CHAPTER 8

Network capability and performance

8 Network capability and performance

Key highlights

- Generation commitments since the 2021 Transmission Annual Planning Report (TAPR) add 740MW to Queensland's semi-scheduled variable renewable energy (VRE) generation capacity taking the total existing and committed semi-scheduled VRE generation capacity to 4,934MW.
- Storage commitments since the 2021 TAPR include the 50MW 2 hour Bouldercombe Battery energy storage system (BESS).
- Record peak transmission delivered demand was recorded for the Ross, North, Central West, Surat, South West and Moreton zones during 2021/22.
- The transmission network has performed reliably during 2021/22, with Queensland grid sections largely unconstrained.

8.1 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
- a summary of the management of high voltages associated with light load conditions
- double circuit transmission lines categorised as vulnerable by the Australian Energy Market Operator (AEMO).

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 3.9.

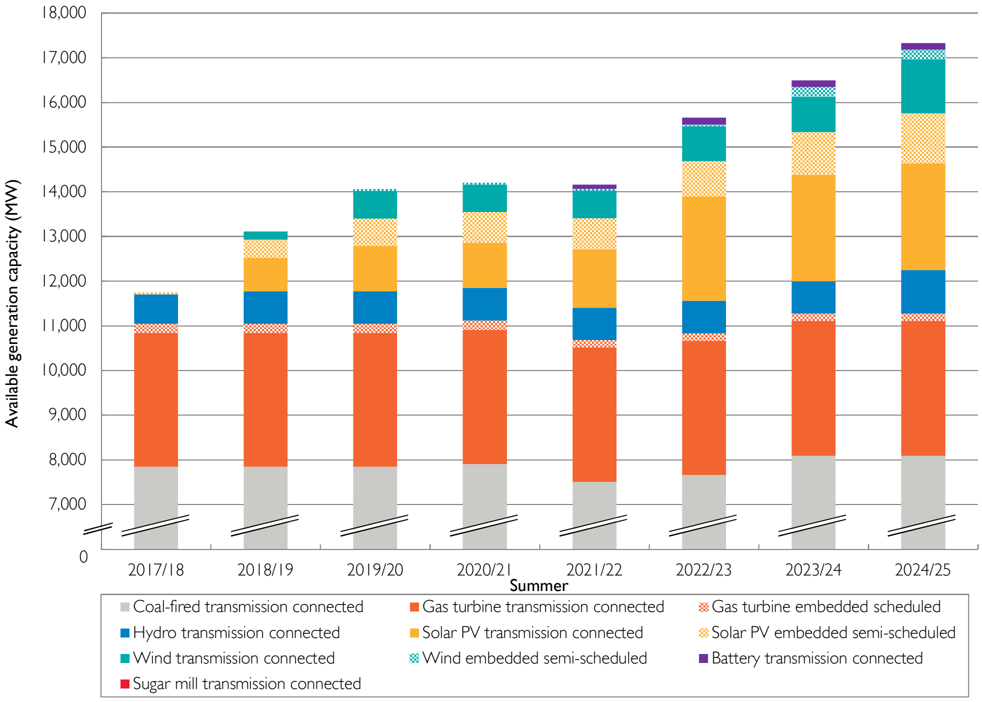
The location and pattern of generation dispatch influences power flows across most of the Queensland network. Future generation dispatch patterns and interconnector flows are uncertain in the deregulated electricity market and will vary substantially due to output of VRE generation and due to the effect 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 3.17) and/or when embedded generation output is lower.

8.2 Available generation capacity

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

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 2021/22, commitments have added 740MW of semi-scheduled VRE capacity, taking Queensland's semi-scheduled VRE generation capacity to 4,934MW. Figure 8.1 illustrates the expected changes to available and committed large-scale generation capacity in Queensland from summer 2017/18 to summer 2024/25.

Figure 8.1 Summer available generation capacity by energy source



8.2.1 Existing and committed transmission connected and direct connect embedded generation

Table 8.1 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 to Powerlink's direct connect customers.

Scheduled transmission connected Bouldercombe BESS has reached committed status since the 2021 TAPR.

Semi-scheduled transmission connected Wandoan South Solar Farm and Clarke Creek Wind Farm have reached committed status since the 2021 TAPR.

Rodds Bay Solar Farm has been de-committed since the 2021 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 National Electricity Rules (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.

8 Network capability and performance

Table 8.1 Available generation capacity – existing and committed generators connected to the Powerlink transmission network or direct connect customers

Generator	Location	Available capacity MW generated (1) Summer 2022/23	Winter 2023	Summer 2023/24	Winter 2024	Summer 2024/25	Winter 2025
Coal-fired							
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	434	886	854	886	854	886
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 PS	720	750	730	750	730	750
Millmerran	Millmerran PS	822	852	822	852	822	852
Total coal-fired		7,659	8,171	8,089	8,171	8,089	8,171
Gas turbine							
Townsville 132kV	Townsville GT PS	150	165	150	165	150	165
Mt Stuart	Townsville South	387	400	387	400	387	400
Yarwun (2)	Yarwun	160	155	160	155	160	155
Condamine (3)	Columboola	139	144	139	144	139	144
Braemar 1	Braemar	491	543	501	543	501	543
Braemar 2	Braemar	480	519	480	519	480	519
Darling Downs	Braemar	563	630	563	630	563	630
Oakey (4)	Tangkam	288	346	288	346	288	346
Swanbank E	Swanbank E PS	350	365	350	365	350	365
Total gas turbine		3,008	3,267	3,018	3,267	3,018	3,267
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
Kidston Pumped Hydro Storage (6)	Kidston					250	250
Total hydro-electric		729	729	729	729	979	979
Solar PV (7)							
Ross River	Ross	116	116	116	116	116	116
Sun Metals (3)	Townsville Zinc	121	121	121	121	121	121
Haughton	Haughton River	100	100	100	100	100	100

Table 8.1 Available generation capacity - existing and committed generators connected to the Powerlink transmission network or direct connect customers (*continued*)

Generator	Location	Available capacity MW generated (1)					
		Summer 2022/23	Winter 2023	Summer 2023/24	Winter 2024	Summer 2024/25	Winter 2025
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
Moura	Moura	82	82	82	82	82	82
Woolooga Energy Park	Woolooga	176	176	176	176	176	176
Blue Grass	Chinchilla	148	148	148	148	148	148
Columboola	Columboola	162	162	162	162	162	162
Gangarri	Wandoan South	120	120	120	120	120	120
Wandoan South	Wandoan South	125	125	125	125	125	125
Edenvale Solar Park	Orana	146	146	146	146	146	146
Western Downs Green Power Hub	Western Downs	400	400	400	400	400	400
Darling Downs	Braemar	108	108	108	108	108	108
Total solar PV		2,383	2,383	2,383	2,383	2,383	2,383
Wind (7)							
Mt Emerald	Walkamin	180	180	180	180	180	180
Kaban	Tumoulin	152	152	152	152	152	152
Clarke Creek (8)	Broadsound			440	440	440	440
Coopers Gap	Coopers Gap	440	440	440	440	440	440
Total wind		772	772	1,212	1,212	1,212	1,212
Battery (7)							
Bouldercombe 2h BESS	Bouldercombe	50	50	50	50	50	50
Wandoan South 1.5h BESS	Wandoan South	100	100	100	100	100	100
Total battery		150	150	150	150	150	150
Sugar mill							
Invicta (5)	Invicta Mill	0	34	0	34	0	34
Total sugar mill		0	34	0	34	0	34
Total all stations		**14,701**	**15,506**	**15,581**	**15,946**	**15,831**	**16,196**

Notes:

(1) Synchronous generator capacities shown are at the generator terminals and are therefore greater than Power Station (PS) 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 PS is an open-cycle, dual-fuel, gas-fired PS. The generated capacity quoted is based on gas fuel operation.

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

(6) Wivenhoe and Kidston Pumped Hydro Storage are shown at full capacity. However, output can be limited depending on water storage levels.

(7) VRE generators and batteries are shown at maximum capacity at the point of connection. The capacities are nominal as the generator rating depends on ambient conditions.

(8) Generators undergoing commissioning are shown at full capacity from the anticipated start of commissioning activities. Actual available generating capacity will vary over the course of the commissioning program.

8.2.2 Existing and committed scheduled and semi-scheduled distribution connected embedded generation

Table 8.2 summarises the available generation capacity of embedded scheduled and semi-scheduled power stations connected, or committed to be connected to Queensland's distribution network.

Non-scheduled embedded Daandine was retired since the 2021 TAPR.

Semi-scheduled embedded Bullyard Solar Farm and Bundaberg Solar Farm have reached committed status since the 2021 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 8.2 Available generation capacity – existing and committed scheduled or semi-scheduled generators connected to the Ergon Energy and Energex (part of the Energy Queensland Group) distribution networks.

