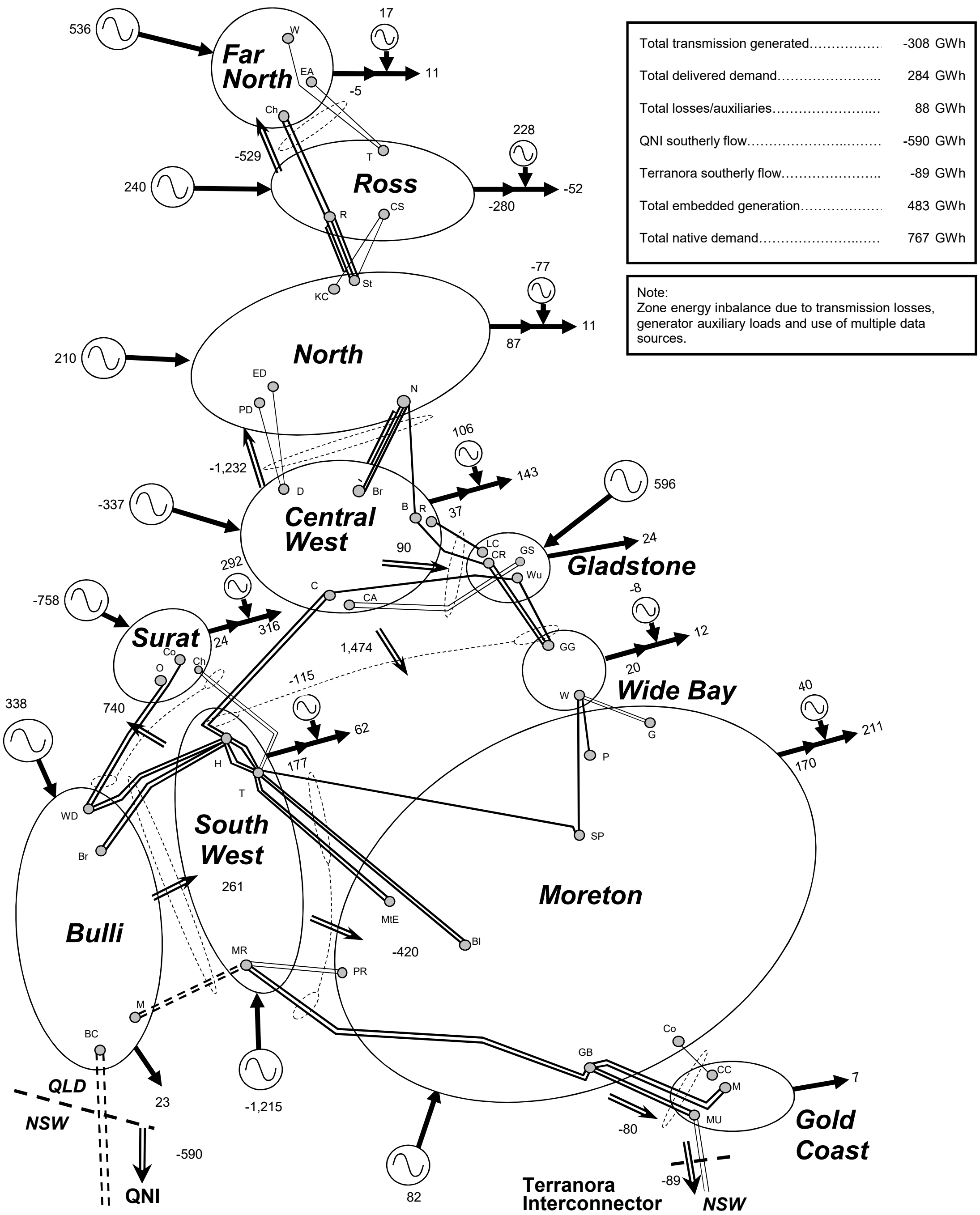
5 Consistent with this chapter, time periods are from April 2017 to March 2018.

Figure 6.7 2018[6] zonal electrical energy transfers (GWh)



[6] Consistent with this chapter, time periods are from April 2018 to March 2019.

Figure 6.8 Change[7] in zonal electrical energy transfers (GWh)



Total transmission generated................	-308 GWh
Total delivered demand........................	284 GWh
Total losses/auxiliaries........................	88 GWh
QNI southerly flow..................................	-590 GWh
Terranora southerly flow.......................	-89 GWh
Total embedded generation..................	483 GWh
Total native demand.............................	767 GWh

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

7 Consistent with this chapter, time periods for the comparison are from April 2018 to March 2019 and April 2017 to March 2018.

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.

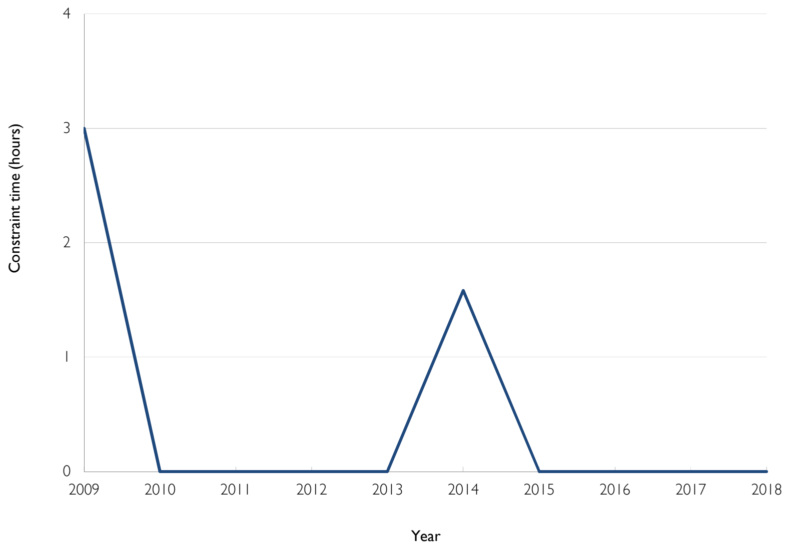
The limit equation in Table D.1 of Appendix D shows that the following variables have a significant effect on transfer capability:

- Far North zone to northern Queensland area[8] 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 2018 to March 2019. 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

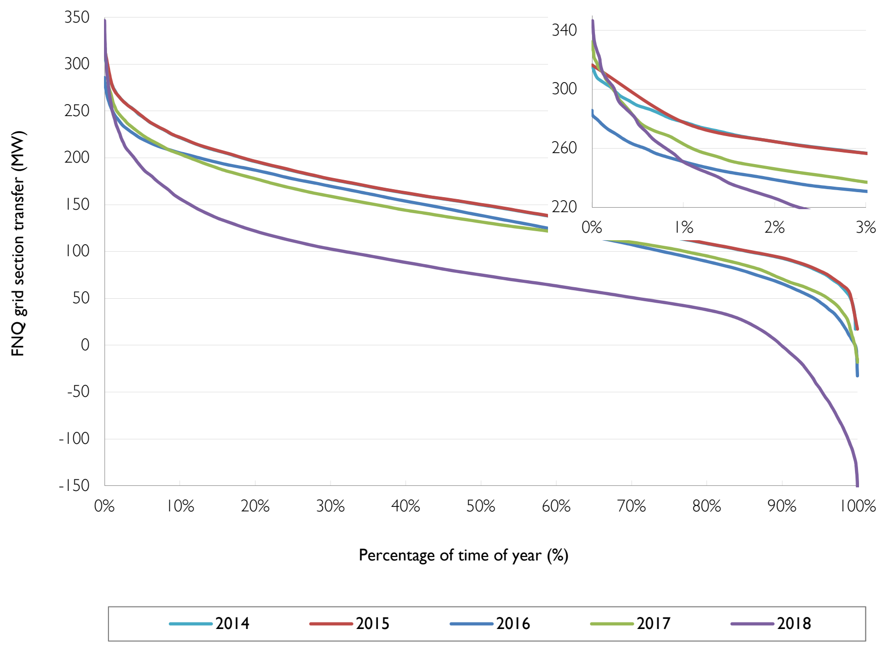


Constraint durations have reduced over time due to the commissioning of various transmission projects[9]. There have been minimal constraints in this grid section since 2008.

Figure 6.10 provides historical transfer duration curves showing a large decrease in energy transfer but similar peak transfers over 2018. This is predominantly attributed to the recently commissioned Mount Emerald wind farm located between Chalumbin and Woree substations. Given production only started in August 2018, annual energy transfers are expected to decrease further over the coming year. Historically, changes in peak flow and energy delivered to the Far North zone by the transmission network have been dependant on the Far North zone load and 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 have also increased capacity factors between 2017 and 2018 adding to the reduction in energy transfers (refer to figures 6.6, 6.7 and 6.8).

