



# Chapter 5:

# Network capability and performance

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### Key highlights

- Semi-scheduled wind farm Mt Emerald (180MW) and solar farms Kidston (50MW), Ross River (125MW), Clare (136MW), Whitsunday (57MW), Hamilton (57MW), Collinsville (42MW), Teebar (53MW), Darling Downs (110MW) and Oakey (25MW) have committed during 2016/17.
- The range of generators connected to the Powerlink network is diversifying with the connection of variable renewable electricity generators.
- During 2016/17, the CQ-SQ grid section was highly utilised reflecting higher CQ and NQ generator scheduling. The utilisation of this grid section is expected to increase with the connection of variable renewable electricity generators in NQ.
- 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.
- During 2016/17, record peak transmission delivered demands were recorded in the Ross, Surat, Bulli and Moreton zones.
- The transmission network has performed reliably during 2016/17, with Queensland grid sections largely unconstrained.

### 5.1 Introduction

This chapter on network capability and performance provides:

- a table of existing and committed generation capacity over the next three years
- sample power flows at times of forecast Queensland maximum summer and winter demands under a range of interconnector flows and generation dispatch patterns
- 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.

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

## 5.2 Existing and committed scheduled, semi-scheduled and transmission connected generation

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

New generators are regarded as committed (incorporated into future studies) when a Connection and Access Agreement (CAA) has been signed. The semi-scheduled solar farms Kidston, Ross River, Clare, Whitsunday, Hamilton, Collinsville, Teebar, Darling Downs and Oakey and Mt Emerald wind farm have reached committed status since the 2016 Transmission Annual Planning Report (TAPR).

In December 2014, Stanwell Corporation withdrew Swanbank E Power Station (PS) from service for up to three years. In June, the Queensland Government announced that it will be brought back online by the first quarter of 2018.

Table 5.1 summarises the available capacity of power stations connected, or committed (as of 1st May) to be connected to Powerlink's transmission network including the non-scheduled market generators at Yarwun, Invicta and Koombooloomba. This table also includes scheduled and semi-scheduled existing embedded generators at Mackay, Barcaldine, Roma and the Townsville PS 66kV component, and committed embedded generators Kidstone SF, Collinsville SF and Oakey SF.

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 connecting to Powerlink's network can be found on Powerlink's website.

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**Table 5.1 Available generation capacity**

Existing and committed plant connected to the Powerlink transmission network and scheduled or semi-scheduled embedded generators.

Generator	Location	Available capacity MW generated (1)					
		Winter 2017	Summer 2017/18	Winter 2018	Summer 2018/19	Winter 2019	Summer 2019/20
Coalfired							
Stanwell	Stanwell	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	700	700	700	700	700	700
Callide Power Plant	Calvale	900	900	900	900	900	900
Tarong North	Tarong	443	443	443	443	443	443
Tarong	Tarong	1,400	1,400	1,400	1,400	1,400	1,400
Kogan Creek	Kogan Creek Power Station Switchyard	744	730	744	730	744	730
Millmerran	Millmerran	852	760	852	760	852	760
Total coalfired		8,179	8,073	8,179	8,073	8,179	8,073
Combustion turbine							
Townsville (Yabulu) (2)	Townsville GT Switchyard	243	233	243	233	243	233
Mt Stuart (3)	Townsville South	419	379	419	379	419	379
Mackay (2)(4)	Mackay	34	34	34	34	34	34
Barcaldine (2)	Barcaldine	37	34	37	34	37	34
Yarwun (5)	Yarwun	160	155	160	155	160	155
Roma (2)	Roma	68	54	68	54	68	54
Condamine	Columboola	144	144	144	144	144	144
Braemar 1	Braemar	504	471	504	471	504	471
Braemar 2	Braemar	519	504	519	504	519	504
Darling Downs	Braemar	633	580	633	580	633	580
Oakey (6)	Oakey GT Power Station	340	282	340	282	340	282
Swanbank E (7)	Swanbank E			365	365	365	365
Total combustion turbine		3,101	2,870	3,466	3,235	3,466	3,235
Hydro electric							
Barron Gorge	Barron Gorge PS	66	66	66	66	66	66
Kareeya (including Koombooloomba) (8)	Kareeya PS	93	93	93	93	93	93
Wivenhoe (9)	Mt England	500	500	500	500	500	500
Total hydro electric		659	659	659	659	659	659

Table 5.1 Available generation capacity (continued)

Generator	Location	Available capacity MW generated (1)					
		Winter 2017	Summer 2017/18	Winter 2018	Summer 2018/19	Winter 2019	Summer 2019/20
Solar PV (10)							
Kidston (2)	Kidston		50	50	50	50	50
Ross River	Ross		125	125	125	125	125
Clare	Clare South		136	136	136	136	136
Whitsunday	Strathmore		57	57	57	57	57
Hamilton	Strathmore		57	57	57	57	57
Collinsville (2)	Collinsville North			42	42	42	42
Teebar	Teebar Creek		53	53	53	53	53
Darling Downs	Braemar		110	110	110	110	110
Oakey (2)	Oakey			25	25	25	25
Total solar			588	655	655	655	655
Wind (10)							
Mt Emerald	Walkamin			180	180	180	180
Sugar mill							
Invicta (8)	Invicta Mill	34	0	34	0	34	0
Total all stations		11,973	12,190	13,173	12,802	13,173	12,802

## Notes:

- (1) The 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) Townsville PS 66kV component, Mackay, Barcaldine, Roma, Kidston, Collinsville and Oakey Solar Farm are embedded scheduled and semi-scheduled generators. Assumed generation is accounted in the transmission delivered forecast.
- (3) Origin Energy has advised AEMO of its intention to retire Mt Stuart at the end of 2023.
- (4) Stanwell Corporation has advised AEMO of its intention to retire Mackay GT at the end of financial year 2020/21.
- (5) Yarwun is a non-scheduled generator; but is required to comply with some of the obligations of a scheduled generator.
- (6) Oakey Power Station is an open-cycle, dual-fuel, gas-fired power station. The generated capacity quoted is based on gas fuel operation.
- (7) The Queensland Government announced that Swanbank E is expected to be brought online in the first quarter of 2018.
- (8) Koombooloomba and Invicta are transmission connected non-scheduled generators.
- (9) Wivenhoe Power Station is shown at full capacity (500MW). However, output can be limited depending on water storage levels in the dam.
- (10) Intermittent generators shown at full capacity.

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### 5.3 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 2017 to summer 2019/20 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 and committed projects (listed in tables 3.1, 3.3 and 3.4), and assume all network elements are available. In providing this information Powerlink has not attempted to predict market outcomes.

### 5.4 Transfer capability

#### 5.4.1 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.

#### 5.4.2 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, Transmission Network Service Providers (TNSPs) define the capability of their network using multiterm 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 Transmission Annual Planning Report (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 5.5 provides a qualitative description of the main system conditions that affect the capability of each grid section.

### 5.5 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.

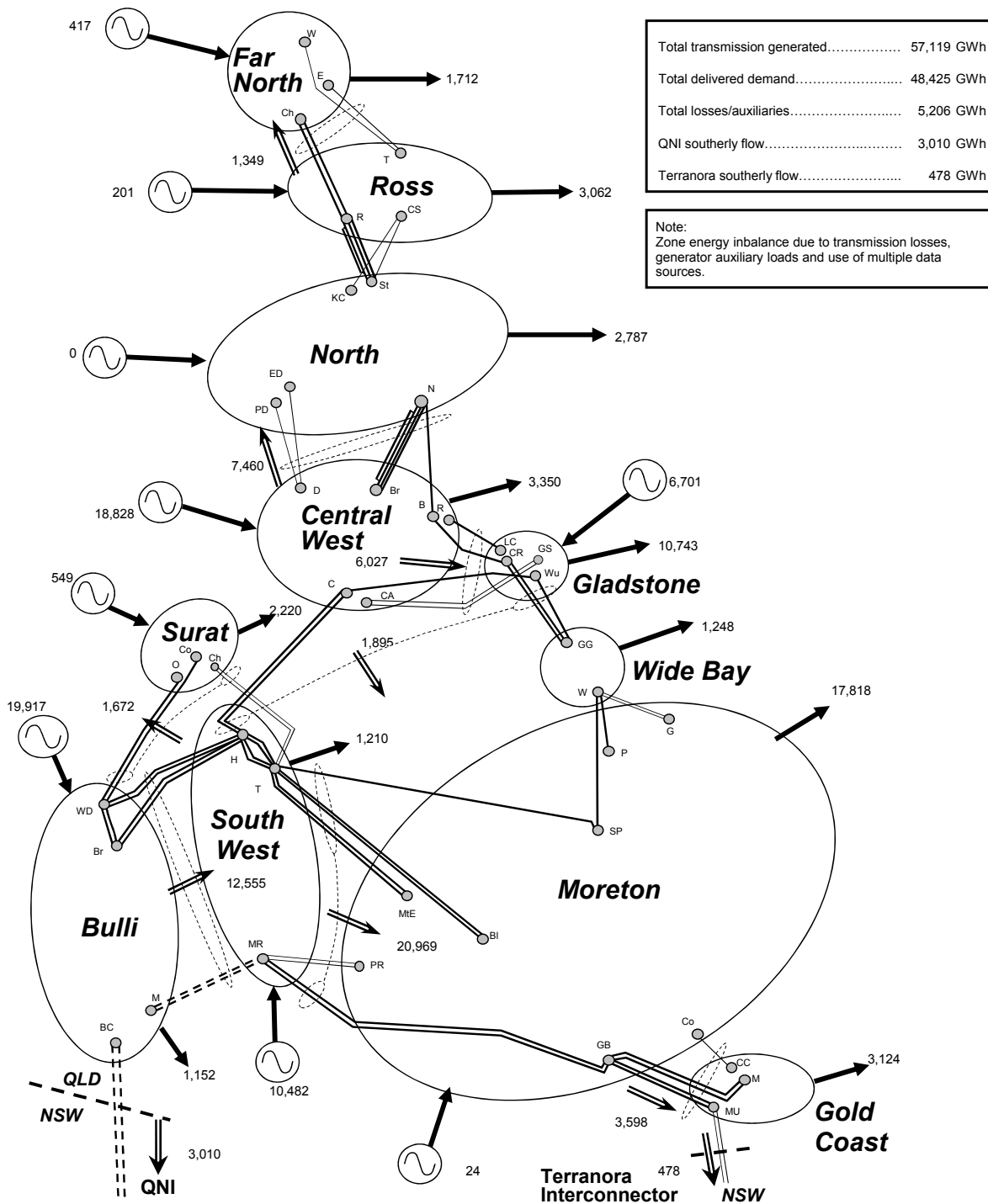
For each grid section, the time that the relevant constraint equations have bound over the last 10 years is provided. Constraint times can be associated with a combination of generator unavailability, network outages, unfavourable dispatches and/or high loads. Constraint times do not include occurrences 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 5.1 and 5.2 provide 2015 and 2016 zonal energy as generated into the transmission network (refer to Figure C.1 in Appendix C for generators included in each zone), transmission delivered energy to Distribution Network Service Providers (DNSPs) and direct connect customers and grid section energy transfers. Figure 5.3 provides the changes in energy transfers from 2015 to 2016. These figures assist in the explanation of differences between 2015 and 2016 grid section transfer duration curves.