Generator	Location	Available capacity MW generated (1)					
		Summer 2022/23	Winter 2023	Summer 2023/24	Winter 2024	Summer 2024/25	Winter 2025
Gas turbine (1)							
Townsville 66kV	Townsville GT PS	78	82	78	82	78	82
Barcaldine	Barcaldine	32	37	32	37	32	37
Roma	Roma	54	68	54	68	54	68
Total gas turbine		164	187	164	187	164	187
Solar PV (2)							
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
Middlemount	Lilyvale	26	26	26	26	26	26
Emerald	Emerald	72	72	72	72	72	72
Bundaberg	Gin Gin				78	78	78
Bullyard	Gin Gin				97	97	97
Aramara	Aramara			104	104	104	104
Susan River	Maryborough	75	75	75	75	75	75
Childers	Isis	56	56	56	56	56	56
Munna Creek	Kilkivan			120	120	120	120
Kingaroy	Kingaroy		40	40	40	40	40
Maryrorough	Yarranlea	27	27	27	27	27	27
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	64	64	64	64	64	64
Total solar PV		685	725	949	1,124	1,124	1,124
Wind (2)							
Kennedy Energy Park	Hughenden	43	43	43	43	43	43
Dulacca	Roma			173	173	173	173
Total wind		43	43	216	216	216	216
Total all stations		**892**	**955**	**1,329**	**1,527**	**1,504**	**1,527**

Notes:

(1) Synchronous generator capacities shown are at the generator terminals and are therefore greater than PS 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) VRE generators shown at maximum capacity at the point of connection. The capacities are nominal as the generator rating depends on ambient conditions.

8.3 Network control facilities

Powerlink participated in the 2022 Power System Frequency Risk Review[2] (PSFRR), published by AEMO in July 2022. The PSFRR, as part of the Emergency Frequency Control Schemes (EFCS) 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 has made three recommendations in relation to Queensland in this review:

- Establishment of an Over Frequency Generation Shedding (OFGS) scheme to manage over frequency if QNI separates.
- Implement a Special Protection Scheme (SPS) for the loss of both Columboola to Western Downs 275kV lines. The loss of both of these lines, which supply the Surat zone, is non-credible but could cause QNI to lose stability.
- Assessment of the risk and solution options to further mitigate instability for the non-credible loss of both Calvale to Halys 275kV lines following the commencement of QNI minor commissioning.

Powerlink enhanced the CQ-SQ SPS with a new Wide Area Monitoring, Protection and Control (WAMPAC) architecture by April 2021. The WAMPAC scheme avails approximately 600MW of northern VRE generation and up to 700MW[4] of southern Queensland loads to be tripped along with the existing SPS. Whilst this scheme reduces the exposure to CQ-SQ separation for this non-credible event, it does not cover the full operational envelope of the CQ-SQ grid section flow. Powerlink is assessing the risks ahead of designing a second tranche of the scheme to further reduce the exposure.

AEMO has identified non-credible contingencies outside Queensland that could result in the loss of stability across QNI. AEMO plans to conduct further investigation to consider applying a protected event or installation of appropriate SPS to manage these scenarios.

AEMO has also assessed the network risk against the 2022 Draft ISP Step Change scenario forecasts. This has highlighted the potential for insufficient Under Frequency Load Shedding (UFLS) during periods of high rooftop photovoltaic (PV) output. AEMO requested that Powerlink, in collaboration with Energy Queensland, identify and implement measures to restore UFLS load. A working group has been formed and is progressing this activity.

Associated with high penetration of rooftop PV installations, Powerlink is reviewing the transient stability limits for CQ-SQ and QNI. The review includes dynamic load models that include rooftop PV behaviour. Powerlink will update this limit advice by April 2023.

Powerlink owns other network control facilities that 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 8.3.

[2] AEMO, 2022 Power System Frequency Risk Review, July 2022.

[3] AEMC, Rule Determination National Electricity Amendment (Emergency Frequency Control Schemes) Rule 2017, March 2017.

[4] Includes both 250MW Wivenhoe PS units (if operating in pumping mode).

Table 8.3 Powerlink owned network control facilities configured to disconnect load as a consequence of non-credible events during system normal conditions

Scheme	Purpose
FNQ Under Voltage Load Shed (UVLS) scheme	Minimise risk of voltage collapse in FNQ
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
CQ-SQ N-2 WAMPAC scheme	Minimise risk of CQ-SQ separation for a non-credible loss of the Calvale to Halys 275kV double circuit transmission line
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

8.4 Existing network configuration

Figures 8.2, 8.3, 8.4 and 8.5 illustrate Powerlink's system intact network as of July 2022.