8 Northern Queensland area is defined as the combined demand of the Far North, Ross and North zones.
9 For example, the second Woree 275/132kV transformer commissioned in 2007/08.

Figure 6.10 Historical FNQ 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.

6.6.2 Central Queensland to North Queensland grid section

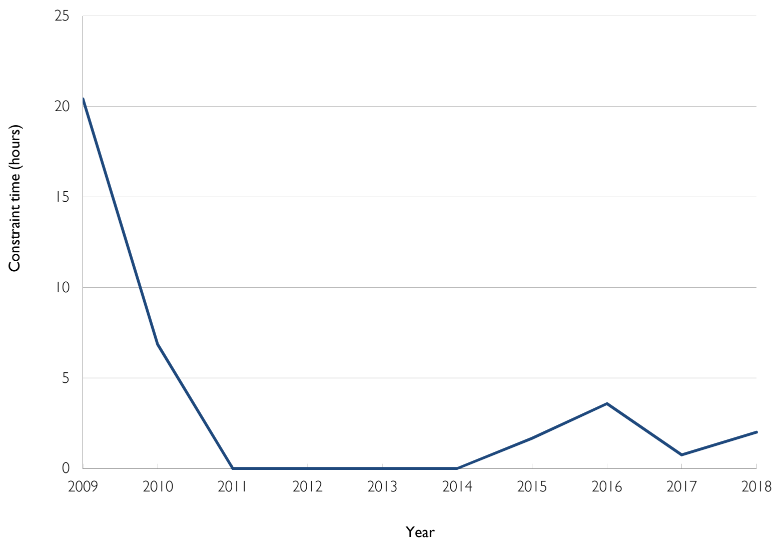
Maximum power transfer across the Central Queensland to North Queensland (CQ-NQ) grid section may be set by thermal ratings associated with an outage of a Stanwell to Broadsound 275kV circuit, under certain prevailing ambient conditions. Power transfers may also be constrained by voltage stability limitations 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 2018, the CQ-NQ grid section experienced 2.0 hours of constrained operation. These constraints were associated with planned and unplanned outages.

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 a large decrease in energy transfer but similar peak transfers over the 2018 year. This is predominantly attributed to the recently commissioned solar farms Ross River, Sun Metals, Clare, Collinsville, Whitsunday, Hamilton, Daydream, Hayman and the Mt Emerald wind farm. Given production only commenced through the year, and ramp ups with commissioning activities, annual energy transfers from Central Queensland are expected to decrease further over the coming year. Notably, peak transfers continue to be maintained at similar levels, as high net loading conditions continue to coincide (refer to figures 6.6, 6.7 and 6.8).

Figure 6.12 Historical CQ-NQ grid section transfer duration curves

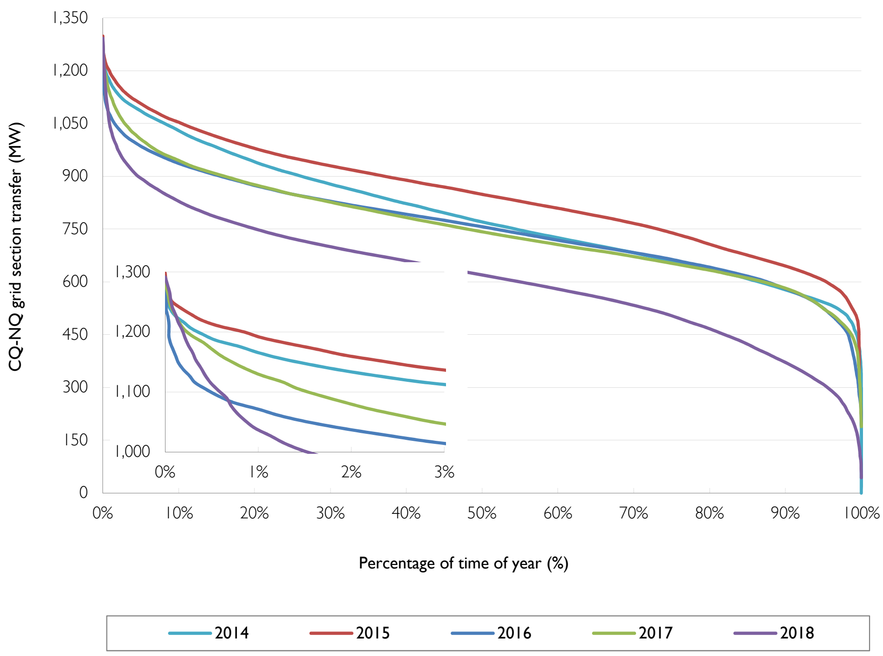
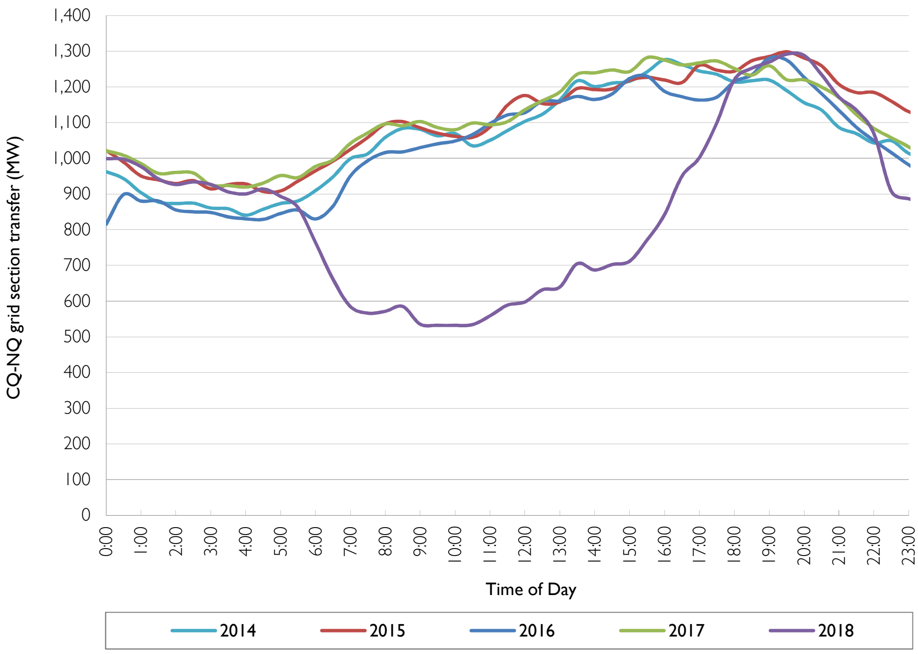


Figure 6.13 provides a different view of the altered power flows experienced over the last year.

Figure 6.13 Historical CQ-NQ peak grid section transfer daily profile



These midday reductions in transfers are introducing operational challenges in voltage control. Midday transfers are forecast to continue reducing with additional commissioning of VRE generators in North Queensland. Correspondingly, voltage control is forecast to become increasingly challenging for longer durations. Section 5.7.4 recommends the installation of a bus reactor to mitigate the risk of over voltages.

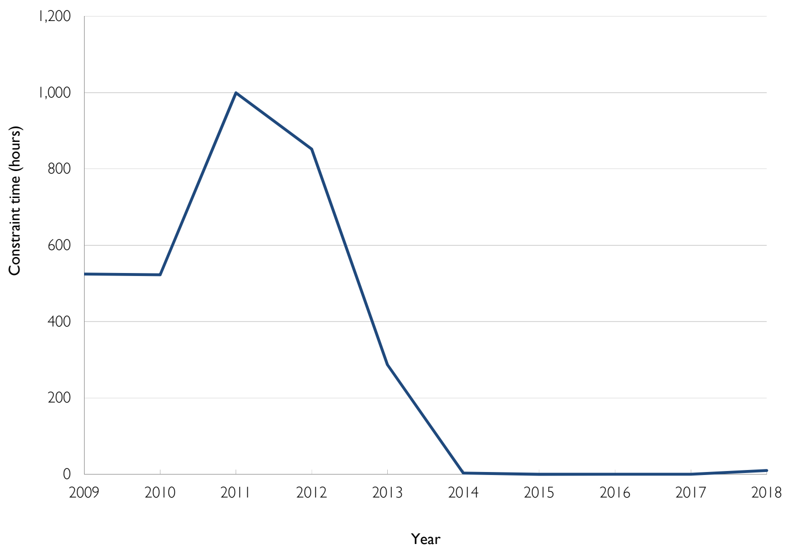
6.6.3 Gladstone grid section

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.