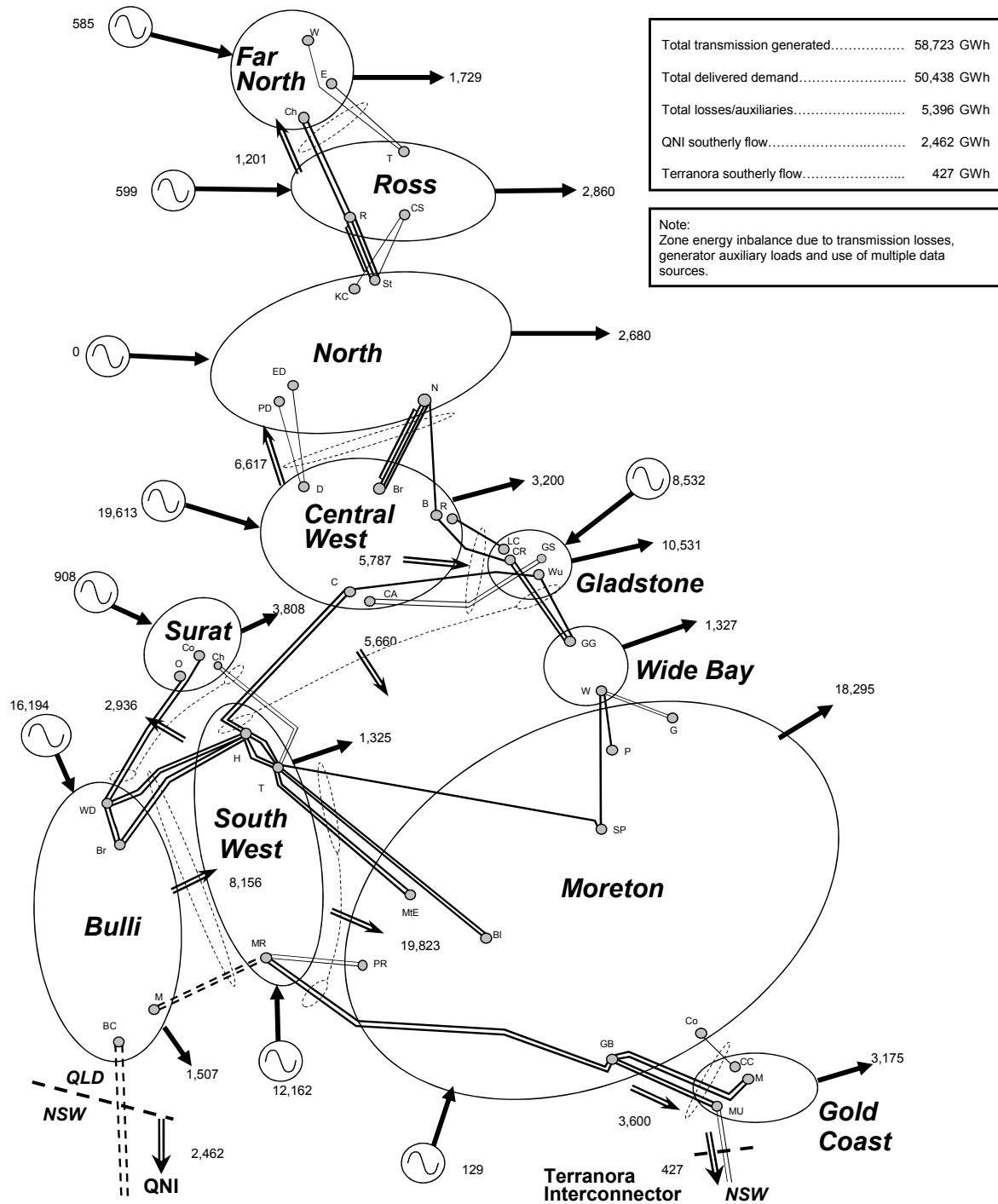
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Figure 5.1 2015<sup>1</sup> zonal electrical energy transfers (GWh)



<sup>1</sup> Consistent with this chapter, time periods are from April 2015 to March 2016.

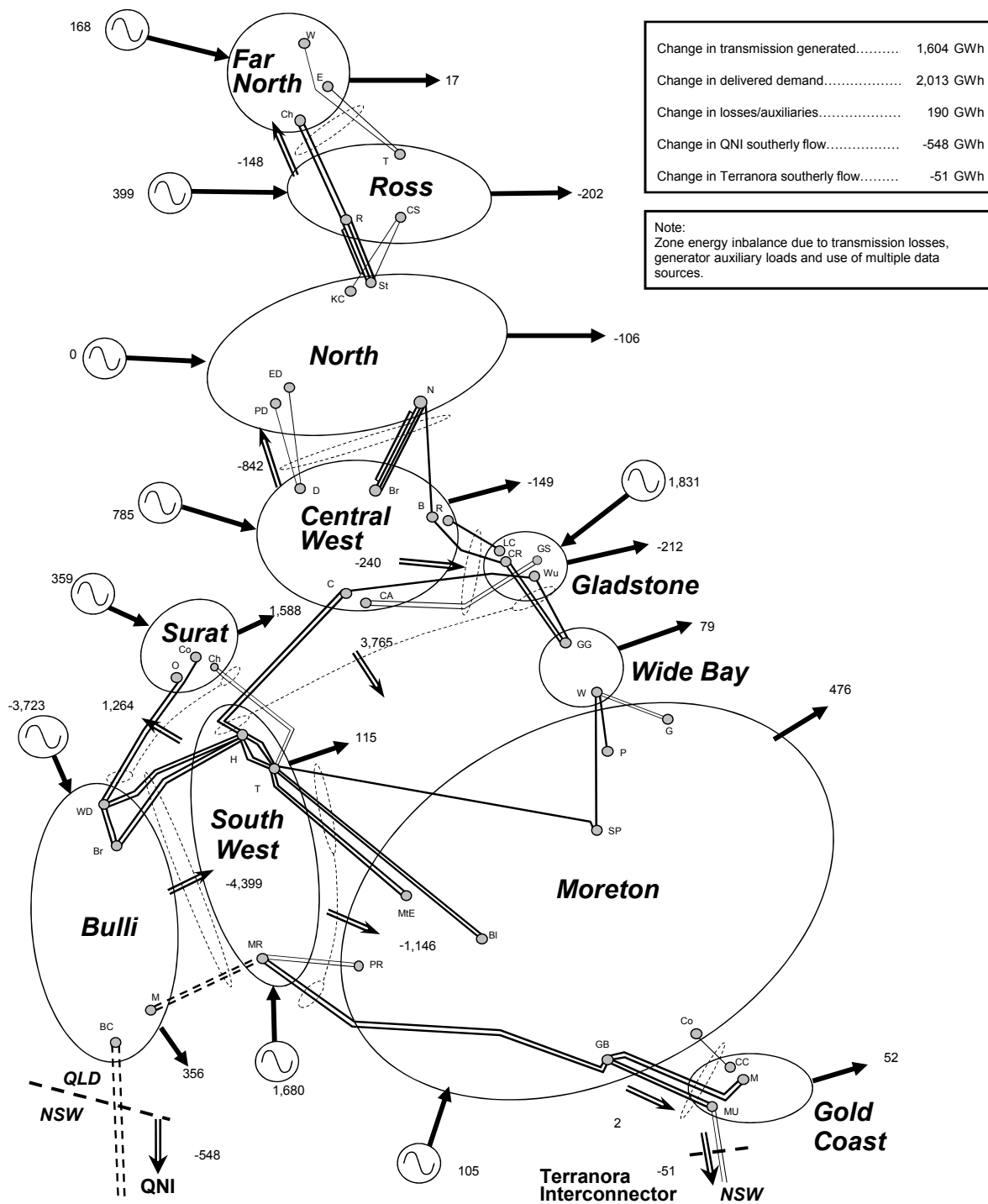
**Figure 5.2** 2016<sup>2</sup> zonal electrical energy transfers (GWh)



<sup>2</sup> Consistent with this chapter, time periods are from April 2016 to March 2017.

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Figure 5.3 Change<sup>3</sup> in zonal electrical energy transfers (GWh)



<sup>3</sup> Consistent with this chapter, time periods for the comparison are from April 2016 to March 2017 and April 2015 to March 2016.

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.

#### 5.5.1 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.

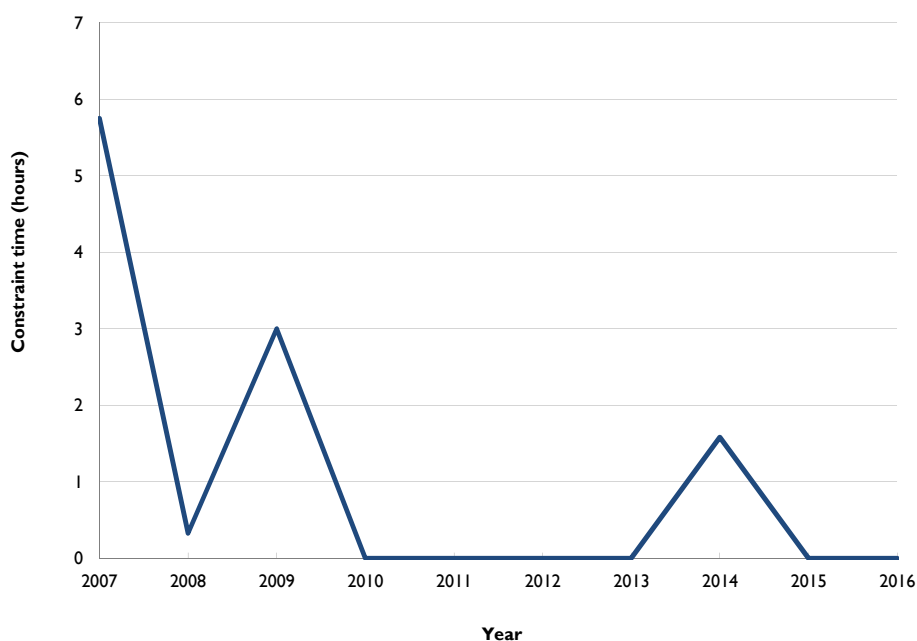
The limit equation in Table D.1 of Appendix D shows that the following variables have a significant effect on transfer capability:

- Far North zone to northern Queensland area<sup>4</sup> 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 2016 to March 2017. Information pertaining to the historical duration of constrained operation for the FNQ grid section is summarised in Figure 5.4.

**Figure 5.4** Historical FNQ grid section constraint times



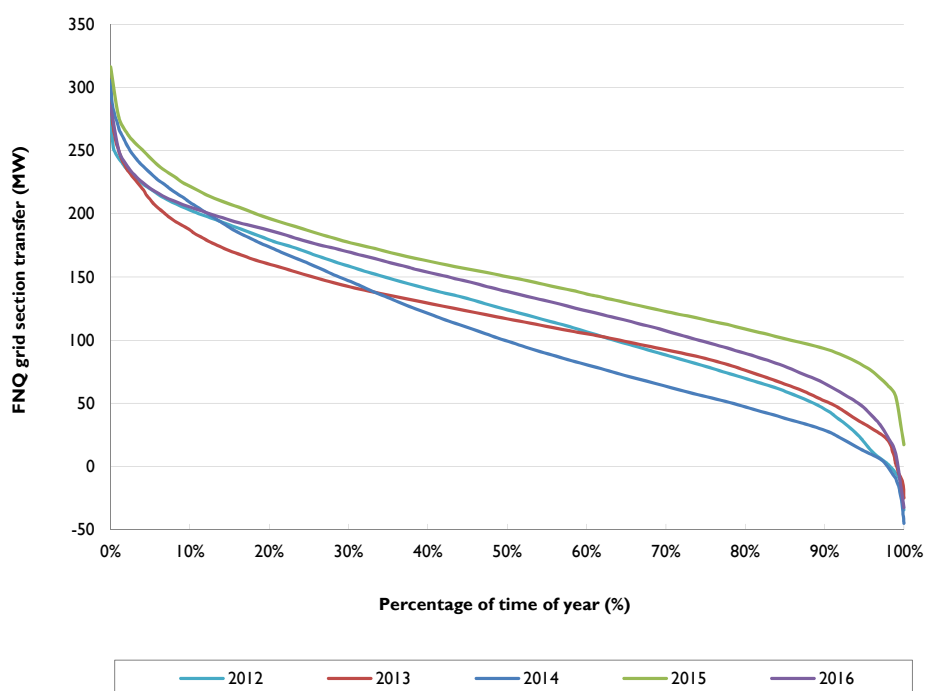
<sup>4</sup> Northern Queensland area is defined as the combined demand of the Far North, Ross and North zones.