Figure 8.2 Existing HV network July 2022 – North Queensland

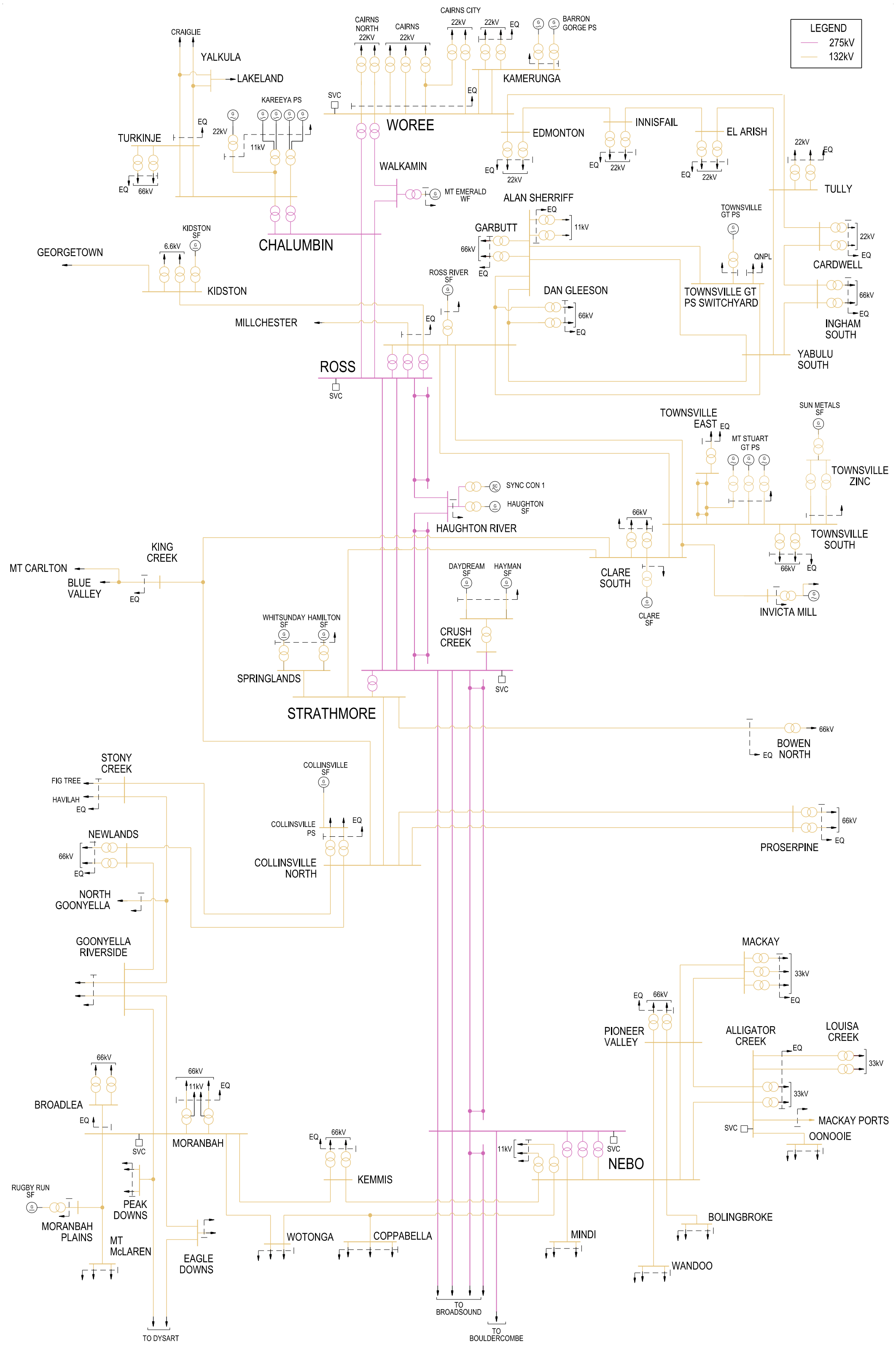


Figure 8.3 Existing HV network July 2022 – Central Queensland

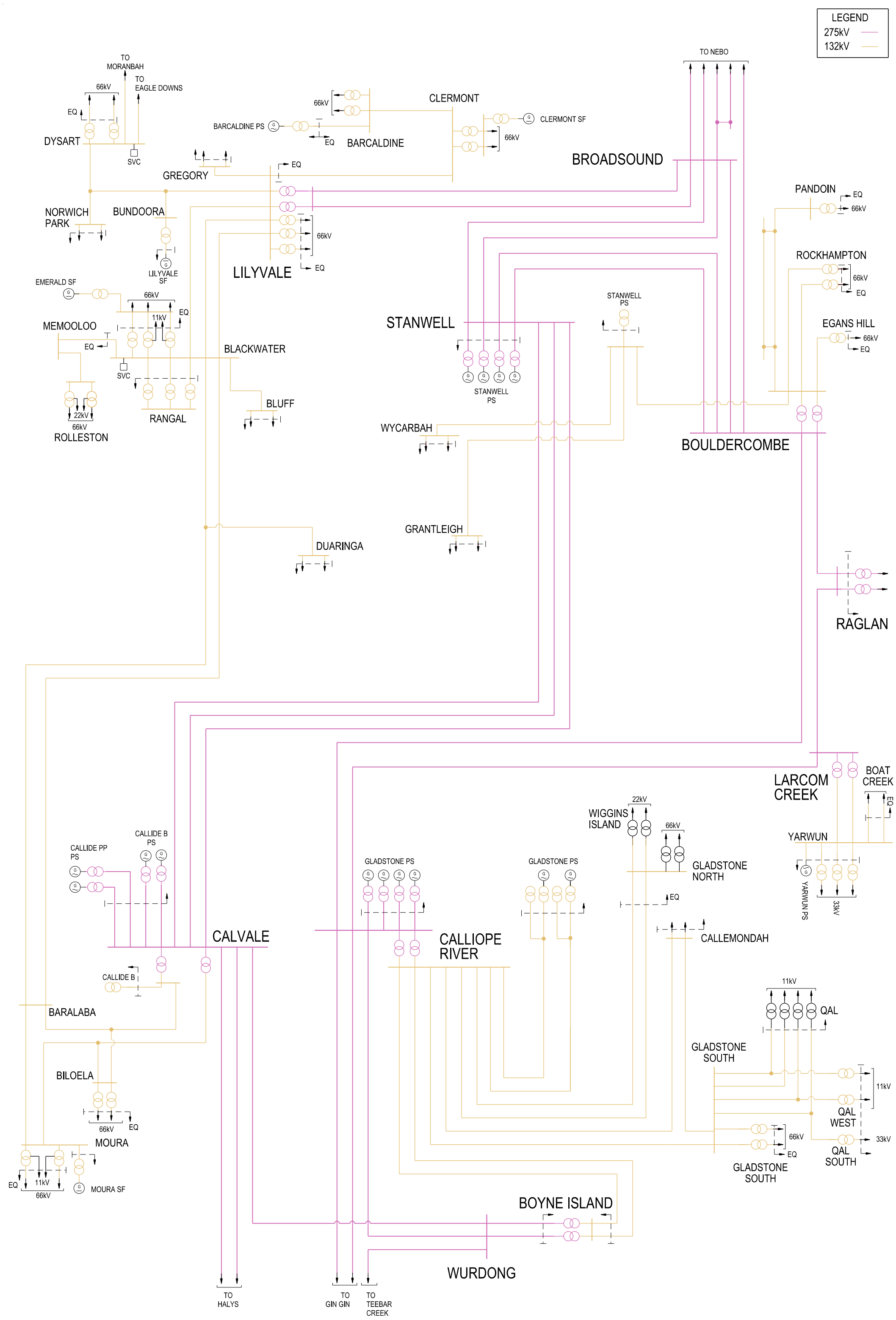


Figure 8.4 Existing HV network July 2022 - South West Queensland

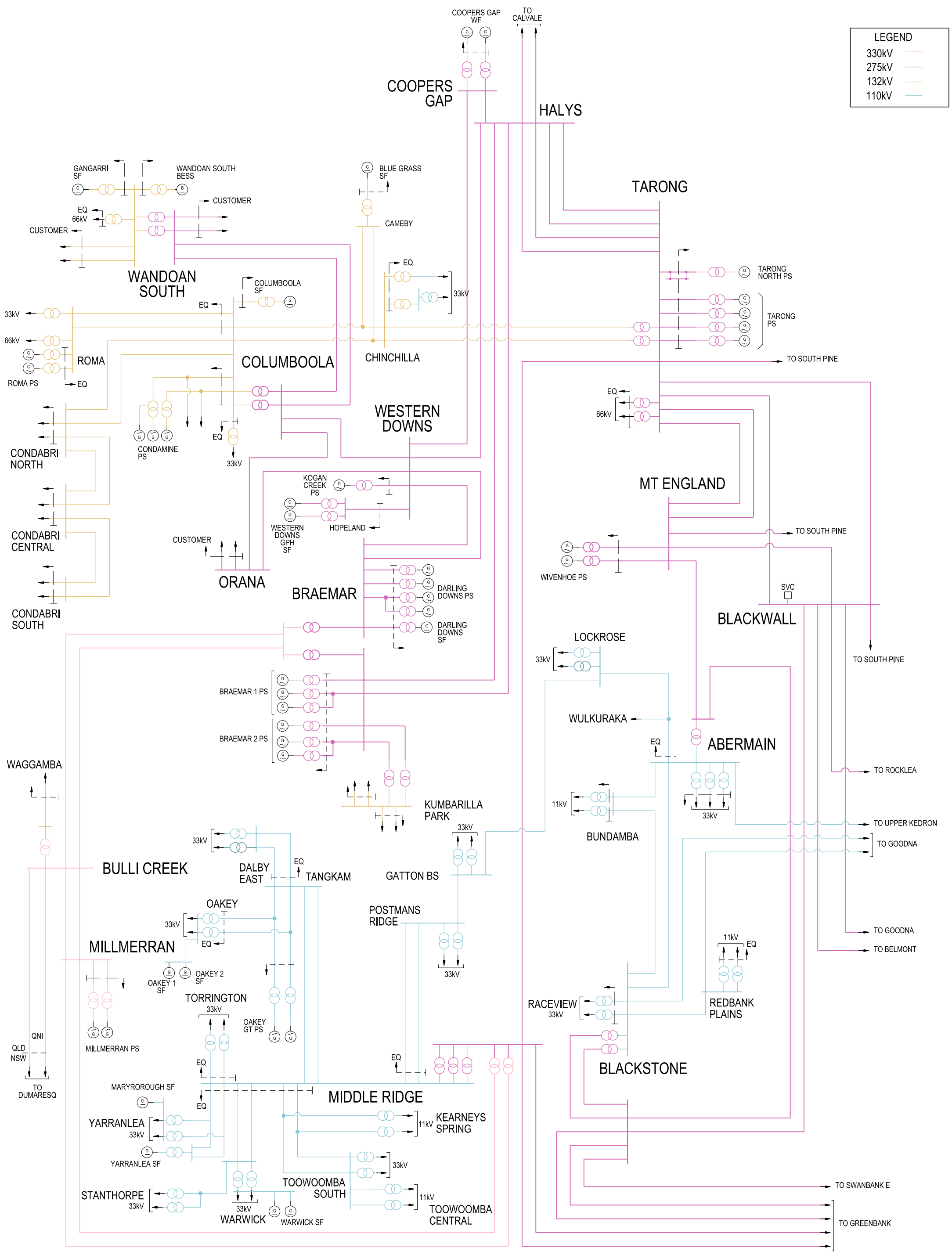
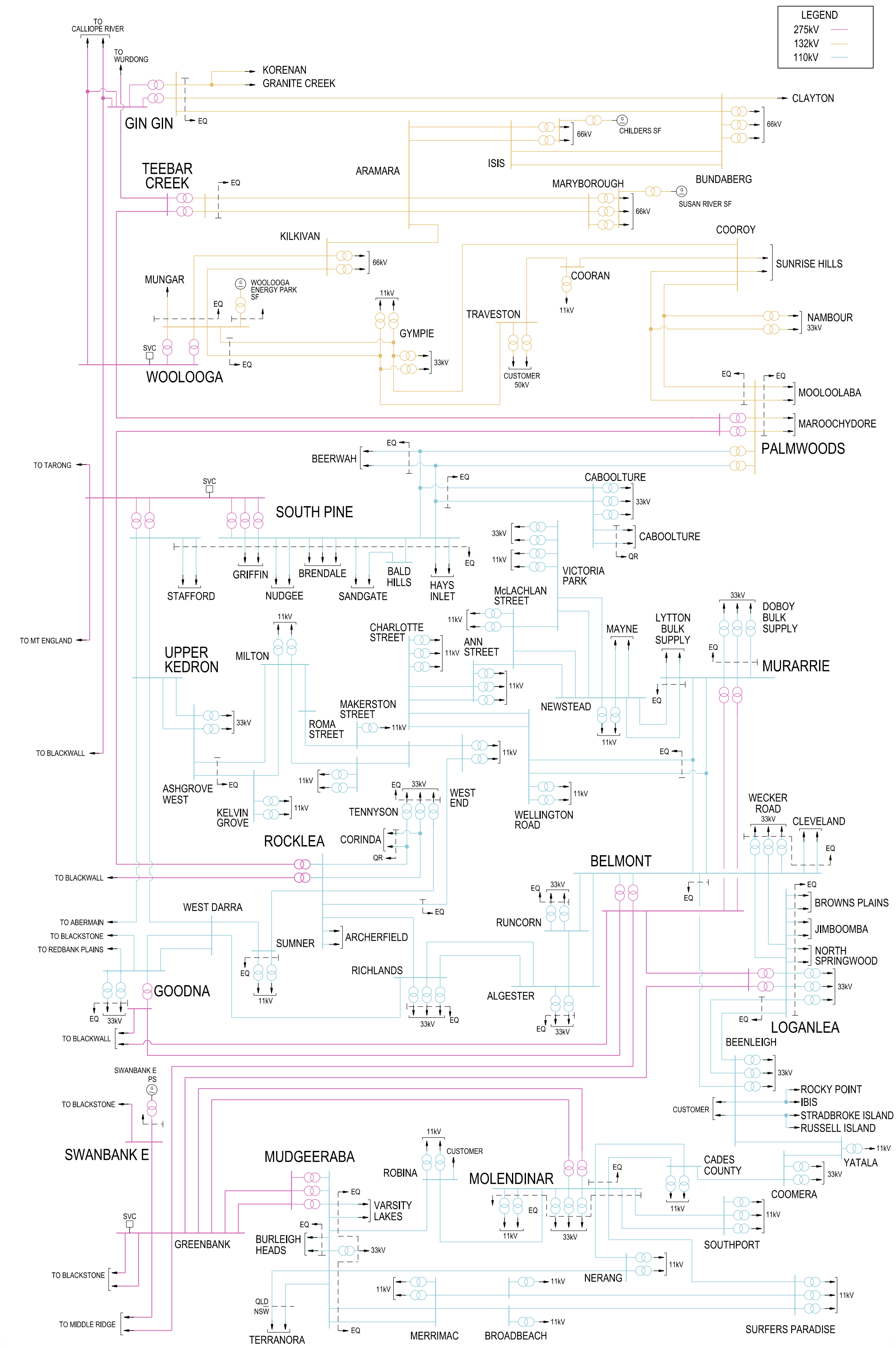