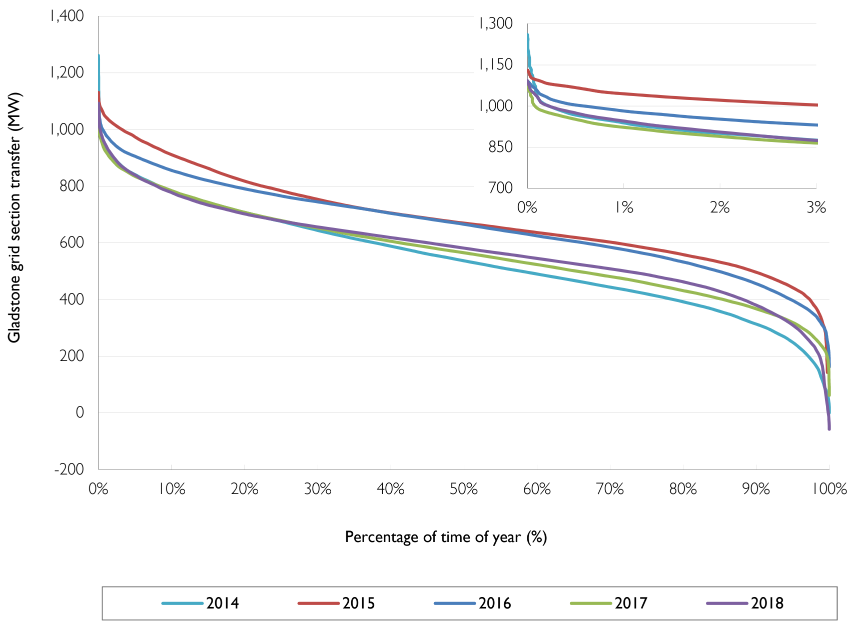
Information pertaining to the historical duration of constrained operation for the Gladstone grid section is summarised in Figure 6.14. During 2018, the Gladstone grid section experienced 10.1 hours of constrained operation.

Figure 6.14 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 6.15 provides historical transfer duration curves showing largely similar utilisation in 2018 compared to 2017. Increased capacity factor from Gladstone Power Station has maintained the transfer through this grid section although more energy is being transferred from north Queensland (refer to figures 6.6, 6.7 and 6.8).

Figure 6.15 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. In 2018, Powerlink commissioned a project which has increased the design temperature of Bouldercombe to Raglan and Larcom Creek to Calliope River 275kV transmission lines. This project was approved by the AER under the Network Capability Incentive Parameter Action Plan (NCIPAP) to assist in relieving 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.

Information pertaining to the historical duration of constrained operation for the CQ-SQ grid section is summarised in Figure 6.16. During 2018, the CQ-SQ grid section experienced 57.2 hours of constrained operation. Constrained operation was mainly associated with planned maintenance outages, with only 29.4 hours or about half of the time, constrained in a system normal state.

Figure 6.16 Historical CQ-SQ grid section constraint times

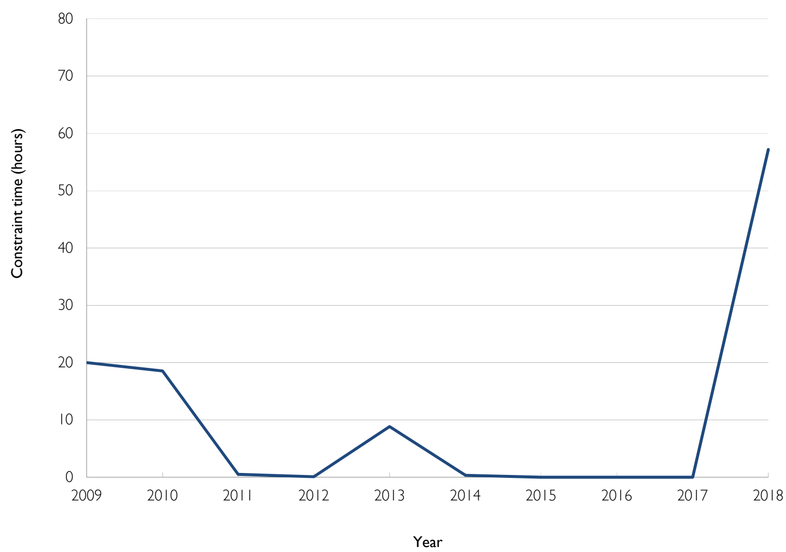
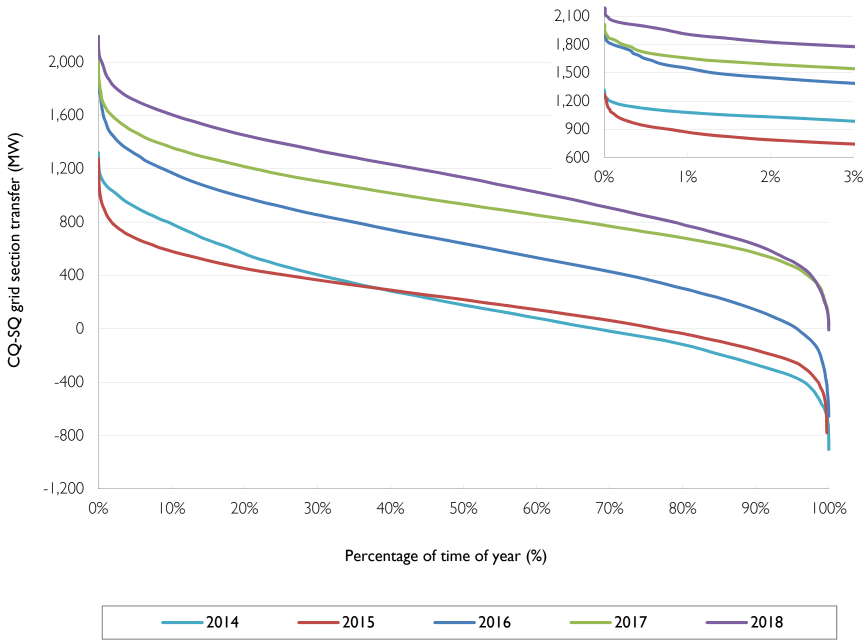


Figure 6.17 provides historical transfer duration curves showing continued increase in utilisation since 2015. This increase in transfer has been predominantly due to a significant reduction in generation from the gas fuelled generators in the Bulli zone and higher interconnector transfers sourced predominantly 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.

Figure 6.17 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 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

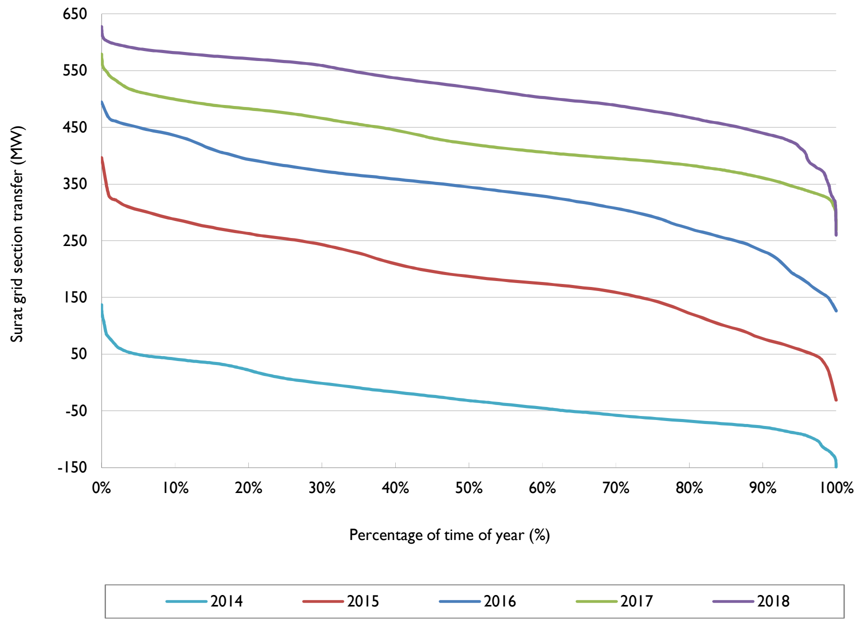
The Surat grid section was introduced in the 2014 TAPR in preparation for the establishment of the Western Downs to Columboola 275kV transmission line[10], Columboola to Wandoan South 275kV transmission line and Wandoan South and Columboola 275kV substations. These network developments were completed 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 6.18 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.