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Constraint durations have reduced over time due to the commissioning of various transmission projects<sup>5</sup>. There have been minimal constraints in this grid section since 2008.

Figure 5.5 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 capacity factor of the hydro generating power stations increased from approximately 30% in 2015 to approximately 40% in 2016 (refer to figures 5.1, 5.2 and 5.3).

**Figure 5.5** 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.

### 5.5.2 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.

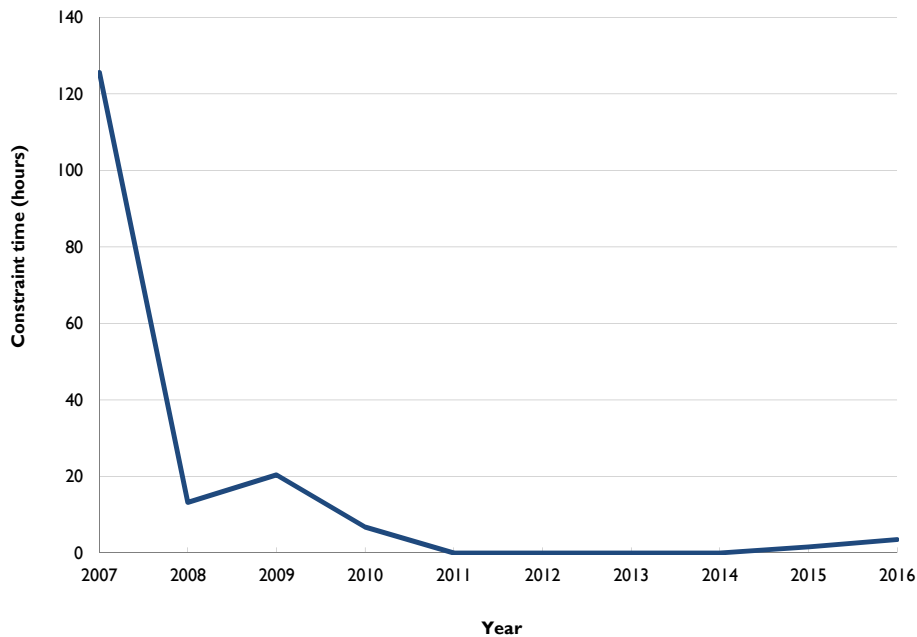
The limit equations in Table D.2 of Appendix D show that the following variables have a significant effect on transfer capability:

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

<sup>5</sup> For example, the second Woree 275/132kV transformer commissioned in 2007/08.

Information pertaining to the historical duration of constrained operation for the CQ-NQ grid section is summarised in Figure 5.6. During 2016, the CQ-NQ grid section experienced 3.58 hours of constrained operation. These constraints were associated with the reclassification of a double circuit between Strathmore and Ross substations as credible due to increased risk during the Tropical Cyclone (TC) Debbie weather event.

**Figure 5.6** Historical CQ-NQ grid section constraint times

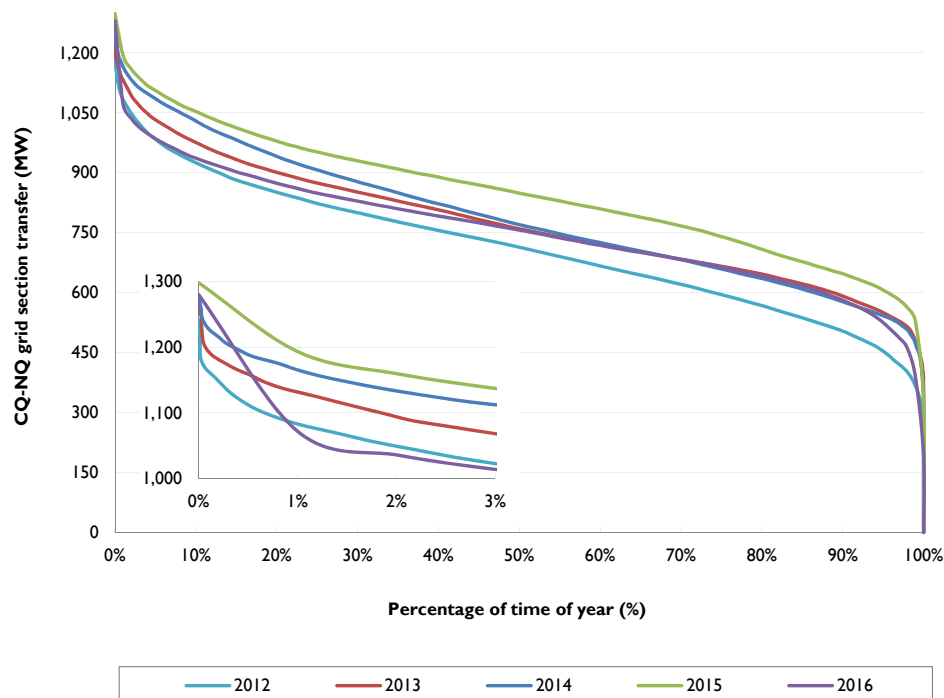


Historically, the majority of the constraint times were associated with thermal constraint equations ensuring operation within plant thermal ratings during planned outages. The staged commissioning of double circuit lines from Broadsound to Ross completed in 2010/11 provided increased capacity to this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

Figure 5.7 provides historical transfer duration curves showing small annual differences in grid section transfer demands and energy. Utilisation of the grid section was lower in 2016 compared to 2015 predominantly due to the higher capacity factor of the generators in FNQ and Ross zones (refer to figures 5.1, 5.2 and 5.3).

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**Figure 5.7** Historical CQ-NQ grid section transfer duration curves



Flooding associated with TC Debbie caused collapse and damage to 19 towers on one of the paralleled 275kV single circuit lines between Broomsound and Nebo. The transmission line was subsequently returned to service with a large section unparallelled. The system normal capacity of the grid section is not impacted. The damaged towers are scheduled for rectification during 2017.

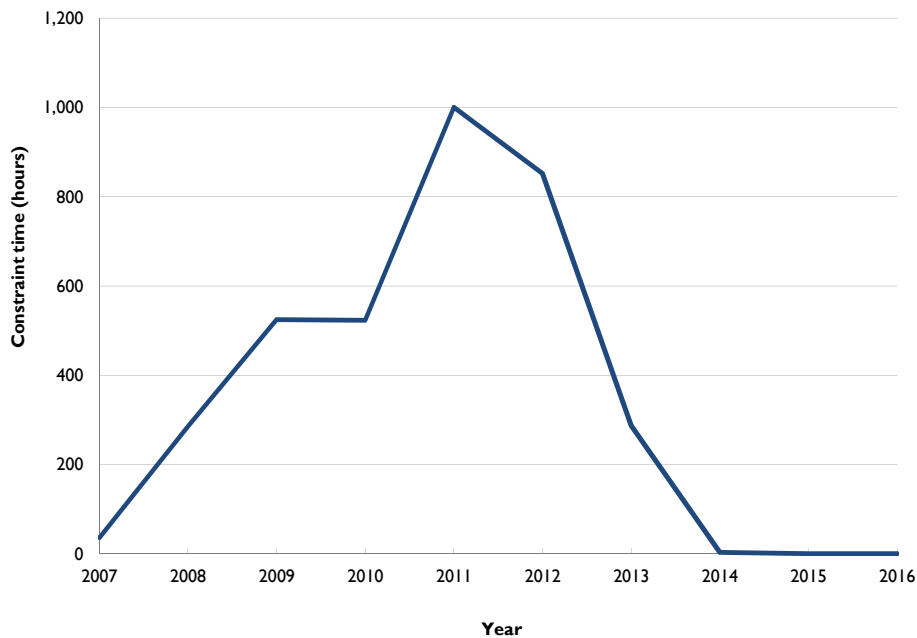
The recent commitment of variable renewable electricity (VRE) generators (refer to Table 5.1) in north Queensland are expected to reduce CQ-NQ transfers, especially during daylight hours. CQ-NQ transfer duration curves in future years are expected to reflect these new transfer patterns with a downward 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 6.2.4.

### 5.5.3 Gladstone grid section

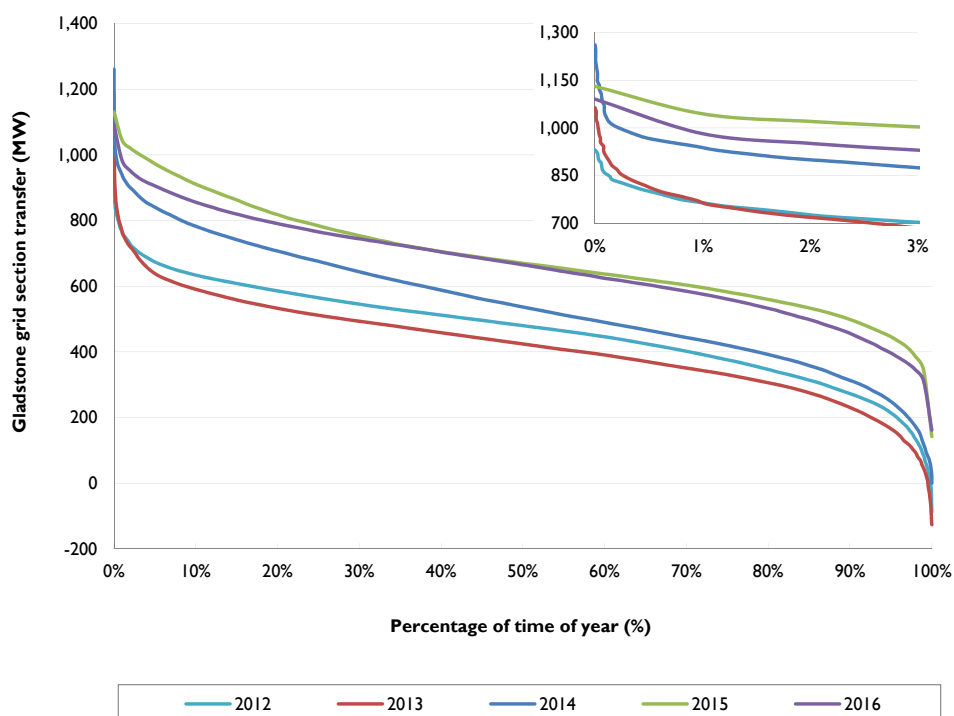
Maximum power transfer across the Gladstone grid section is set by the thermal rating of the Bouldercombe to Raglan, Larcom Creek to Calliope River, Calvale to Wurdong or the Calliope River to Wurdong 275kV circuits, or the Calvale 275/132kV transformer.