Figure 8.5 Existing HV network July 2022 - South East Queensland



8.5 Transfer capability

8.5.1 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.1 provides definitions and Figure C.2 in Appendix C shows the location of relevant grid sections on the Queensland network.

8.5.2 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. For example, AEMO and Powerlink are currently investigating an update to dynamic load models which include aggregate representation of rooftop PV systems. 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 8.6 provides a qualitative description of the main system conditions that affect the capability of each grid section.

8.6 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 categorised as occurring during intact or outage conditions based on AEMO's constraint description. 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 affected by load, generation and transfers to neighbouring zones. Figures 8.6 and 8.7 provide 2020/21 and 2021/22 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 8.8 provides the changes in energy transfers from 2020/21 to 2021/22. These figures assist in the explanation of differences between 2020/21 and 2021/22 grid section transfer duration curves.

Figure 8.6 2020/21 zonal electrical energy transfers (GWh)

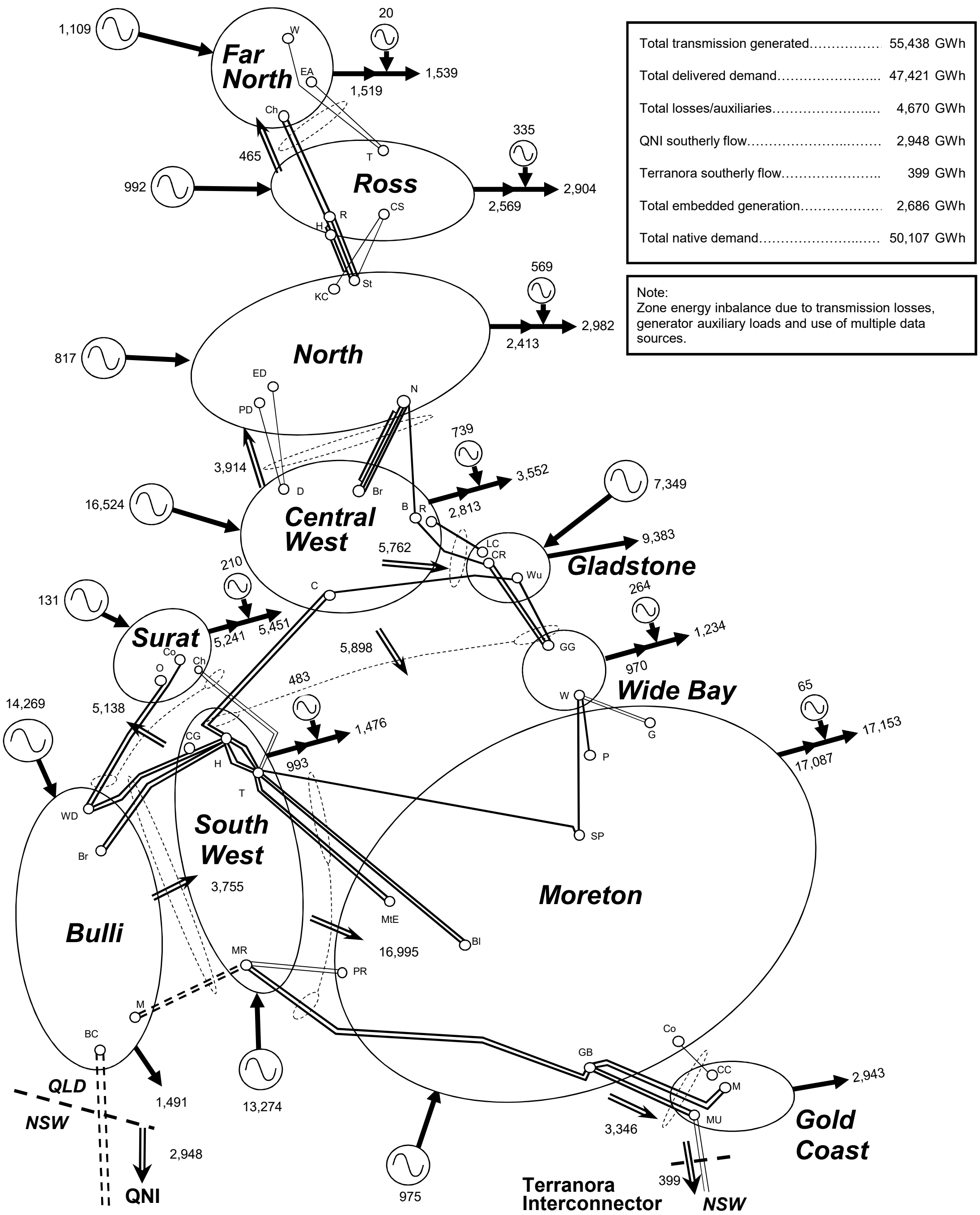


Figure 8.7 2021/22 zonal electrical energy transfers (GWh)