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

Figure 6.18 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 2018 to March 2019. Information pertaining to the historical duration of constrained operation for the SWQ grid section is summarised in Figure 6.19.

Figure 6.19 Historical SWQ grid section constraint times

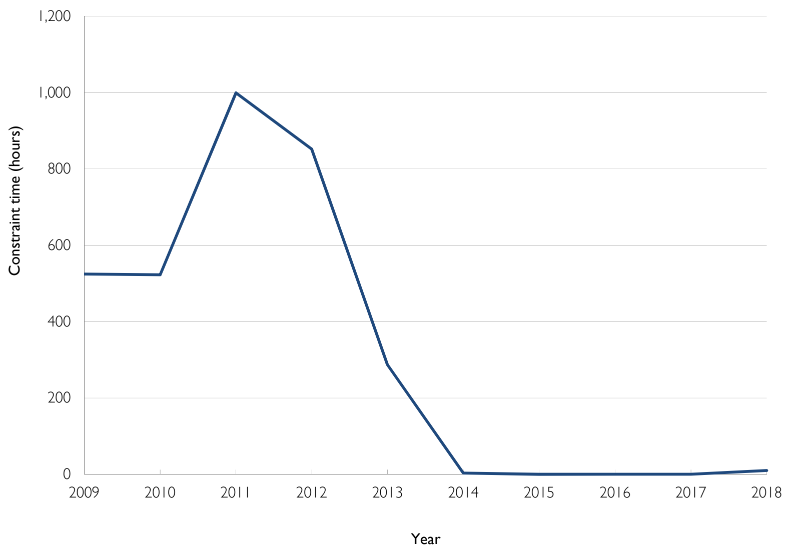
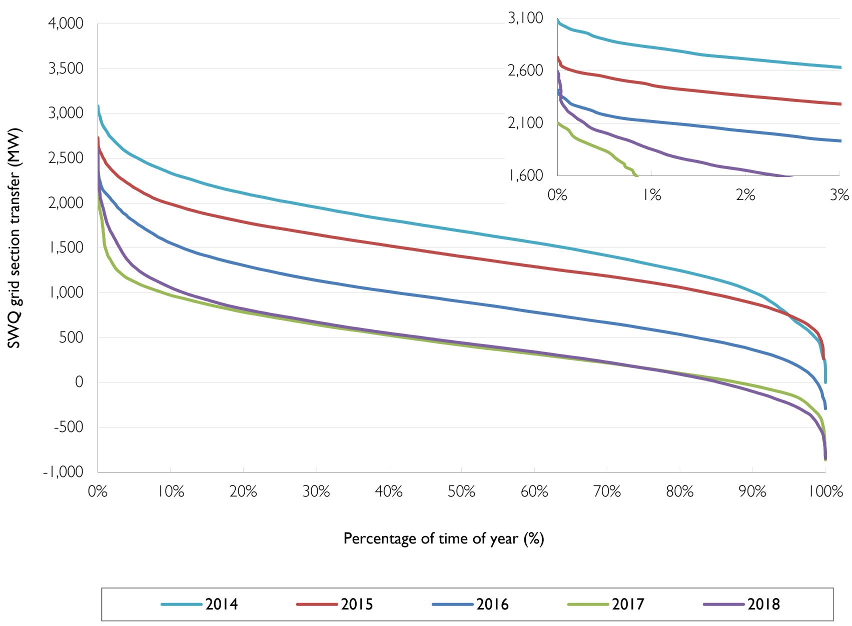


Figure 6.20 provides historical transfer duration curves showing reductions in energy transfer since 2014. Increases in QNI southerly flows, reductions in gas fuelled generation in the Bulli zone, increases in SW zone generation and CQ-SQ transfers (refer to figures 6.6, 6.7 and 6.8) are predominantly responsible for the reduction in SWQ utilisation.

Figure 6.20 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.

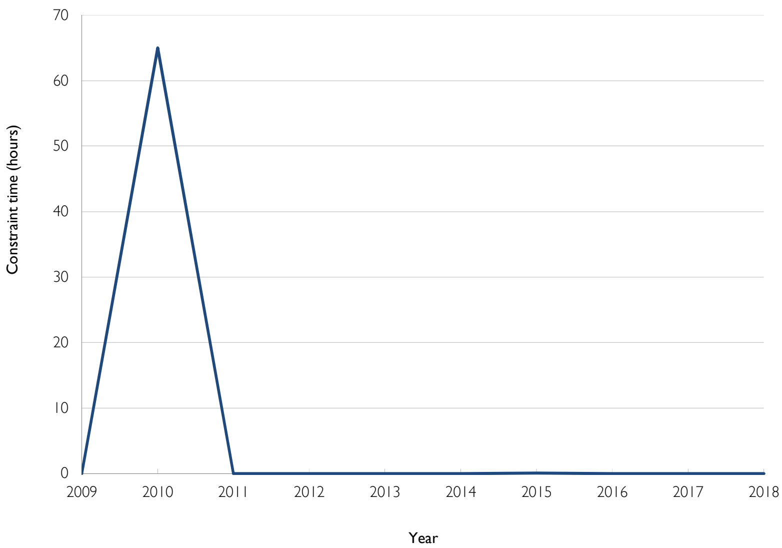
Limit equations in Table D.4 of Appendix D show that the following variables have a significant effect on transfer capability:

- 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 2018 to March 2019. Information pertaining to the historical duration of constrained operation for the Tarong grid section is summarised in Figure 6.21.

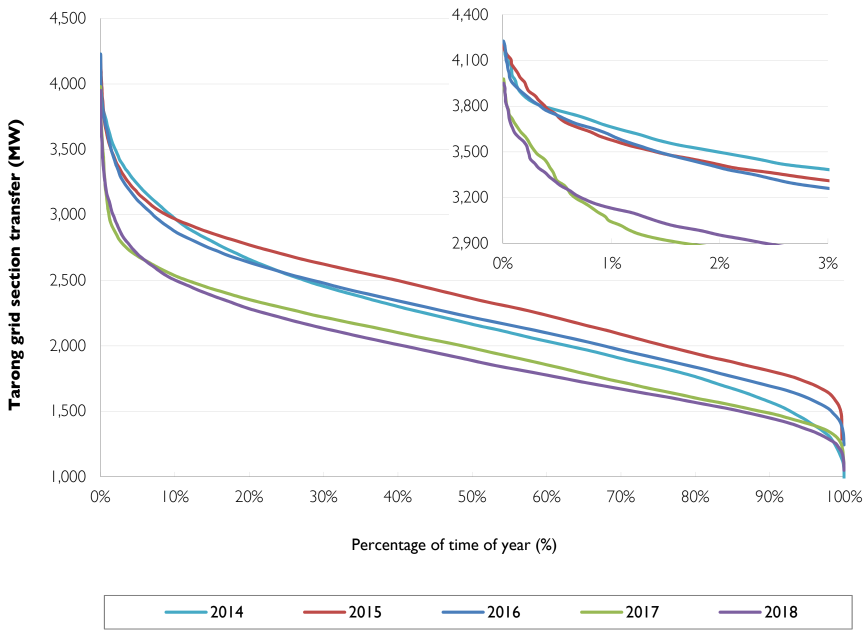
Figure 6.21 Historical Tarong grid section constraint times



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 6.22 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 2018 trace reflects lower energy transfers into SEQ as a result of Wivenhoe and Swanbank E generation and greater transfers from CQ and NQ generators (refer to figures 6.6, 6.7 and 6.8).

Figure 6.22 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.

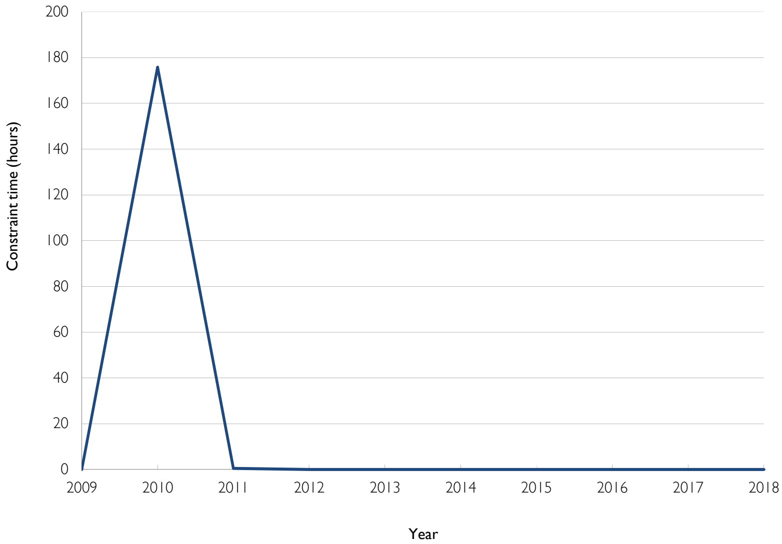
The limit equation in Table D.5 of Appendix D shows that the following variables have a significant effect on transfer capability:

- 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 2018 to March 2019. Information pertaining to the historical duration of constrained operation for the Gold Coast grid section is summarised in Figure 6.23.