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 5.8. During 2016, the Gladstone grid section experienced 0.42 hours of constrained operation.

**Figure 5.8** 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 5.9 provides historical transfer duration curves showing a slight decrease in utilisation in 2016 compared to 2015. This reduction in transfer is predominantly associated with a significant increase in Gladstone zone generation (refer to figures 5.1, 5.2 and 5.3).

**Figure 5.9** Historical Gladstone grid section transfer duration curves

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The utilisation of the Gladstone grid section is expected to increase if the newly 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.

### 5.5.4 Central Queensland to South Queensland grid section

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

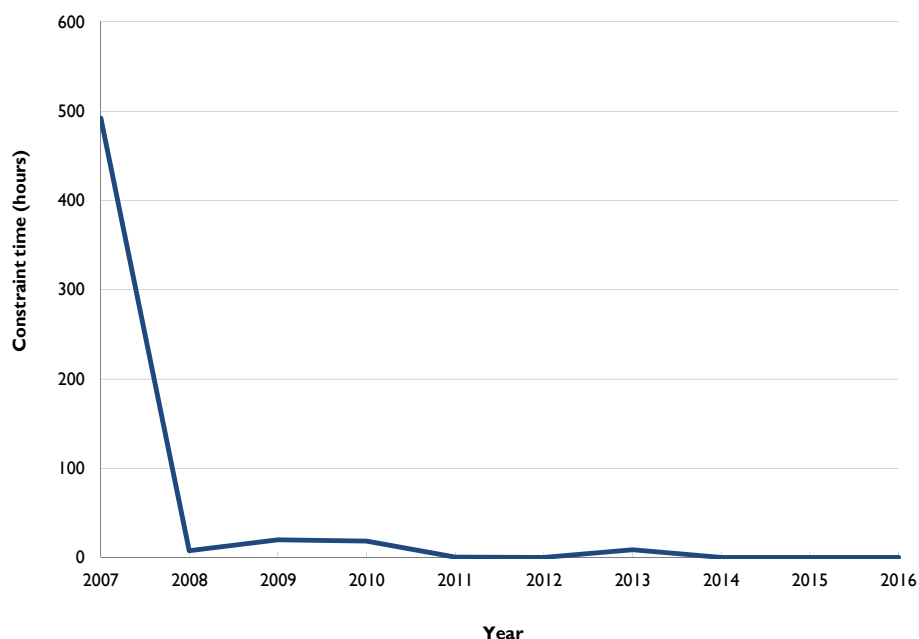
The voltage stability limit is set by insufficient reactive power reserves in the Central West and Gladstone zones following a contingency. More generating units online in these zones increase reactive power support and therefore transfer capability.

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

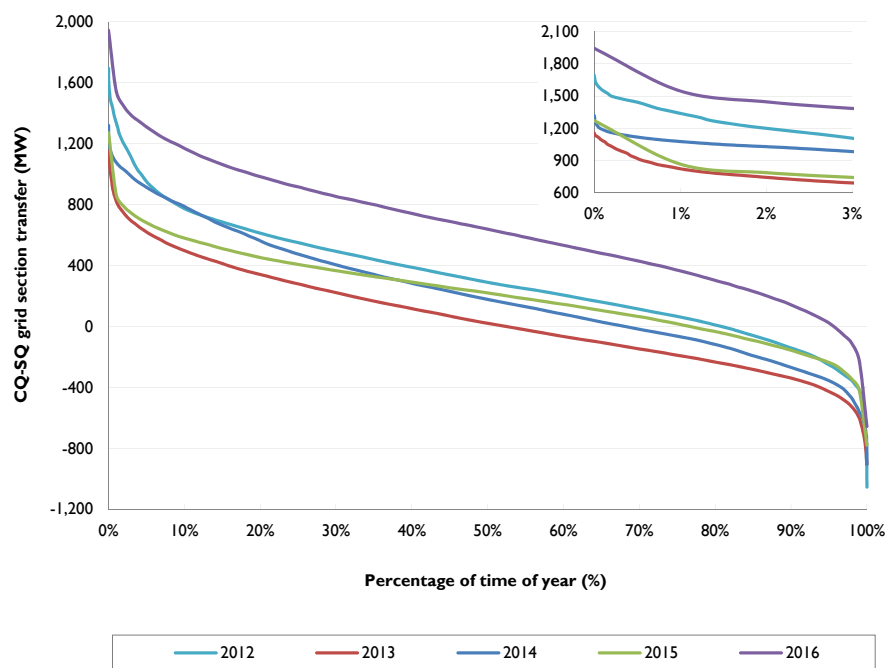
- number of generating units online in the Central West and Gladstone zones
- level of Gladstone Power Station generation.

The CQ-SQ grid section did not constrain operation during April 2016 to March 2017. Information pertaining to the historical duration of constrained operation for the CQ-SQ grid section is summarised in Figure 5.10.

**Figure 5.10** Historical CQ-SQ grid section constraint times



The reduction in constraint times since 2007 to near zero levels can be attributed to lower central to southern Queensland transfers. Central to southern Queensland energy transfers have seen a sharp decline following the commissioning of significant levels of generation in the South West Queensland (SWQ) area between 2006 and 2010. Figure 5.11 provides historical transfer duration curves showing a large increase in utilisation in 2016. This increase in transfer is predominantly due to a significant reduction in generation from the gas fuelled generators in the Bulli zone substituted by generation in central and north Queensland (refer to figures 5.1, 5.2 and 5.3). 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 5.11** 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 or economic life from the next five to 10 years. This is discussed in Section 6.3.3.

#### 5.5.5 Surat grid section

The Surat grid section was introduced in the 2014 TAPR in preparation for the establishment of the Columboola to Western Downs 275kV transmission line<sup>6</sup>, 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. This is because the reduction in power transfer due to increased local generation is greater than the reduction in grid section transfer capability.

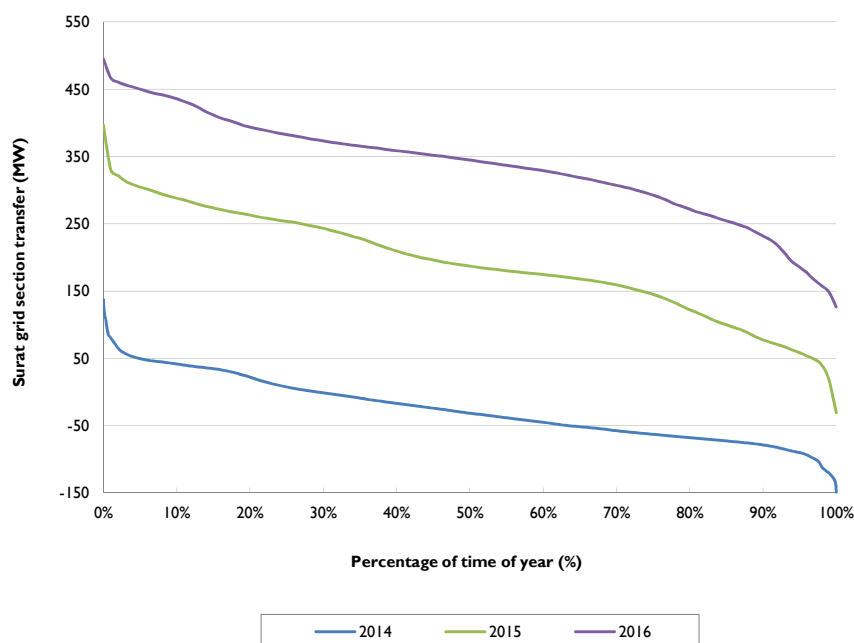
There have been no constraints recorded over the brief history of the Surat grid section.

Figure 5.12 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 net importer of energy.

<sup>6</sup> The Orana Substation is connected to one of the Columboola to Western Downs 275kV transmission lines.

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**Figure 5.12** 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.

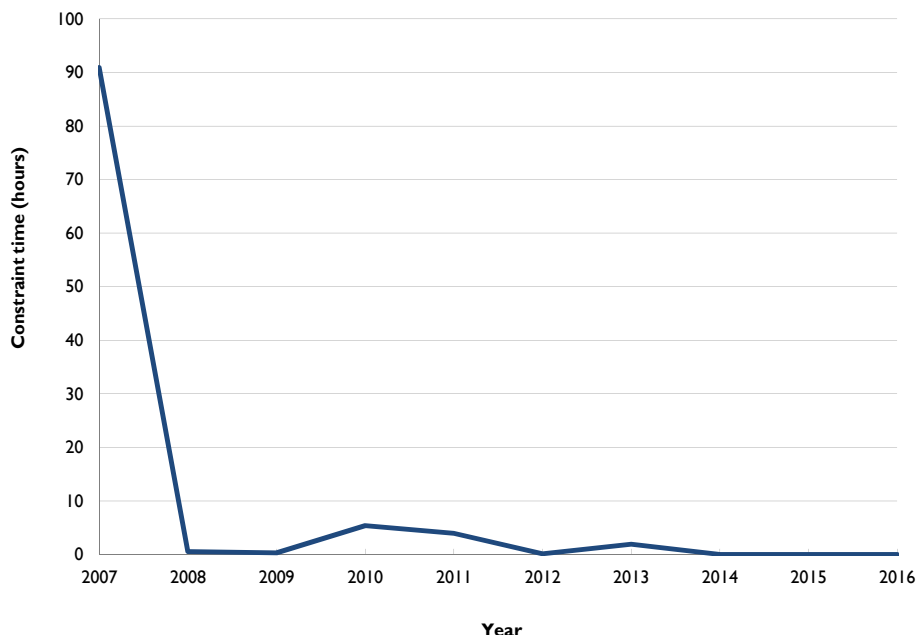
The development of large loads in Surat (additional to those included in the forecasts), without corresponding increases in generation, can significantly increase the levels of Surat grid section transfers. This is discussed in Section 6.2.4.

### 5.5.6 South West Queensland grid section

The 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 2016 to March 2017. Information pertaining to the historical duration of constrained operation for the SWQ grid section is summarised in Figure 5.13.

Figure 5.13 Historical SWQ grid section constraint times

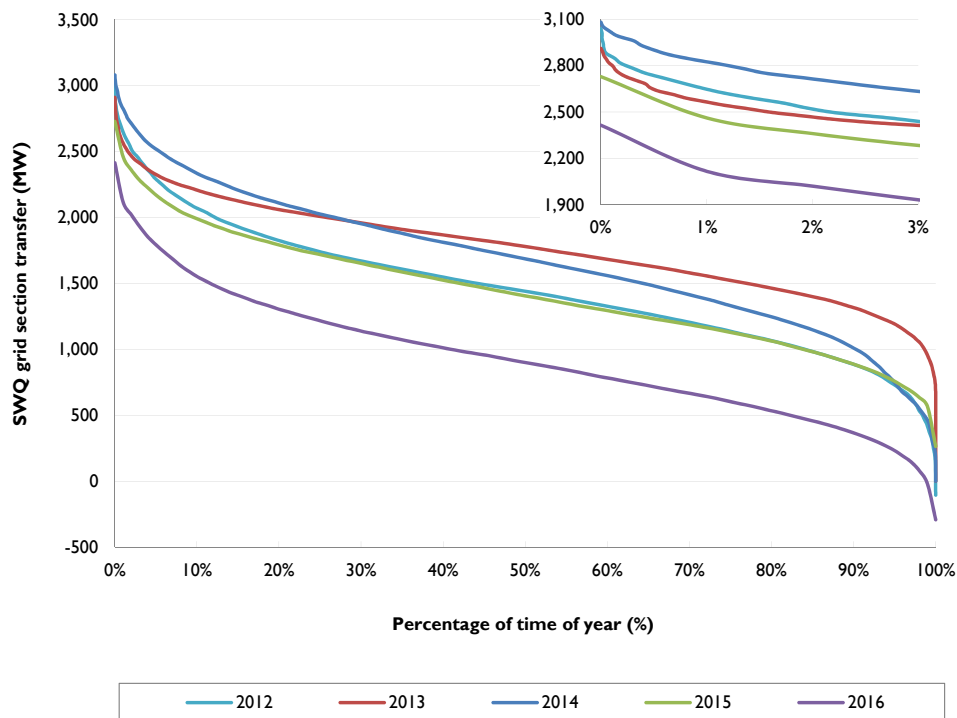


The commissioning of significant levels of base load generation in the SWQ area between 2006 and 2010 increased the utilisation of this grid section. The majority of constraint times in the 2007 period were due to thermal constraint equations ensuring operation within plant thermal ratings during planned outages.