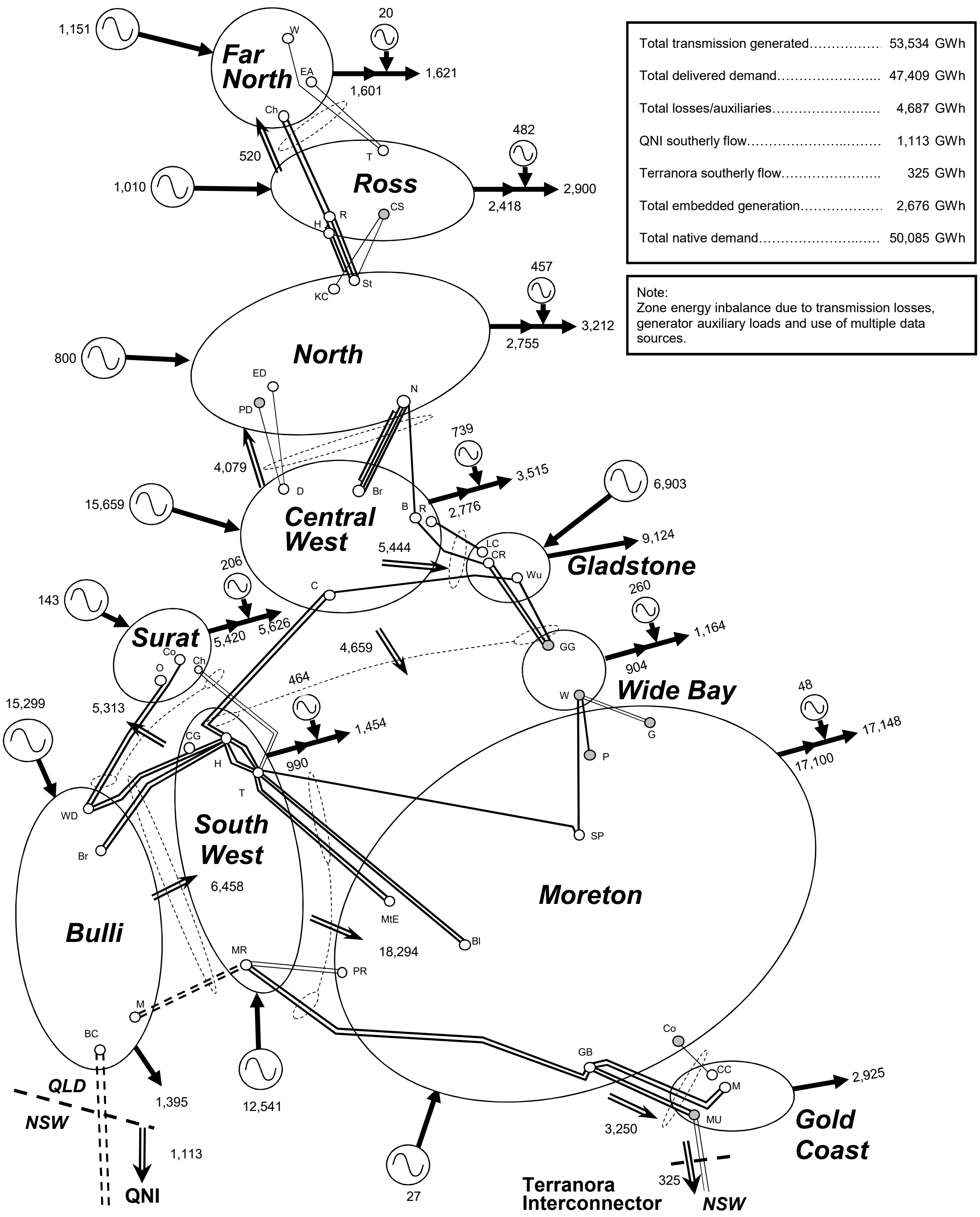
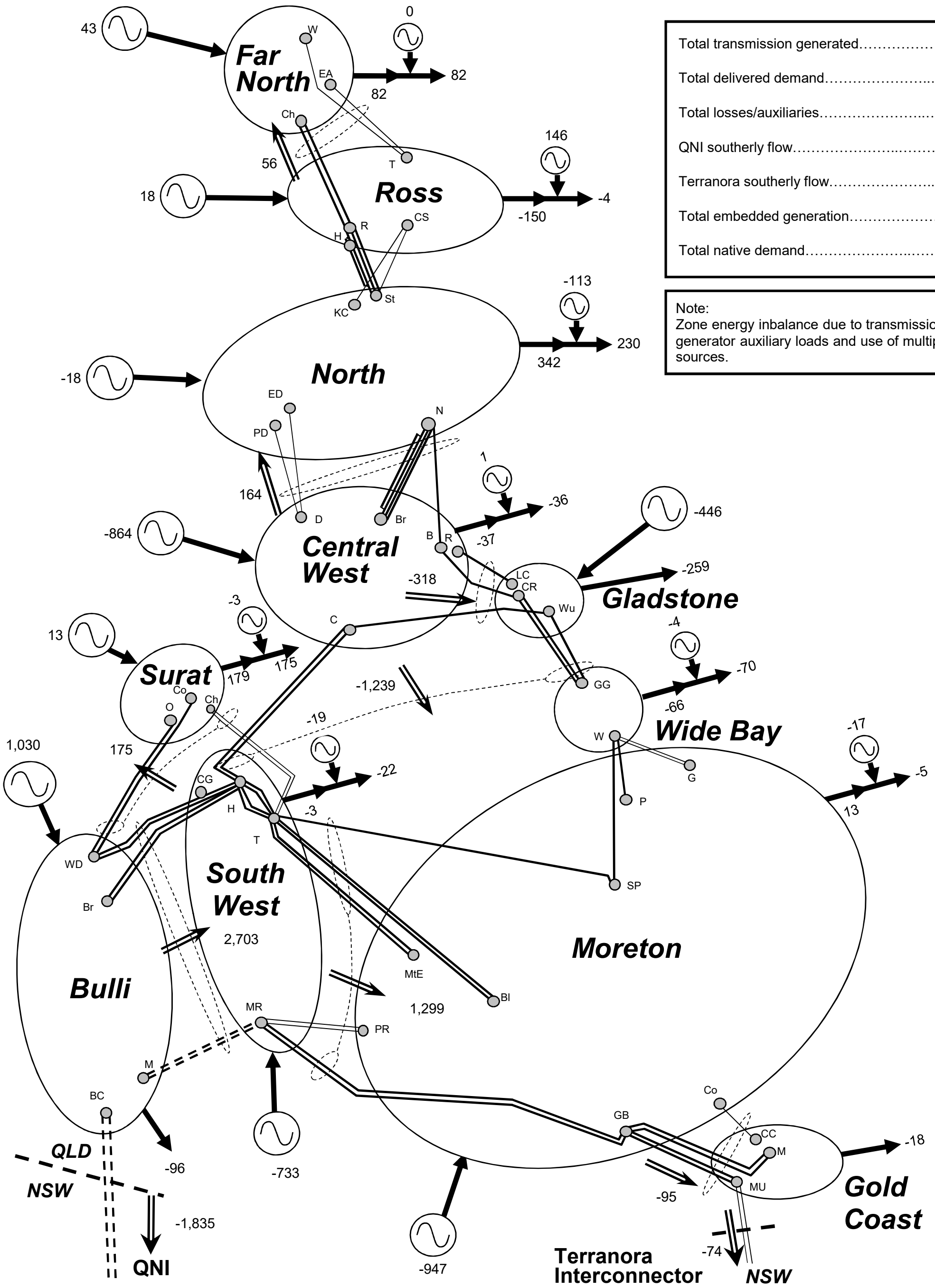


Figure 8.8 Change in zonal electrical energy transfers (GWh)



Total transmission generated	-1,904 GWh
Total delivered demand	-13 GWh
Total losses/auxiliaries	17 GWh
QNI southerly flow	-1,835 GWh
Terranora southerly flow	-74 GWh
Total embedded generation	-10 GWh
Total native demand	-22 GWh

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

8.6.1 Far North Queensland (FNQ) grid section

Maximum power transfer across the FNQ grid section is set by voltage stability associated with an outage of the Woree SVC or Mt Emerald Wind Farm.

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 generation
- Far North zone shunt compensation levels.

Local hydro and wind 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 2021/22. Information pertaining to the historical duration of constrained operation for the FNQ grid section is summarised in Figure 8.9.

Figure 8.9 Historical FNQ grid section constraint times

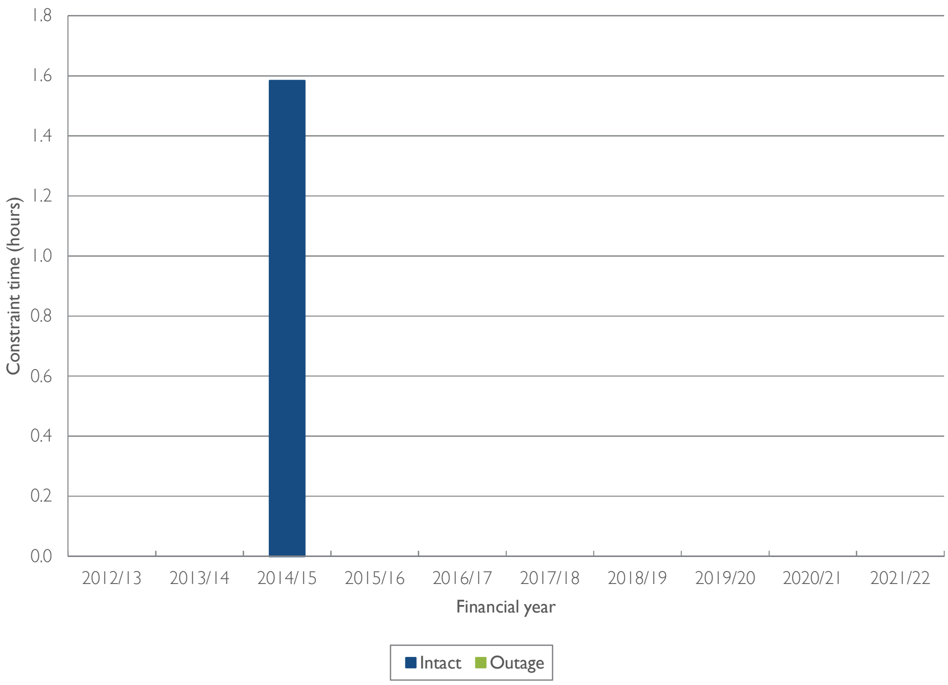
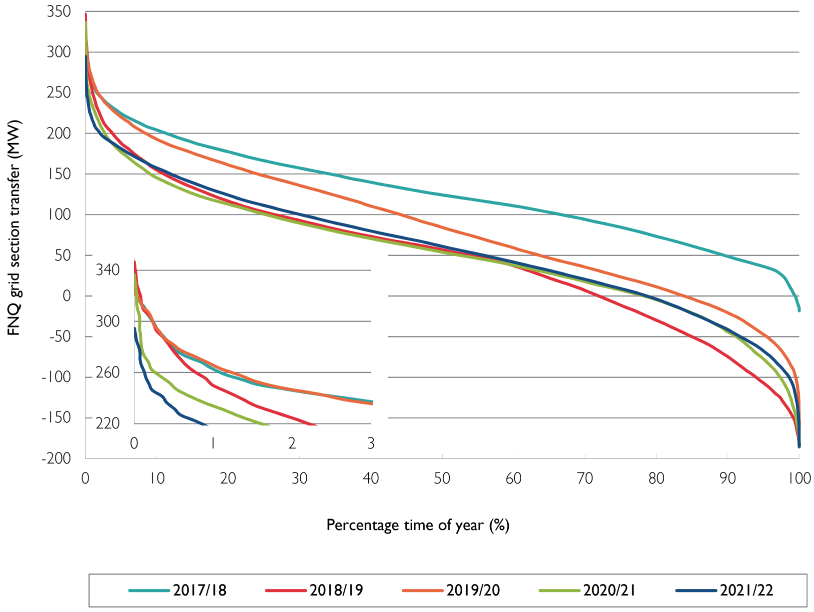


Figure 8.10 provides historical transfer duration curves showing a similar profile to 2020/21. Historically, changes in peak flow and energy delivered to the Far North zone by the transmission network have been dependant on the Far North zone load and generation from the hydro generating power stations at Barron Gorge and Kareeya. These vary depending on rainfall levels in the Far North zone. The total delivered energy of the Far North zone has increased since 2020/21. This increase has been supplied by increases in the total energy transferred across the Far North grid section and the combined hydro generating PS and Mt Emerald Wind Farm generation (refer to figures 8.6, 8.7 and 8.8).