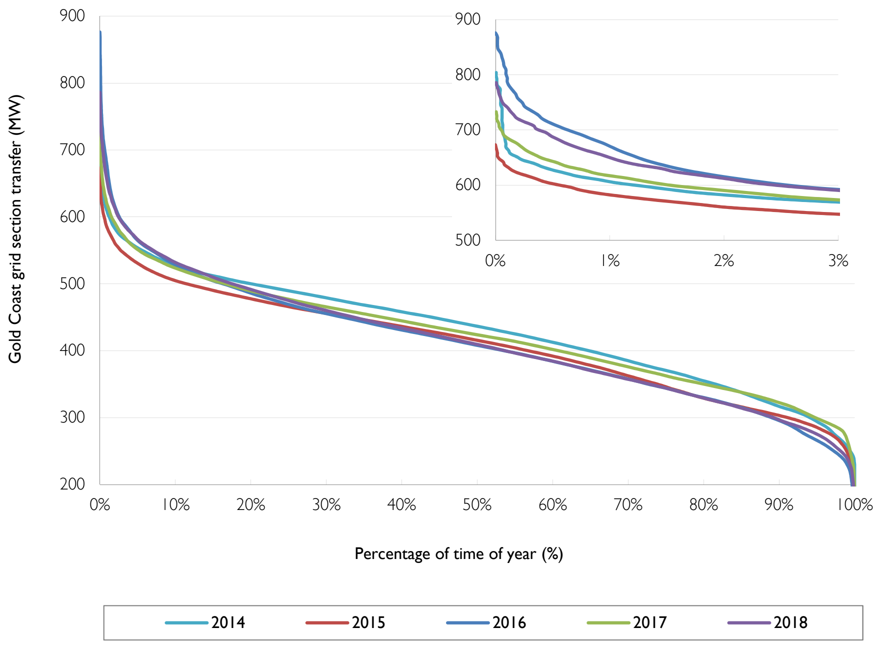
Figure 6.23 Historical Gold Coast grid section constraint times



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 6.24 provides historical transfer duration curves showing changes in grid section transfer demands and energy in line with changes in transfer to northern NSW and changes in Gold Coast loads. Gold Coast zone demand was higher in 2018 compared to 2017 (refer to Section 6.7.11).

Figure 6.24 Historical Gold Coast grid section transfer duration curves



Due to condition drivers, Powerlink is proposing to retire one of the aging 275/110kV transformers at Mudgeeraba Substation by 2020. This is discussed further in Section 5.7.11.

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:

- voltage stability associated with a fault on the Sapphire to Armidale 330kV transmission line in NSW
- 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.

On November 2018, Powerlink and TransGrid released a Project Specification Consultation Report (PSCR) on 'Expanding NSW-Queensland transmission capacity', as the first step in the Regulatory Investment Test for Transmission (RIT-T) process. This RIT-T is investigating options to increase overall net market benefits in the NEM through relieving congestion on the transmission network between NSW and Queensland. Powerlink and TransGrid are currently working through public submissions on the PSCR and the power system and market modelling to assess various network and non-network options. Findings will be published in the Project Assessment Draft Report (PADR) anticipated later in 2019. This is discussed further in Section 5.7.14.

6.7 Zone performance

This section presents, where applicable, a summary of:

- the capability of the transmission network to deliver 2018 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.

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 remained steady in 2018, compared to 2017 (refer to Figure 6.8), despite significant increases in embedded VRE generation and Queensland's installed rooftop photovoltaic (PV) reaching 2,440MW in February 2019.

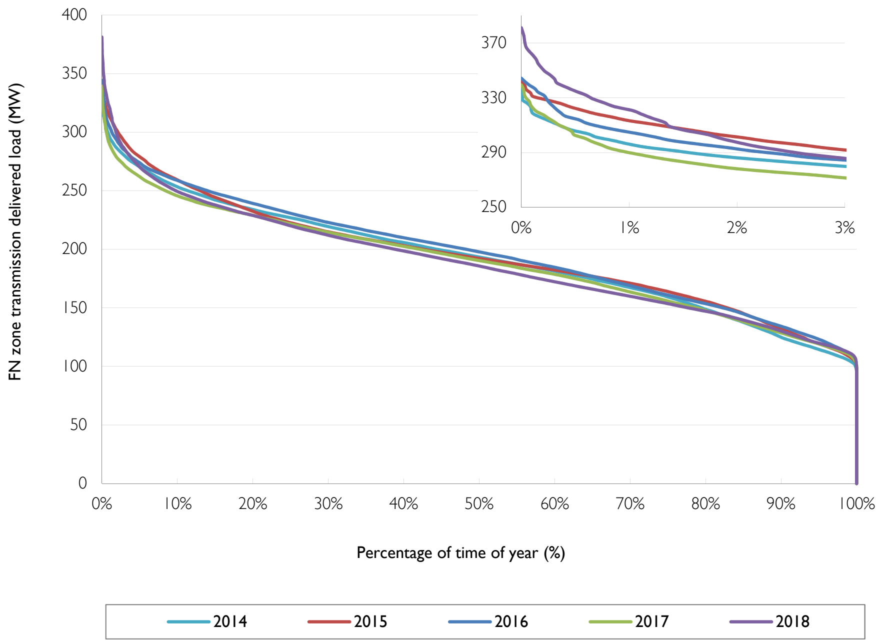
6.7.1 Far North zone

The Far North zone experienced no load loss for a single network element outage during 2018.

The Far North zone includes the scheduled embedded generator Lakeland Solar and Storage as defined in Figure 2.4. This embedded generator provided approximately 21GWh during 2018.

Figure 6.25 provides historical transmission delivered load duration curves for the Far North zone. Energy delivered from the transmission network has reduced by 0.3% between 2017 and 2018. The maximum transmission delivered demand in the zone was 381MW, which is the highest maximum demand over the last five years.

Figure 6.25 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. Additional reactive sources are not required in the Far North zone within the five-year outlook period for the control of high voltages.

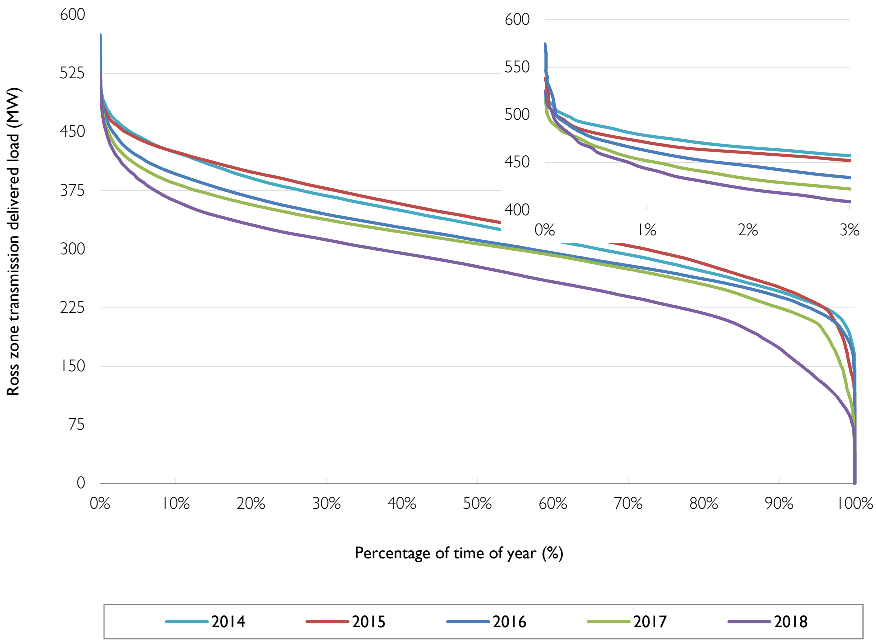
6.7.2 Ross zone

The Ross zone experienced no load loss for a single network element outage during 2018.