Figure 5.14 provides historical transfer duration curves showing a reduction in 2016 energy transfer to levels compared to 2015. Reductions in gas fuelled generation in the Bulli zone, increases in SW zone generation and CQ-SQ transfers (refer to figures 5.1, 5.2 and 5.3) are predominantly responsible for the reduction in SWQ utilisation.

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Figure 5.14 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.

### 5.5.7 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.

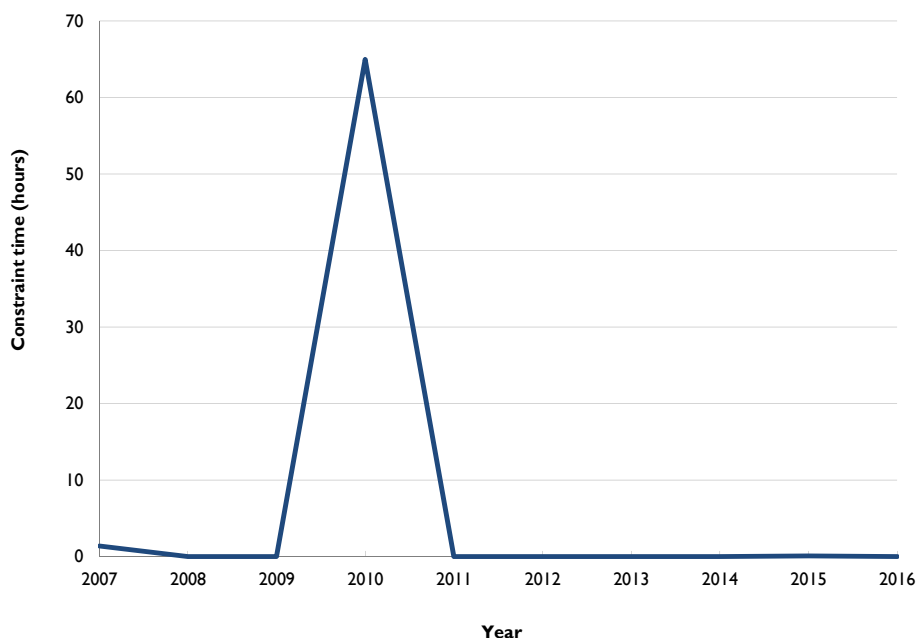
Limit equations in Table D.4 of Appendix D show that the following variables have a significant effect on transfer capability:

- 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 2016 to March 2017. Information pertaining to the historical duration of constrained operation for the Tarong grid section is summarised in Figure 5.15.

Figure 5.15 Historical Tarong grid section constraint times

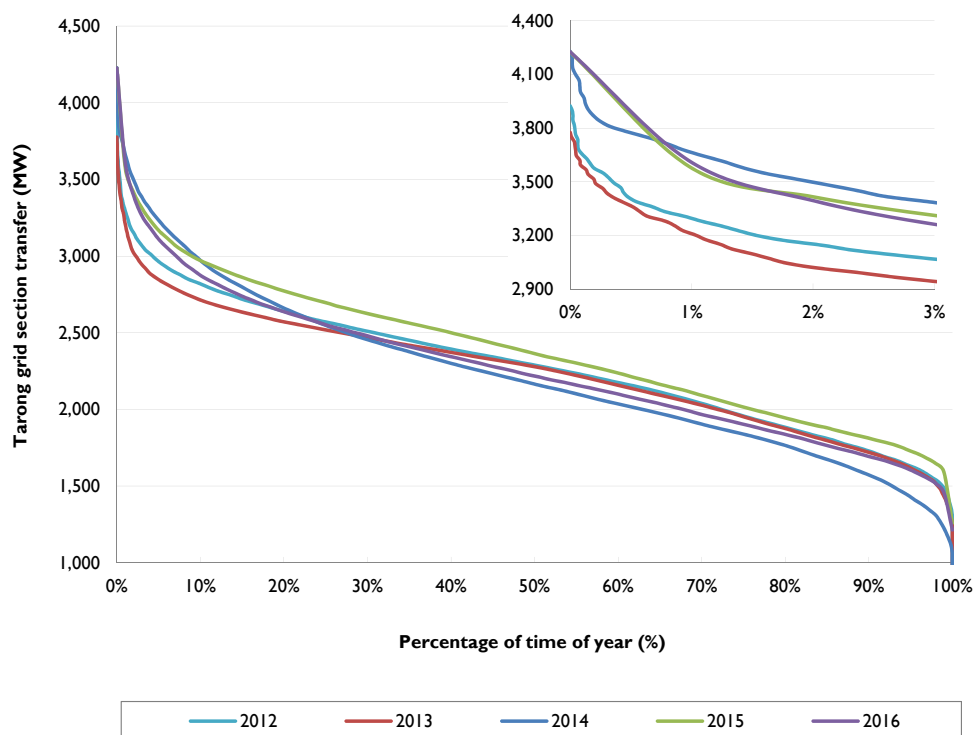


Constraint times have been minimal over the last 10 years, with the exception of 2010/11 where constraint times are associated with line outages as a result of severe weather events in January 2011.

Figure 5.16 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 placed into cold storage in December 2014. The 2016 trace reflects high transfers associated with high summer demand (refer to figures 5.1, 5.2 and 5.3).

## 5 Network capability and performance

**Figure 5.16** 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.

### 5.5.8 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.

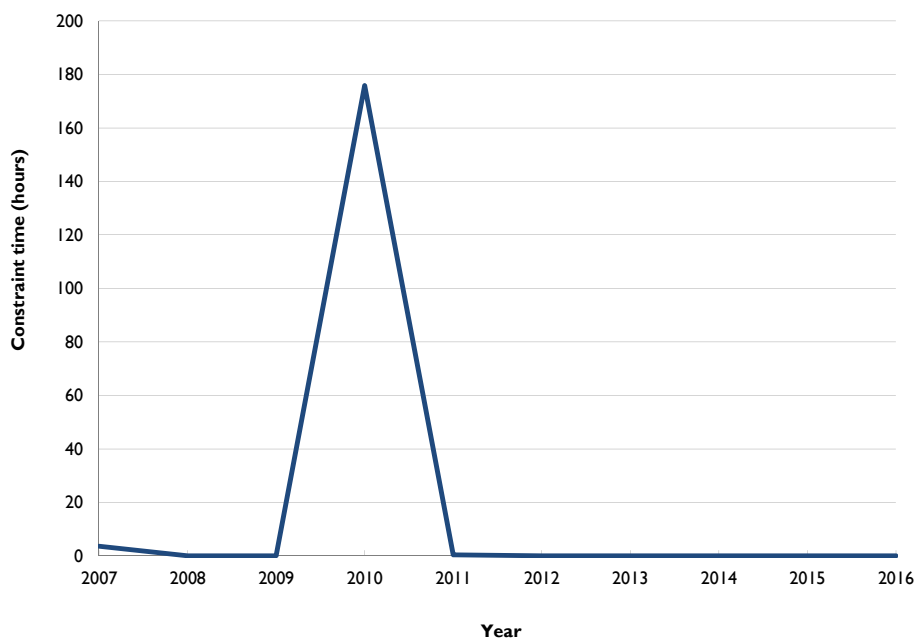
The limit equation in Table D.5 of Appendix D shows that the following variables have a significant effect on transfer capability:

- 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 2015 to March 2016. Information pertaining to the historical duration of constrained operation for the Gold Coast grid section is summarised in Figure 5.17.

Figure 5.17 Historical Gold Coast grid section constraint times

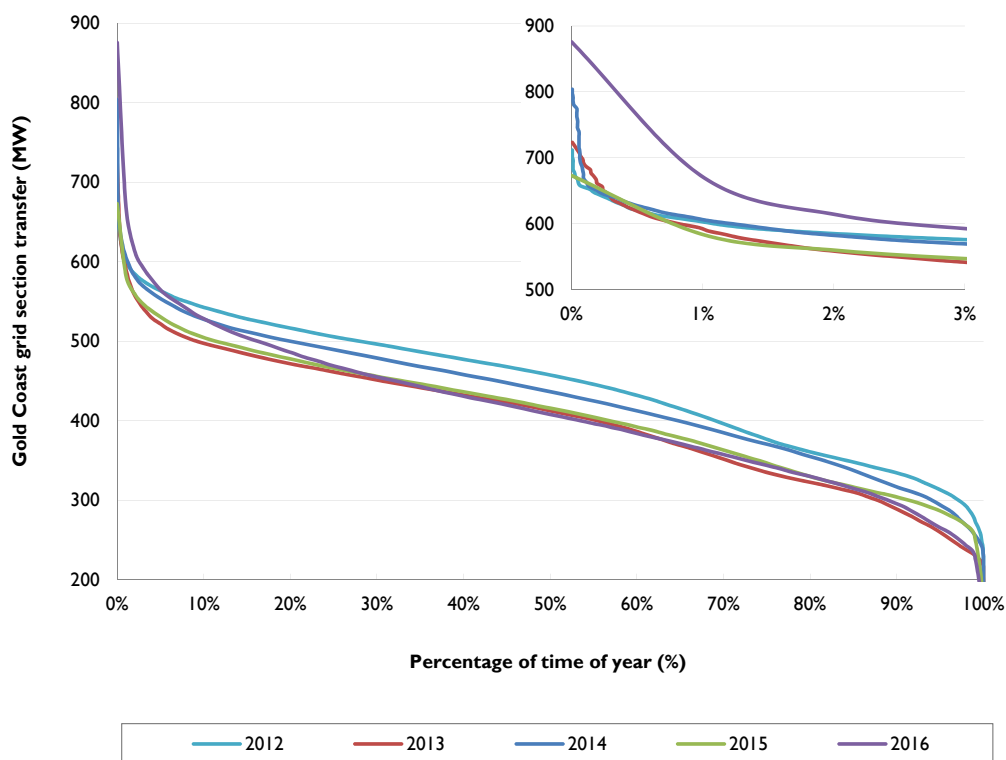


Powerlink delivered increases to the Gold Coast grid section transfer capacity with projects including the establishment of the Greenbank Substation in 2006/07 and Greenbank SVC in 2008/09. Constraint times have been minimal since 2007, with the exception of 2010 where constraint times are associated with the planned outage of one of the 275kV Greenbank to Mudgeeraba feeders.