Figure 8.10 Historical FNQ grid section transfer duration curves



In May 2021 it was announced that the Queensland Government would invest $40 million in transmission line infrastructure in North Queensland to establish a Queensland REZ (QREZ), with Neoen's Kaban Wind Farm identified as the foundational proponent.

The proposed transmission augmentation works are to energise one side of the existing 132kV coastal double circuit transmission line, originally constructed to accommodate transmission at 275kV. This results in the establishment of a third 275kV transmission line into Woree. Work on the proposed transmission augmentation is expected to be completed by November 2023.

8.6.2 Central Queensland to North Queensland (CQ-NQ) grid section

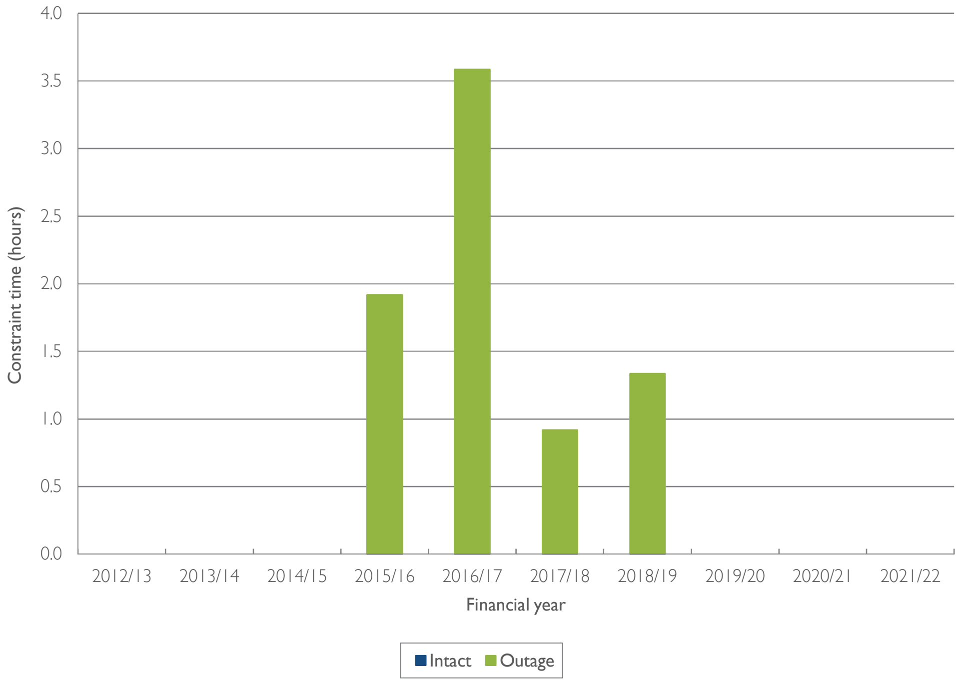
Maximum power transfer across the CQ-NQ grid section may be set by thermal ratings associated with an outage of a Stanwell to Broadsound 275kV circuit, under certain prevailing ambient conditions. Power transfers may also be constrained by voltage stability limitations associated with the contingency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

The CQ-NQ grid section did not constrain operation during 2021/22. Information pertaining to the historical duration of constrained operation for the CQ-NQ grid section is summarised in Figure 8.11.

Figure 8.11 Historical CQ-NQ grid section constraint times



The constraint times were associated with thermal constraint equations during planned outages to ensure operation within plant thermal ratings.

Figure 8.12 provides historical transfer duration curves showing decreases in energy transfer over recent years. Despite reductions in total energy transfer, the peak power transfer in 2021/22 is similar to previous years. This new transfer duration shape is predominantly attributed to the addition of solar and wind farms in the Far North, Ross and North zones.

Figure 8.12 Historical CQ-NQ grid section transfer duration curves

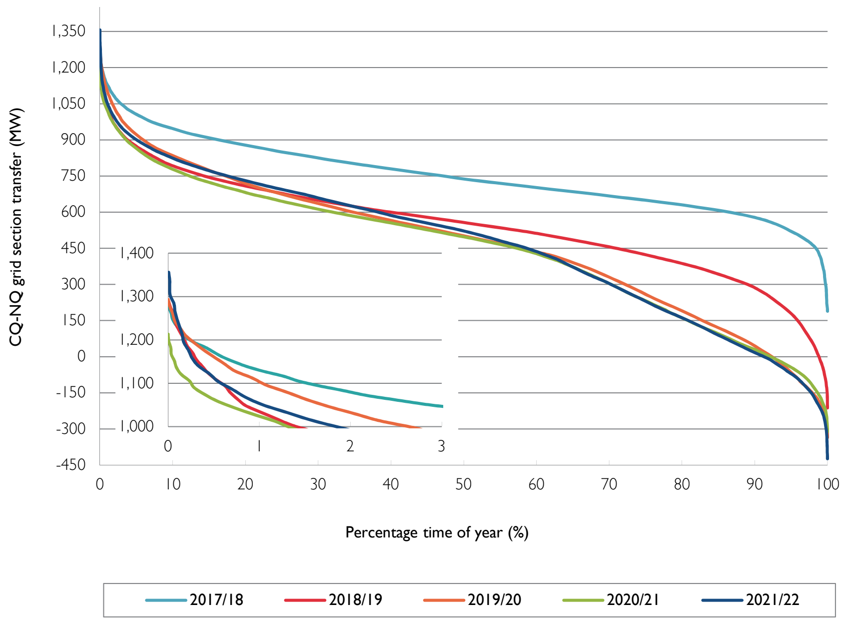
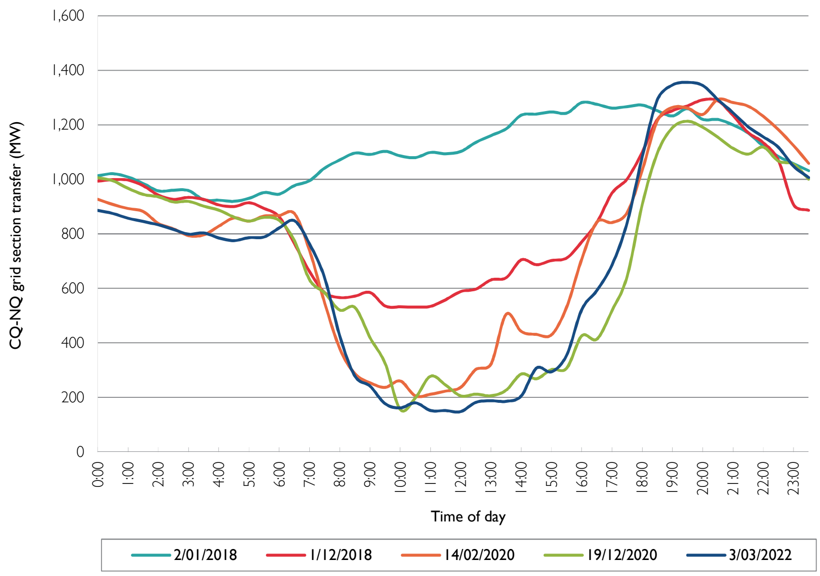


Figure 8.13 provides a different view of the altered power flows experienced over the last years for the day corresponding to the annual peak CQ-NQ transfer. This shows the impact of solar generation in creating minimum demands and network transfers in the middle of day.

Figure 8.13 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 integration of additional rooftop PV and large-scale VRE in NQ. Correspondingly, voltage control is forecast to become increasingly challenging for longer durations.

In February 2021, Powerlink completed the Project Assessment Conclusions Report (PACR)[5] recommending the establishment of a 150MVAr 300kV bus reactor at Broadsound, which is expected to be commissioned by August 2023.