The Ross zone includes the scheduled embedded Townsville Power Station 66kV component, semi-scheduled distribution connected embedded Kidston Solar Farm and direct connected embedded Sun Metal Solar Farm, and the significant non-scheduled embedded generator at Pioneer Mill as defined in Figure 2.4. These embedded generators provided approximately 506GWh during 2018.

Figure 6.26 provides historical transmission delivered load duration curves for the Ross zone. Energy delivered from the transmission network has reduced by 10.5% between 2017 and 2018. The reduction in energy delivered is predominantly due to the increase in embedded generation. The peak transmission delivered demand in the zone was 525MW which is below the highest maximum demand over the last five years of 574MW set in 2016.

Figure 6.26 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.

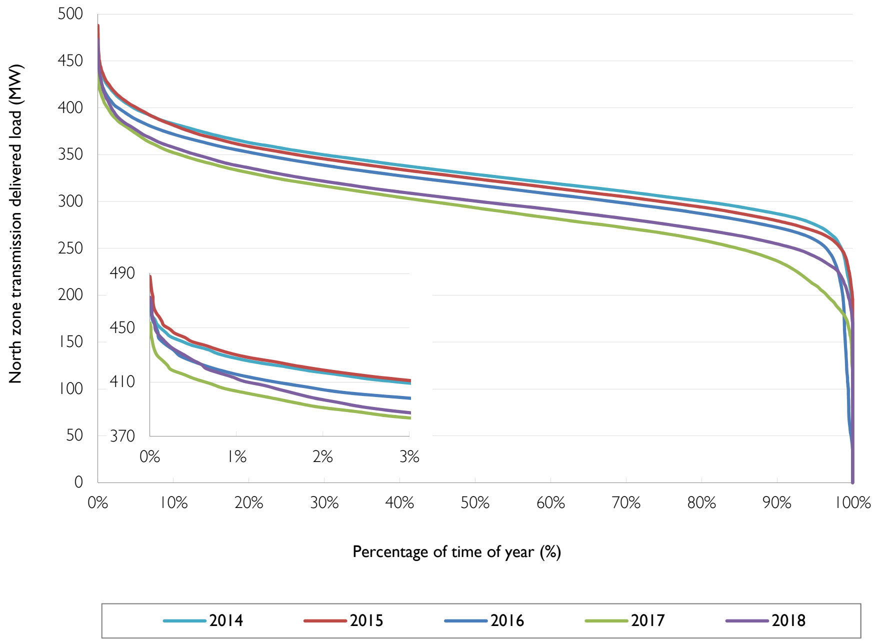
6.7.3 North zone

The North zone experienced no load loss for a single network element outage during 2018.

The North zone includes the scheduled embedded Mackay generator, semi-scheduled embedded generator Collinsville Solar Farm and significant non-scheduled embedded generators Moranbah North, Moranbah and Racecourse Mill as defined in Figure 2.4. These embedded generators provided approximately 562GWh during 2018.

Figure 6.27 provides historical transmission delivered load duration curves for the North zone. Energy delivered from the transmission network has increased by 3.4% between 2017 and 2018. The peak transmission delivered demand in the zone was 473MW, which is below the highest maximum demand over the last five years of 488MW set in 2015.

Figure 6.27 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:

- Strathmore to Clare South and Collinsville North to King Creek to Clare South 132kV double circuit transmission line, last tripped January 2019
- 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 currently managed with existing reactive sources. However, midday power transfer levels are forecast to reduce as additional VRE generators are commissioned in North Queensland. As a result, voltage control is forecast to become increasingly challenging for longer durations. This is discussed in sections 6.6.2 and 5.7.4.

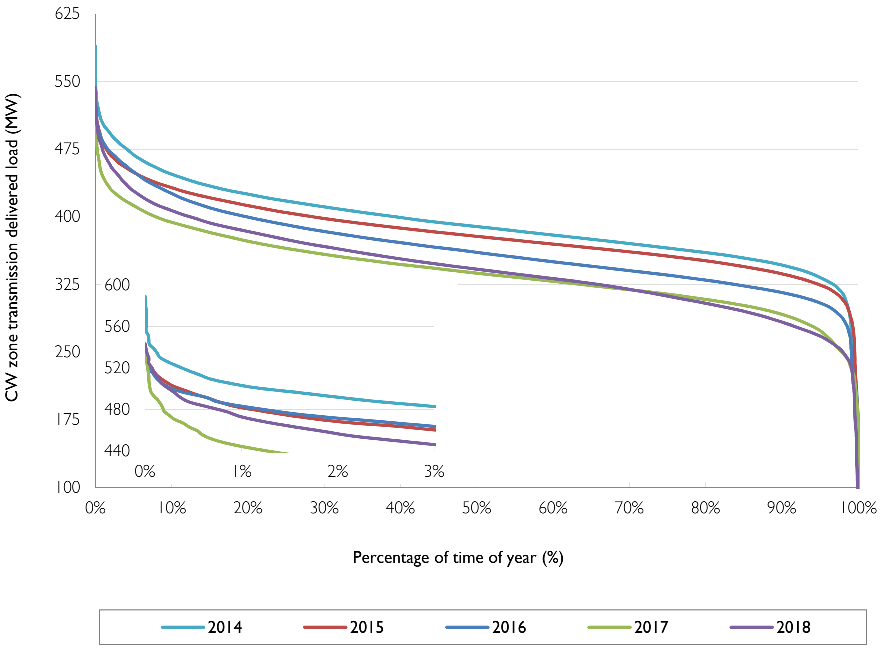
6.7.4 Central West zone

The Central West zone experienced no load loss for a single network element outage during 2018.

The Central West zone includes the scheduled embedded Barcaldine generator, semi-scheduled embedded generators Clermont Solar Farm and Emerald Solar Farm and significant non-scheduled embedded generators Barcaldine Solar Farm, Longreach Solar Farm, German Creek and Oaky Creek as defined in Figure 2.4. These embedded generators provided approximately 567GWh during 2018.

Figure 6.28 provides historical transmission delivered load duration curves for the Central West zone. Energy delivered from the transmission network has increased by 1.2% between 2017 and 2018. The peak transmission delivered demand in the zone was 543MW, which is below the highest maximum demand over the last five years of 589MW set in 2014.

Figure 6.28 Historical Central West zone transmission delivered load duration curves



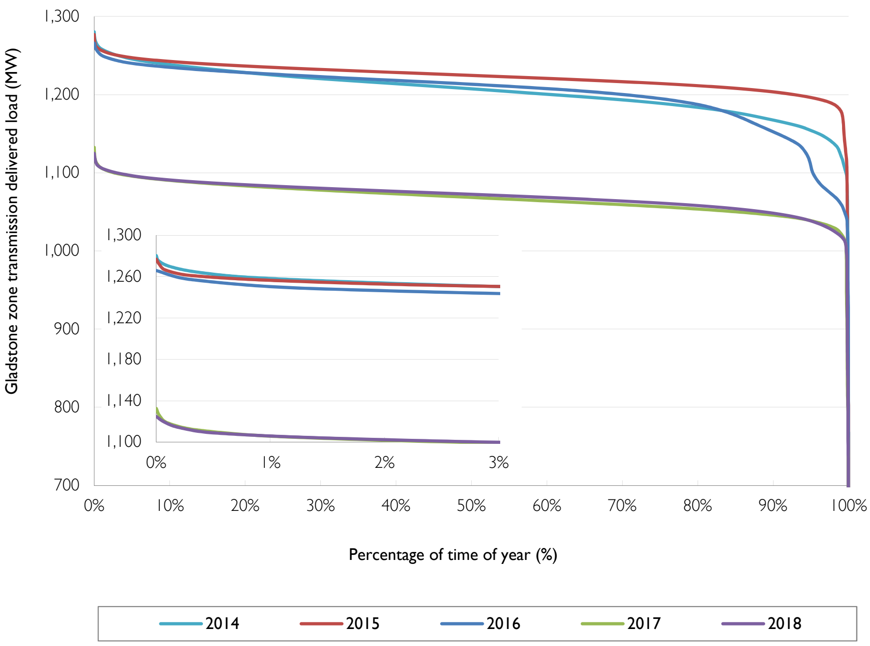
6.7.5 Gladstone zone

The Gladstone zone experienced no load loss for a single network element outage during 2018.

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

Figure 6.29 provides historical transmission delivered load duration curves for the Gladstone zone. Energy delivered from the transmission network has increased by 0.3% between 2017 and 2018. The peak transmission delivered demand in the zone was 1,125MW, which is below the highest maximum demand over the last five years of 1,280MW set in 2014.