Figure 5.18 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 higher in 2016 compared to 2015 (refer to figures 5.1, 5.2 and 5.3).

## 5 Network capability and performance

Figure 5.18 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. An approved project is underway to replace one of transformer. This is discussed in Section 4.2.8.

### 5.5.9 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, 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.

In 2014, Powerlink and TransGrid completed a Regulatory Investment Test for Transmission (RIT-T) consultation which described the outcomes of a detailed technical and economic assessment into the upgrade of QNI. This is discussed further in Section 6.5.2.

AEMO's 2016 National Transmission Development Plan (NTNDP) indicated net positive market benefits in increasing the capability of QNI from 2026/27. This is discussed further in Section 6.5.2.

## 5.6 Zone performance

This section presents, where applicable, a summary of:

- the capability of the transmission network to deliver 2016 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) 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.

### 5.6.1 Far North zone

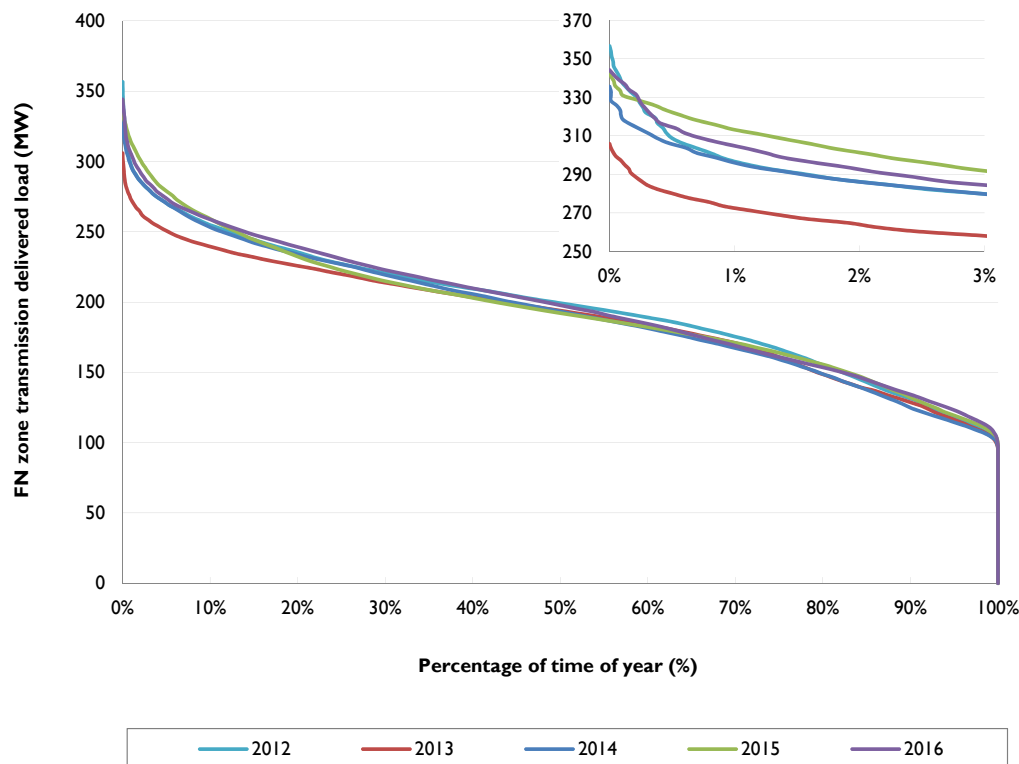
The Far North zone experienced no load loss for a single network element outage during 2016.

The Far North zone contains no scheduled/semi-scheduled embedded generators or significant non-scheduled embedded generators as defined in Figure 2.4.

Figure 5.19 provides historical transmission delivered load duration curves for the Far North zone. Energy delivered from the transmission network has increased by 1.0% between 2015 and 2016. The maximum transmission delivered demand in the zone was 344MW which is below the highest maximum demand over the last five years of 357MW set in 2012.

## 5 Network capability and performance

Figure 5.19 Historical Far North zone transmission delivered load duration curves



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

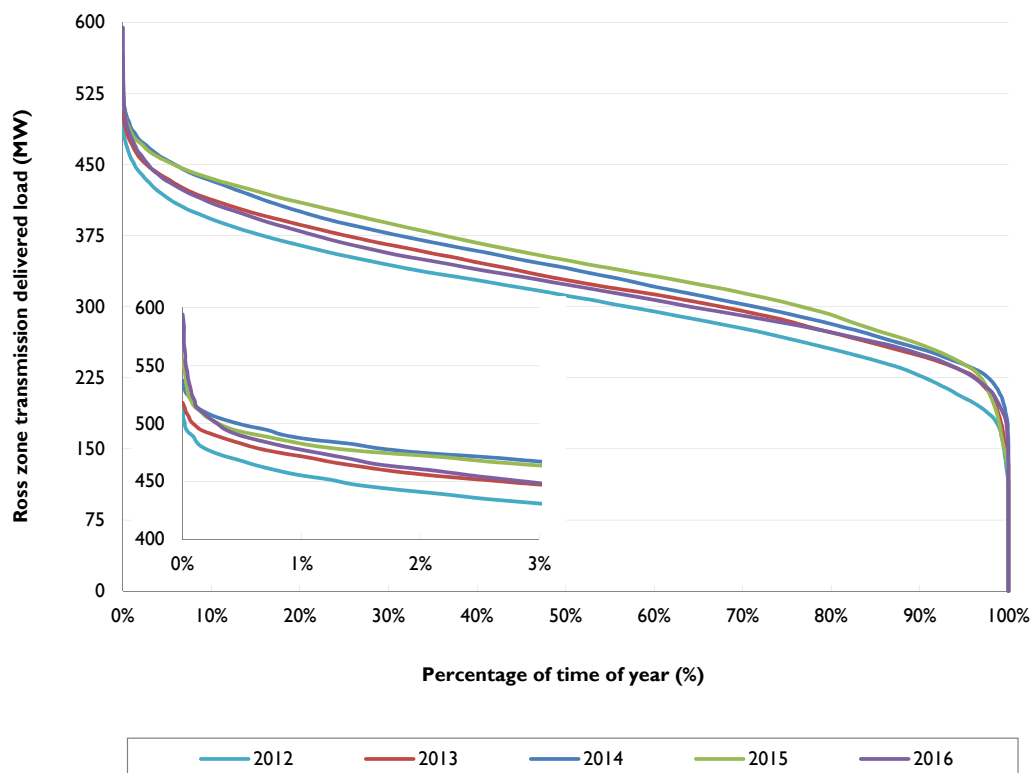
High voltages associated with light load conditions are managed with existing reactive sources. The need for voltage control devices increased with the reinforcements of the Strathmore to Ross 275kV double circuit transmission line and the replacement of the coastal 132kV transmission lines between Yabulu 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.

### 5.6.2 Ross zone

The Ross zone experienced no load loss for a single network element outage during 2016.

The Ross zone includes the scheduled embedded Townsville Power Station 66kV component and the significant non-scheduled embedded generator at Pioneer Mill as defined in Figure 2.4. These embedded generators provided approximately 309GWh during 2016.

Figure 5.20 provides historical transmission delivered load duration curves for the Ross zone. Energy delivered from the transmission network has reduced by 6.6% between 2015 and 2016 predominantly due to the increase in embedded generation. The peak transmission delivered demand in the zone was 594MW which is the highest maximum demand for the zone.

**Figure 5.20** Historical Ross zone transmission delivered load duration curves

As a result of double circuit outages associated with lightning strikes, AEMO have 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.

### 5.6.3 North zone

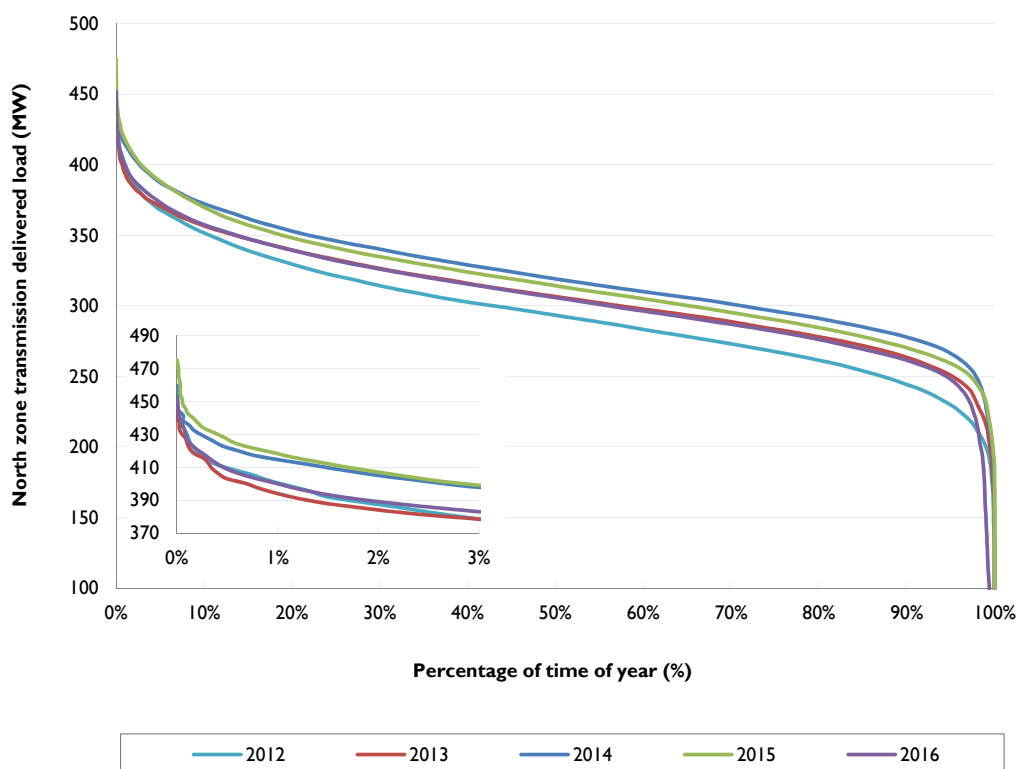
The North zone experienced no load loss for a single network element outage during 2016.

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 679GWh during 2016.

Figure 5.21 provides historical transmission delivered load duration curves for the North zone. Energy delivered from the transmission network has reduced by 3.8% between 2015 and 2016 predominantly due to the increase in embedded generation. The peak transmission delivered demand in the zone was 452MW which is below the highest maximum demand over the last five years of 475MW set in 2015.