8.6.3 NQ System Strength

System strength is a measure of the ability of a power system to remain stable under normal conditions and to return to a steady state condition following a system disturbance. System strength can be considered low in areas with low levels of local synchronous generation and deteriorates further with high penetration of inverter-based resources.

Powerlink has determined that the dominant limitation to VRE hosting capacity is the potential for multiple generators, and other transmission-connected dynamic plant, to interact in an unstable manner. These dynamic plant control interactions manifest as an unstable or undamped oscillation in the power system voltage. The frequency of the oscillation is dependent on the participating plants, but is broadly characterised as between 8Hz and 15Hz.

North Queensland (NQ) has been the focus of system strength limitations in Queensland due to the high of number of VRE plants and relatively low synchronous fault levels. Electromagnetic Transient-type (EMT) analysis has been performed to determine the system conditions that could result in unstable operation of VRE plant. The limit equations in Table D.3 of Appendix D reflect the output of this analysis. The limit equations show that the following variables have a significant effect on NQ system strength:

- number of synchronous units online in Central and NQ
- NQ demand
- status of Haughton Synchronous Condenser.

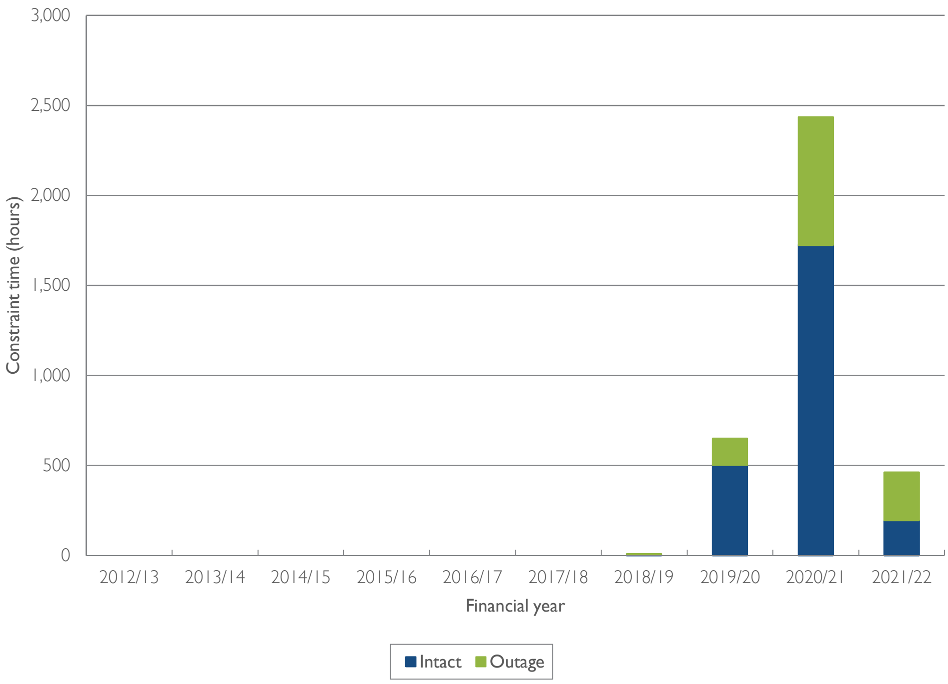
[5] Powerlink, Project Assessment Conclusions Report - Managing voltage control in Central Queensland, February 2021.

Information pertaining to the historical duration of constrained operation for inverter-based resources in NQ is summarised in Figure 8.14. During 2021/22, inverter-based resources in NQ experienced 462 hours of constrained operation, of which 195 hours occurred during intact system conditions. This is a significant reduction from 2020/21. The reduction in constrained operation is due to two primary reasons:

- retuning of inverter controls at several solar farms in north Queensland and Mt Emerald Wind Farm
- commissioning of Haughton Synchronous Condenser.

In December 2021, AEMO declared a fault level shortfall at the Gin Gin node in the Wide Bay zone. Subsequently Powerlink initiated an Expression of interest (EOI) for services to address this fault level shortfall[6]. While the shortfall was declared in the Wide Bay zone, it may be best addressed by a solution elsewhere in the state. The EOI closed at the end of June 2022 and options are being assessed. The result of this process may have further impact on the North Queensland system strength limit advice.

Figure 8.14 Historical NQ system strength constraint times (1)



Note:

(1) AEMO's Infoserver (and therefore the 2021 TAPR) includes bound constraints applying to unavailable VRE (e.g. solar farms during the night). These constraint records are now removed from the calculation. Constraint times for 2020/21 have been revised.

8.6.4 Gladstone grid section

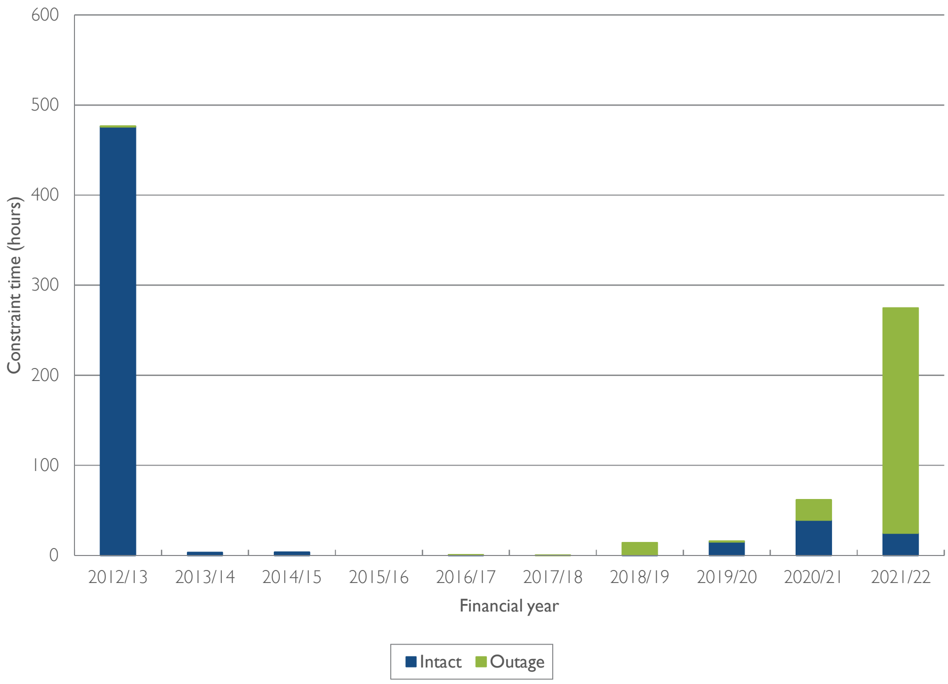
Maximum power transfer across the Gladstone grid section is set by the thermal rating of the Bouldercombe to Raglan, Larcom Creek to Calliope River, Calvale to Wurdong or the Calliope River to Wurdong 275kV circuits.

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 National Electricity Market Dispatch Engine (NEMDE).

6 Powerlink, Request for power system security services in central, southern and broader Queensland regions, May 2022.

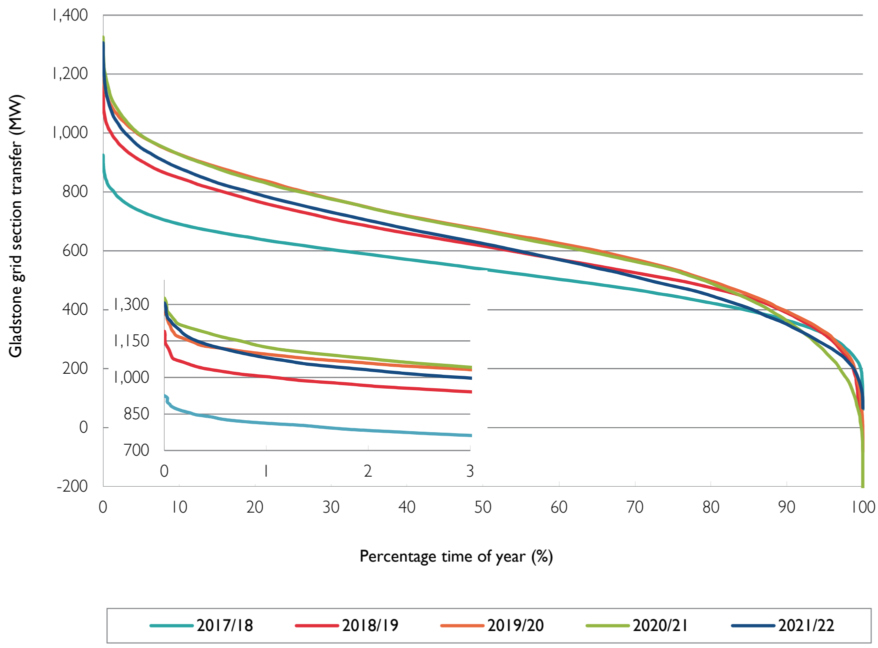
Information pertaining to the historical duration of constrained operation for the Gladstone grid section is summarised in Figure 8.15. During 2021/22, the Gladstone grid section experienced 275 hours of constrained operation, 25 hours during intact system conditions due to low Gladstone PS generation. The large increase in constrained operation was due to outages associated with planned maintenance activities on lines between Central West and Gladstone zones.