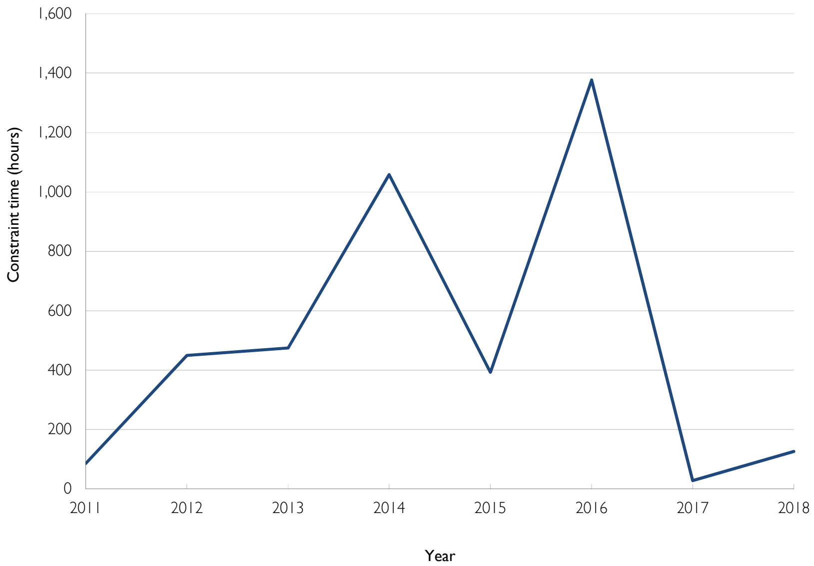
Figure 6.29 Historical Gladstone zone transmission delivered load duration curves



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 Boyne Smelter Limited's (BSL) 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 6.30. 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 this decade during 2018, due to the BSL's reduced production the constraint only bound 126.3 hours.

Figure 6.30 Historical Q>NIL_BI_FB constraint times



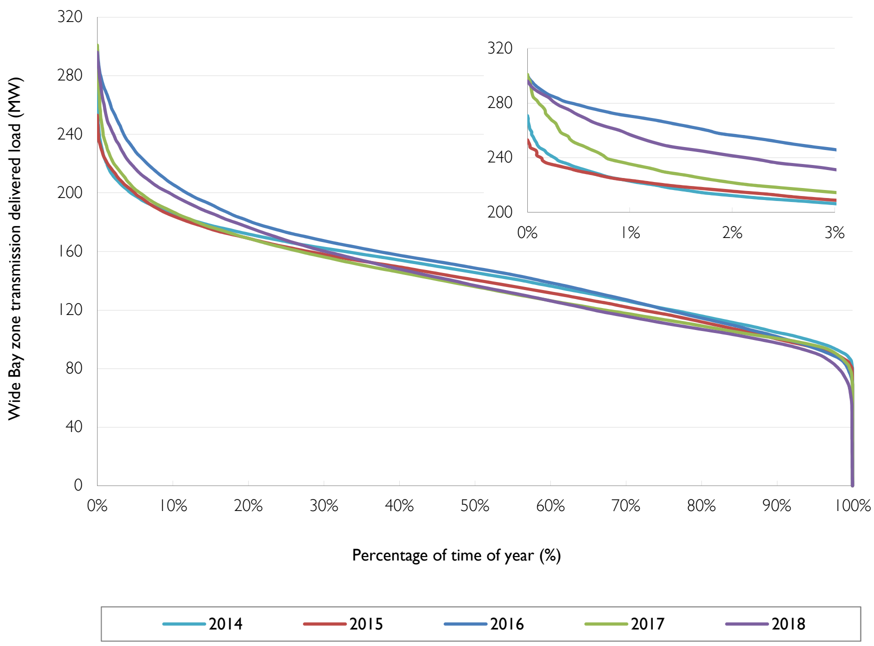
6.7.6 Wide Bay zone

The Wide Bay zone experienced no load loss for a single network element outage during 2018.

The Wide Bay zone includes the semi-scheduled embedded generators Childers Solar Farm and Susan River Solar Farm, and significant non-scheduled embedded generator Isis Central Sugar Mill as defined in Figure 2.4. These embedded generators provided approximately 30GWh during 2018.

Figure 6.31 provides historical transmission delivered load duration curves for the Wide Bay zone. Energy delivered from the transmission network increased by 1.6% between 2017 and 2018. The peak transmission delivered demand in the zone was 296MW, which is below the highest maximum demand over the last five years of 301MW set in 2017.

Figure 6.31 Historical Wide Bay zone transmission delivered load duration curves



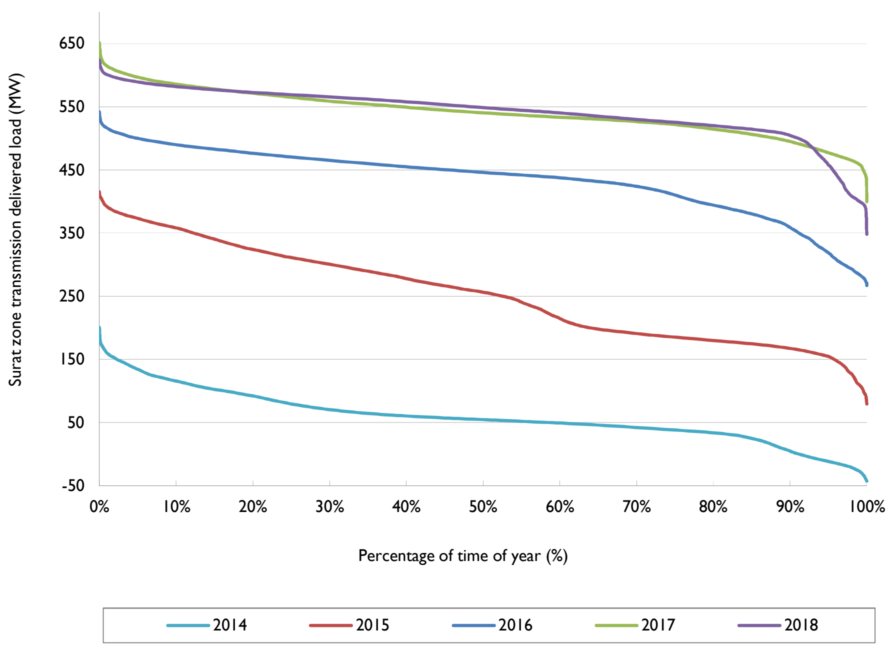
6.7.7 Surat zone

The Surat zone experienced no load loss for a single network element outage during 2018.

The Surat zone includes the scheduled embedded Roma and Condamine generators as defined in Figure 2.4. This embedded generator provided approximately 316GWh during 2018.

Figure 6.32 provides historical transmission delivered load duration curves for the Surat zone. Energy delivered from the transmission network has increased by approximately 0.2% between 2017 and 2018. The peak transmission delivered demand in the zone was 624MW, which is below the highest maximum demand over the last five years of 651MW set in 2017. The CSG load in the zone has now reached expected demand levels.

Figure 6.32 Historical Surat zone transmission delivered load duration curves



As a result of double circuit outages associated with lightning strikes, AEMO includes the Tarong to Chinchilla 132kV double circuit transmission line in the vulnerable list. This double circuit tripped due to lightning in February 2018.

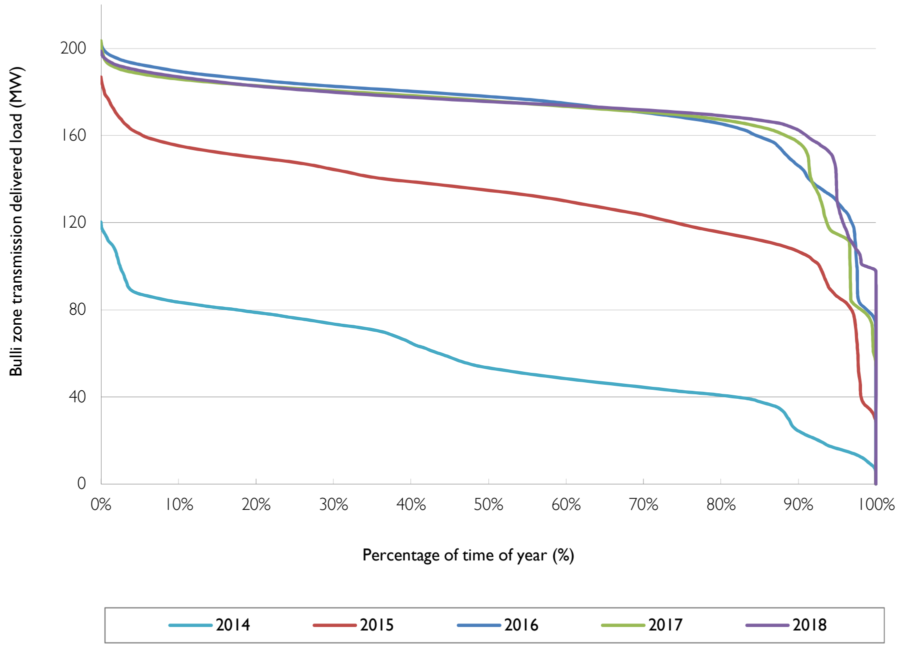
6.7.8 Bulli zone

The Bulli zone experienced no load loss for a single network element outage during 2018.