## 5 Network capability and performance

**Figure 5.21** Historical North zone transmission delivered load duration curves



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

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

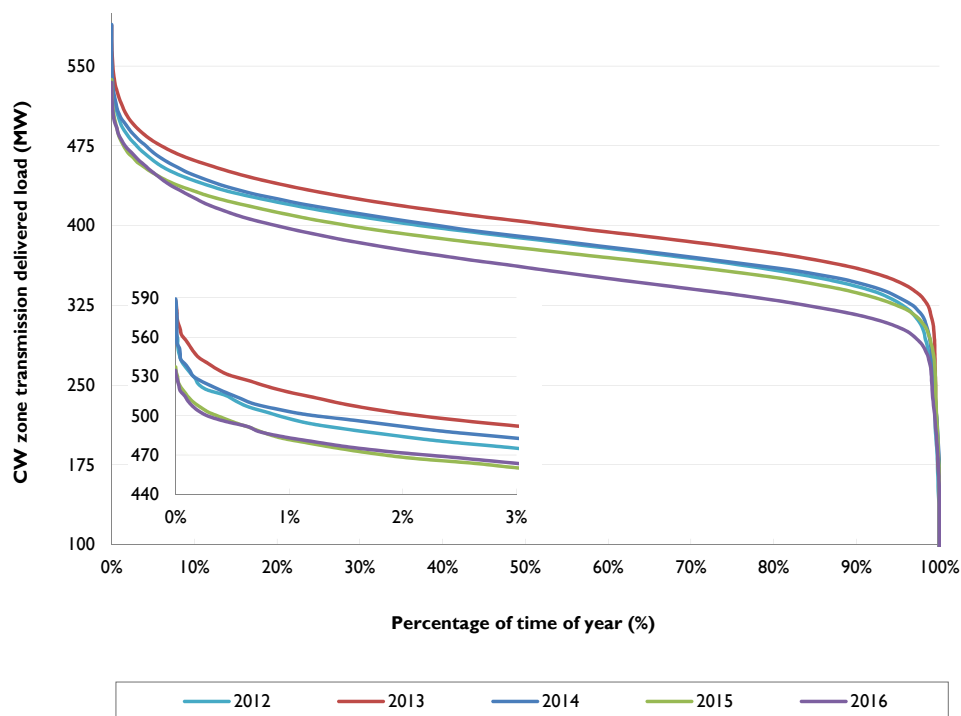
High voltages associated with light load conditions are managed with existing reactive sources. A Braemar 275kV reactor was relocated to replace two transformer tertiary connected reactors decommissioned due to condition at Nebo Substation in August 2013. Generation developments in the Braemar area resulted 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.

### 5.6.4 Central West zone

The Central West zone experienced no load loss for a single network element outage during 2016.

The Central West zone includes the scheduled embedded Barcaldine generator and significant non-scheduled embedded generators Barcaldine SF, German Creek and Oaky Creek as defined in Figure 2.4. These embedded generators provided approximately 439GWh during 2016.

Figure 5.22 provides historical transmission delivered load duration curves for the Central West zone. Energy delivered from the transmission network has reduced by 4.5% between 2015 and 2016. The peak transmission delivered demand in the zone was 535MW which is below the highest maximum demand over the last five years of 589MW set in 2014.

**Figure 5.22** Historical Central West zone transmission delivered load duration curves

As a result of double circuit outages associated with lightning strikes, AEMO include 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.

#### 5.6.5 Gladstone zone

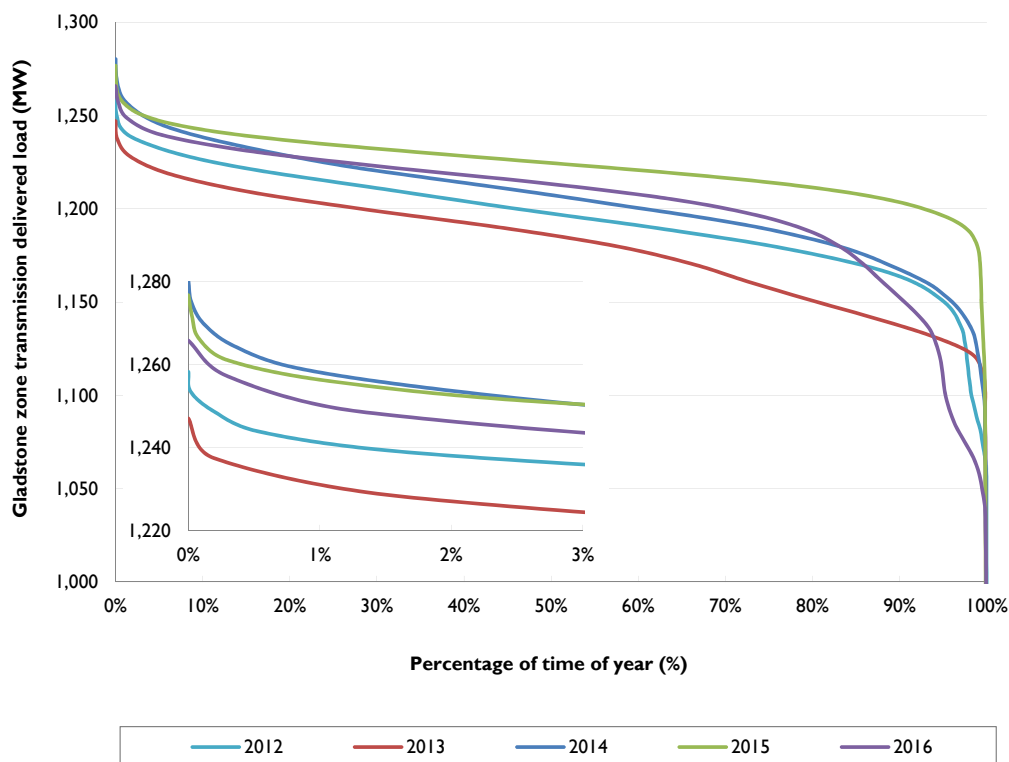
The Gladstone zone experienced no load loss for a single network element outage during 2016.

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

Figure 5.23 provides historical transmission delivered load duration curves for the Gladstone zone. Energy delivered from the transmission network has reduced by 2.0% between 2015 and 2016. The peak transmission delivered demand in the zone was 1,266MW which is below the highest maximum demand over the last five years of 1,280MW set in 2014.

## 5 Network capability and performance

Figure 5.23 Historical Gladstone zone transmission delivered load duration curves

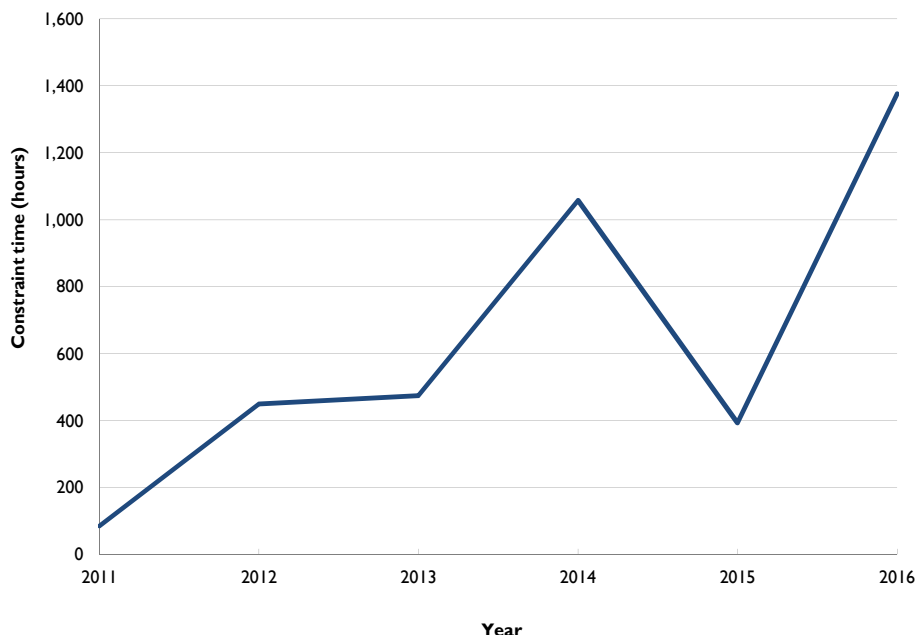


Constraints occur within the Gladstone zone under intact network conditions. These constraints are associated with maintaining power flows within the continuous current rating of a 132kV feeder bushing within Boyne Smelters Limited's substation. The constraint limits generation from Gladstone Power Station, mainly from the units connected at 132kV. AEMO identify this constraint by constraint identifier Q>NIL\_BI\_FB. This constraint was implemented in AEMO's market system from September 2011. During the 2016 period, 1,377 hours were recorded against this constraint.

A project was considered by Powerlink and AEMO under the NCIPAP to address this congestion. The project was found not to be economically feasible at this time.

Information pertaining to the historical duration of constrained operation due to this constraint is summarised in Figure 5.24. The trend is reflective of the operation of the two 132kV connected Gladstone Power Station units. The annual energy production from Gladstone PS 132kV connected units in the 2016 period was the highest in the six year period.

Figure 5.24 Historical Q>NIL\_BI\_FB constraint times



#### 5.6.6 Wide Bay zone

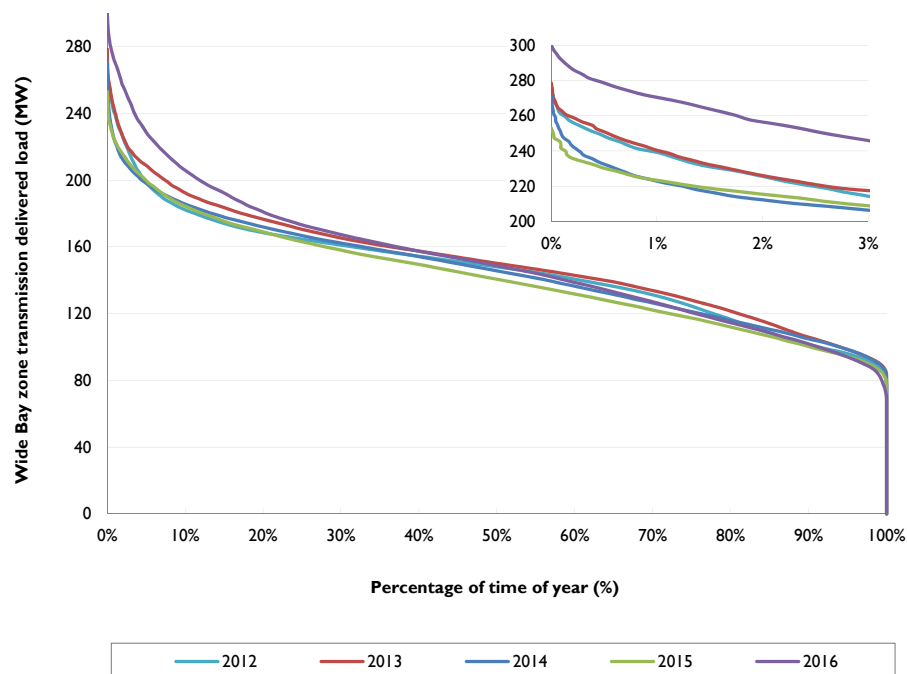
The Wide Bay zone experienced no load loss for a single network element outage during 2016.

The Wide Bay zone includes the non-scheduled embedded Isis Central Sugar Mill as defined in Figure 2.4. This embedded generator provided approximately 23GWh during 2016.

Figure 5.25 provides historical transmission delivered load duration curves for the Wide Bay zone. Energy delivered from the transmission network increased by 6.4% between 2015 and 2016 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 300MW which is the highest maximum demand over the last five years.