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

Figure 6.33 provides historical transmission delivered load duration curves for the Bulli zone. Energy delivered from the transmission network has increased by approximately 1.5% between 2017 and 2018. The peak transmission delivered demand in the zone was 199MW, which is below the highest maximum demand over the last five years of 204MW set in 2017. The CSG load in the zone has now reached expected demand levels.

Figure 6.33 Historical Bulli zone transmission delivered load duration curves



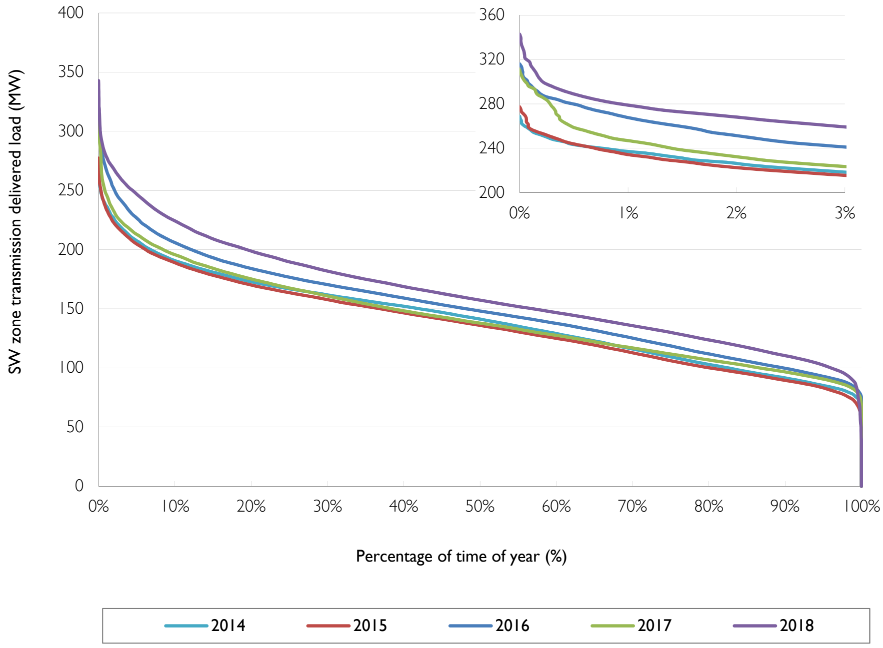
6.7.9 South West zone

The South West zone experienced no load loss for a single network element outage during 2018.

The South West zone includes the semi-scheduled embedded generator Oakey 1 Solar Farm and significant non-scheduled embedded generator Daandine Power Station as defined in Figure 2.4. These embedded generators provided approximately 131GWh during 2018.

Figure 6.34 provides historical transmission delivered load duration curves for the South West zone. Energy delivered from the transmission network has increased by 14.2% between 2017 and 2018. The peak transmission delivered demand in the zone was 343MW, which is the highest maximum demand over the past five years.

Figure 6.34 Historical South West zone transmission delivered load duration curves

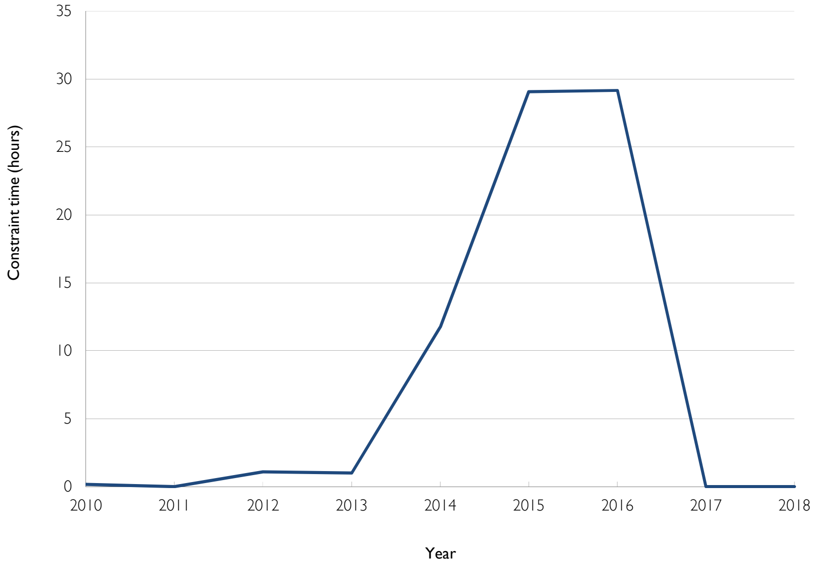


Constraints occur within the South West zone under intact network conditions. These constraints are associated with maintaining power flows of the 110kV transmission lines between Tangkam and Middle Ridge substations within the feeder's thermal ratings at times of high Oakey Power Station generation. 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. There were no constraints recorded against this constraint equations in 2018. Oakey's production reduced significantly since 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 6.35.

Figure 6.35 Historical Q>NIL_MRTA_A and Q>NIL_MRTA_B constraint times



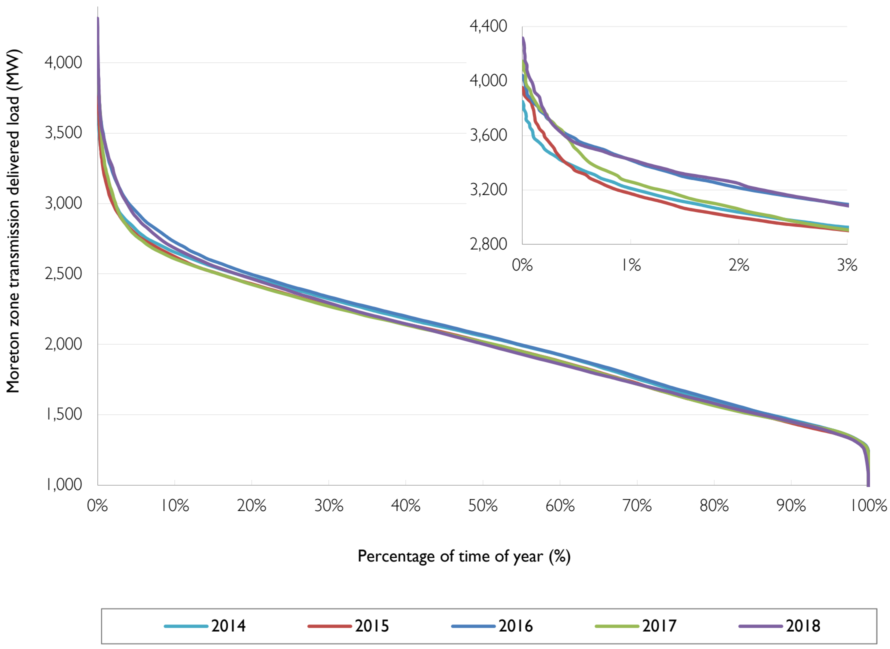
6.7.10 Moreton zone

The Moreton zone experienced no load loss for a single network element outage during 2018.

The Moreton zone includes the significant non-scheduled embedded generators Sunshine Coast Solar Farm, Bromelton and Rocky Point as defined in Figure 2.4. These embedded generators provided approximately 96GWh during 2018.

Figure 6.36 provides historical transmission delivered load duration curves for the Moreton zone. Energy delivered from the transmission network has increased by 1.0% between 2017 and 2018. The peak transmission delivered demand in the zone was 4,316W, which is the highest ever maximum demand for the zone.

Figure 6.36 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. There are no additional reactive sources 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 2018.

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

Figure 6.37 provides historical transmission delivered load duration curves for the Gold Coast zone. Energy delivered from the transmission network has increased by 0.2% between 2017 and 2018. The peak transmission delivered demand in the zone was 732MW, which is the highest maximum demand over the last five years.

Figure 6.37 Historical Gold Coast zone transmission delivered load duration curves