## 5 Network capability and performance

Figure 5.25 Historical Wide Bay zone transmission delivered load duration curves

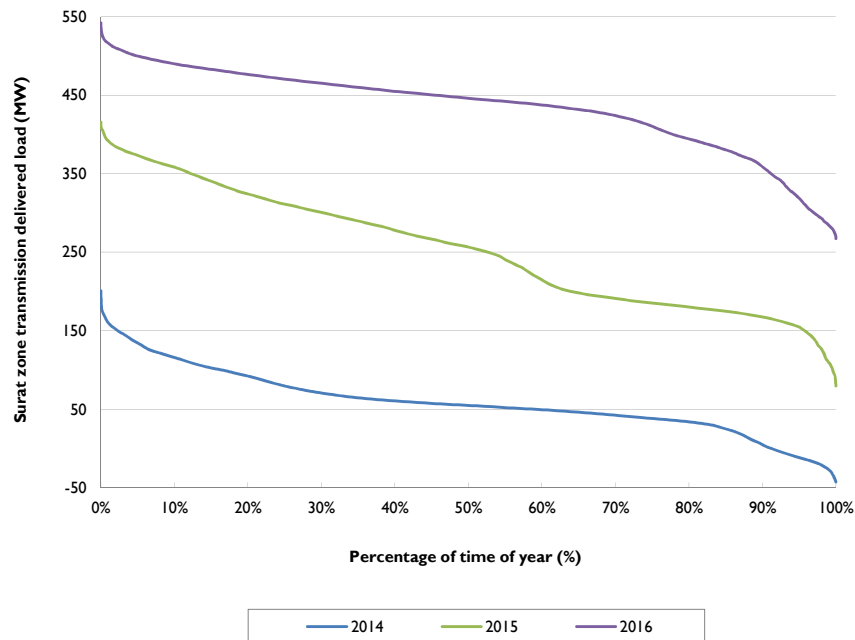


### 5.6.7 Surat zone

The Surat zone experienced no load loss for a single network element outage during 2016.

The Surat zone includes the scheduled embedded Roma generator as defined in Figure 2.4. This embedded generator provided approximately 71GWh during 2016.

The Surat zone was introduced in the 2014 TAPR, Figure 5.26 provides transmission delivered load duration curve since its introduction. The curves reflect the ramping of CSG load in the zone.

**Figure 5.26** Historical Surat zone transmission delivered load duration curves

As a result of double circuit outages associated with lightning strikes, AEMO include 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 March 2015.

#### 5.6.8 Bulli zone

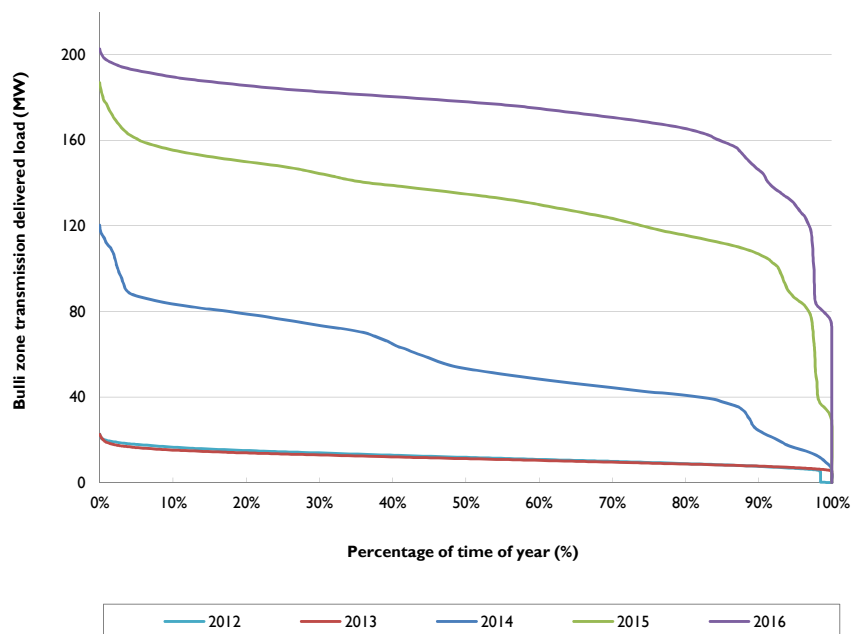
The Bulli zone experienced no load loss for a single network element outage during 2016.

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

Figure 5.27 provides historical transmission delivered load duration curves for the Bulli zone. Energy delivered from the transmission network has increased by approximately 30.9% between 2015 and 2016. The peak transmission delivered demand in the zone was 203MW. The significant increase is due to the ramping up of CSG load in the zone.

## 5 Network capability and performance

Figure 5.27 Historical Bulli zone transmission delivered load duration curves



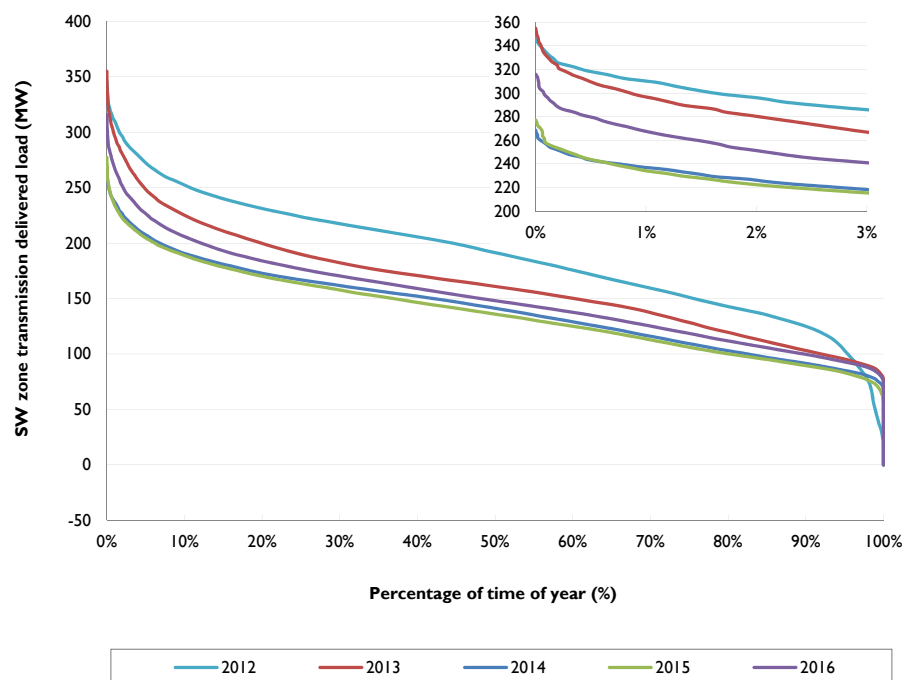
### 5.6.9 South West zone

The South West zone experienced no load loss for a single network element outage during 2016.

The South West zone includes the significant non-scheduled embedded Daandine Power Station as defined in Figure 2.4. This embedded generator provided approximately 241GWh during 2016.

Figure 5.28 provides historical transmission delivered load duration curves for the South West zone. Energy delivered from the transmission network has increased by 9.5% between 2015 and 2016. The peak transmission delivered demand in the zone was 316MW.

Figure 5.28 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 identify 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. During the 2016 period, 29.17 hours of constraints were recorded against this constraint.

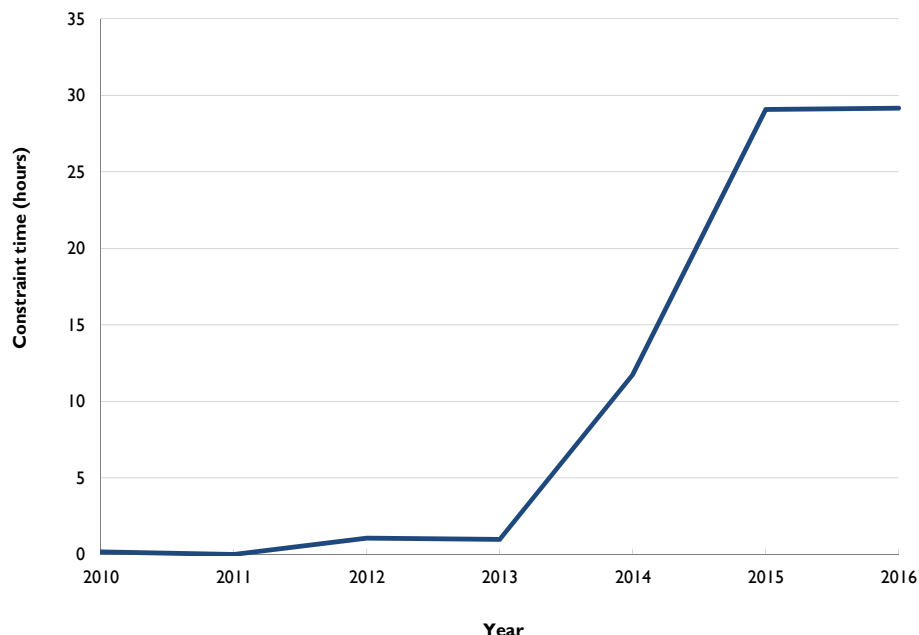
Projects were considered by Powerlink and AEMO under the NCIPAP to address this congestion. These projects were found not to be economically feasible at this time.

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 5.29.

## 5 Network capability and performance

Figure 5.29 Historical Q>NIL\_MRTA\_A and Q>NIL\_MRTA\_B constraint times

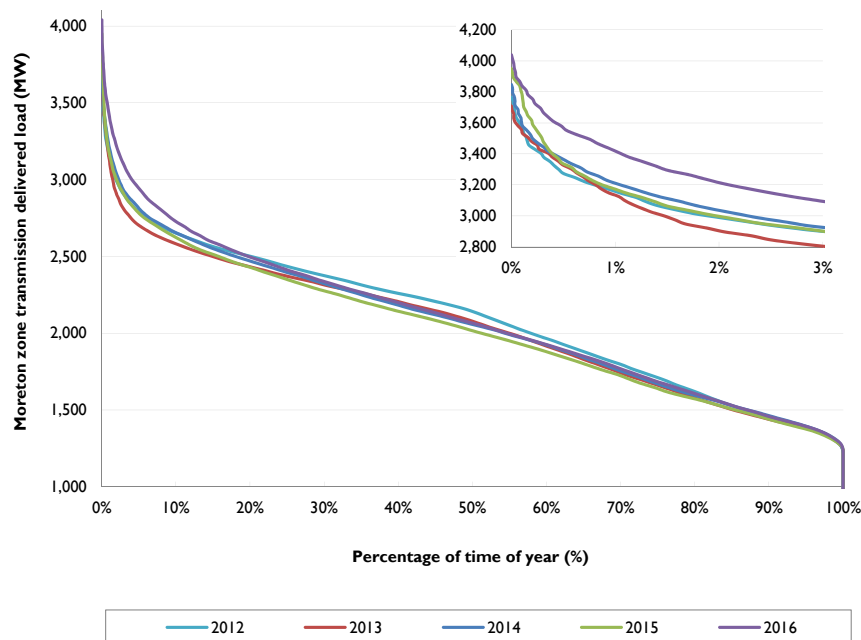


### 5.6.10 Moreton zone

The Moreton zone experienced no load loss for a single network element outage during 2016.

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 18GWh during 2016.

Figure 5.30 provides historical transmission delivered load duration curves for the Moreton zone. Energy delivered from the transmission network has increased by 2.7% between 2015 and 2016 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 4,040MW which exceeds the previous transmission delivered demand of 4,023MW set in 2009/10.

**Figure 5.30** Historical Moreton zone transmission delivered load duration curves

High voltages associated with light load conditions are managed with existing reactive sources. In preparation for the withdrawal of Swanbank E, Powerlink and AEMO agreed on a 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.

#### 5.6.11 Gold Coast zone

The Gold Coast zone experienced no load loss for a single network element outage during 2016.

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

Figure 5.31 provides historical transmission delivered load duration curves for the Gold Coast zone. Energy delivered from the transmission network has increased by 1.7% between 2015 and 2016 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 727MW which is the highest maximum demand over the last five years.

## 5 Network capability and performance

Figure 5.31 Historical Gold Coast zone transmission delivered load duration curves