Figure 8.15 Historical Gladstone grid section constraint times



Power flows across this grid section are highly dependent on the balance of generation and demand in Gladstone and transfers to between CQ and SQ. Figure 8.16 provides historical transfer duration curves showing decreased utilisation in 2021/22 compared to 2020/21. Reduced demand in the Gladstone zone and lower transfers between CQ and SQ is responsible for this change (refer to figures 8.6, 8.7 and 8.8).

Figure 8.16 Historical Gladstone grid section transfer duration curves



8.6.5 CQ-SQ 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.

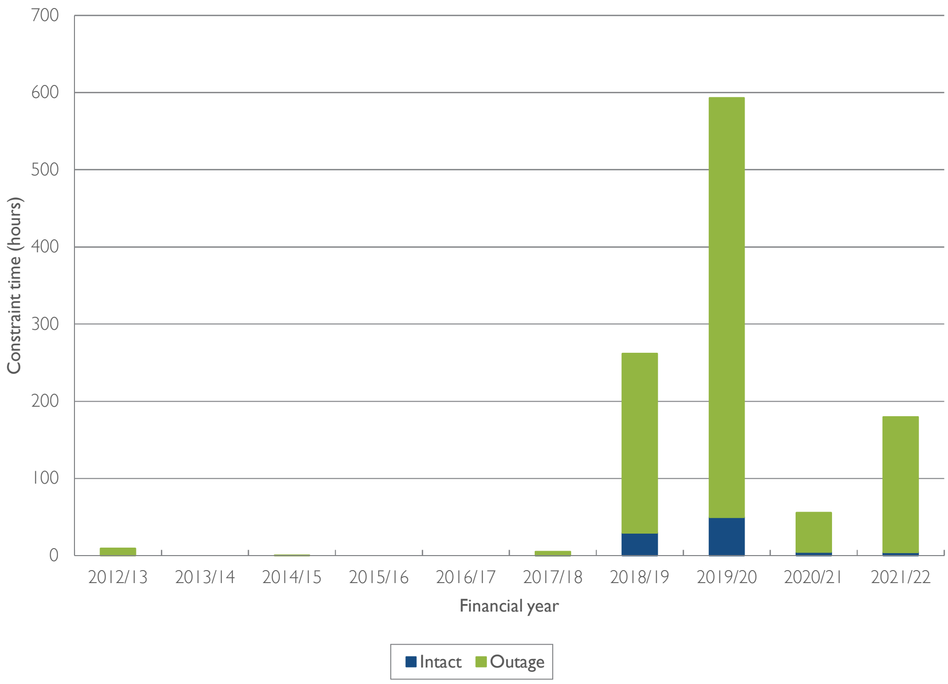
The voltage stability limit is set by insufficient reactive power reserves in the Central West and Gladstone zones following a contingency. More generating units online in these zones increase reactive power support and therefore transfer capability.

The limit equation in Table D.4 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 PS generation.

Information pertaining to the historical duration of constrained operation for the CQ-SQ grid section is summarised in Figure 8.17. During 2021/22, the CQ-SQ grid section experienced 179 hours of constrained operation. Constrained operation was due to outages associated with planned maintenance activities. Only four hours of constrained operation was during system normal conditions.

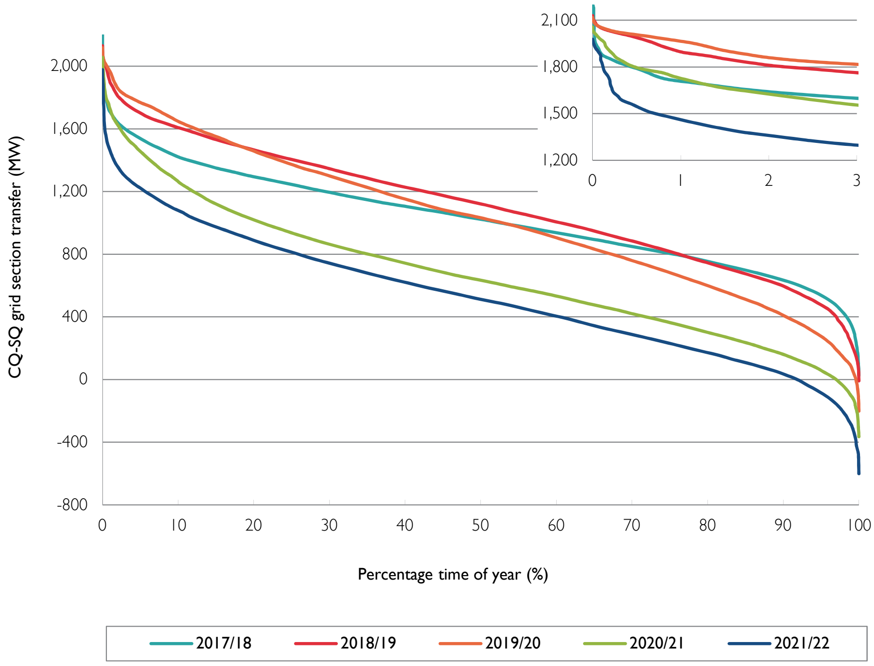
Figure 8.17 Historical CQ-SQ grid section constraint times



Associated with high penetration of rooftop PV installations in southeast Queensland, Powerlink is reviewing the transient stability limit for CQ-SQ. The review includes dynamic load models that include rooftop PV behaviour. Powerlink has committed to update this limit advice by April 2023.

Figure 8.18 provides historical transfer duration curves showing utilisation decreasing over the last two years. This decrease in transfer has been predominantly due to a significant reduction in generation in central Queensland and reduced flows over the interconnector with NSW. Over 2021/22 output from the large thermal generators in central Queensland markedly reduced (refer to figures 8.6, 8.7 and 8.8), the decrease was not as large as was observed between 2019/20 and 2020/21 but continues to break annual production lows for the area. The utilisation of the CQ-SQ grid section is highly dependent on the operation of central Queensland thermal generation.

Figure 8.18 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.

8.6.6 Surat grid section

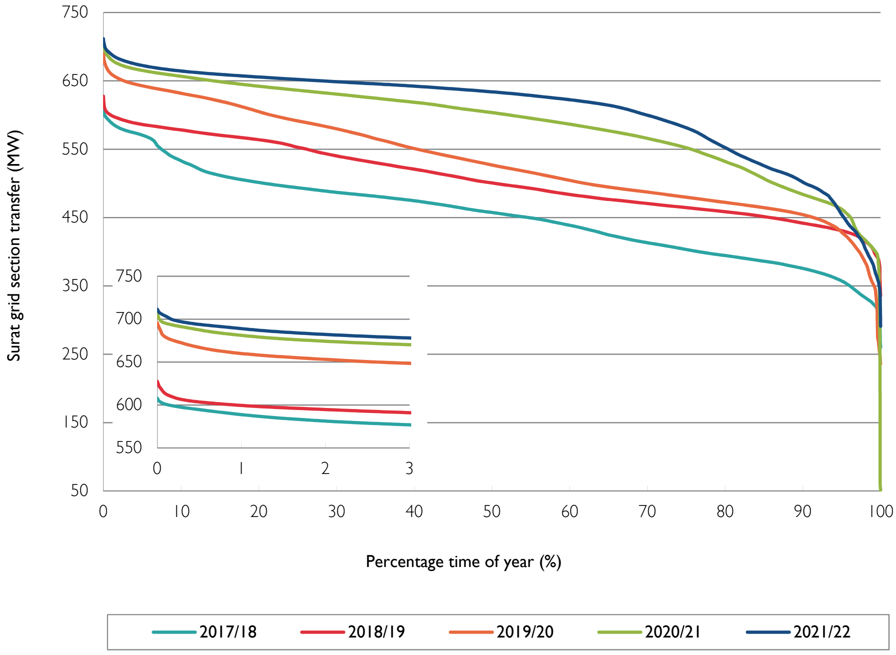
The Surat grid section was introduced in the 2014 TAPR in preparation for the establishment of the Western Downs to Columboola 275kV transmission line, Columboola to Wandoan South 275kV transmission line and Wandoan South and Columboola 275kV substations. These network developments were completed in 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[7]. 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 history of the Surat grid section.

Figure 8.19 provides the transfer duration curve since 2017/18. Grid section transfers depict the last stages of ramping of coal seam gas (CSG) load. The zone has transformed from a net exporter to a significant net importer of energy. Energy transfers are expected to reduce with the commitment of Bluegrass, Columboola, Gangarri and Edenvale solar farms and Dulacca Wind Farm. All of these VRE generators are expected to be commissioned over the next year.

[7] The Orana Substation is connected to one of the Western Downs to Columboola 275kV transmission lines (refer to Figure 8.4).

Figure 8.19 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.

8.6.7 South West Queensland (SWQ) 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 thermal rating of the Middle Ridge 330/275kV transformer sets maximum power transfer across the SWQ grid section.

The SWQ grid section did not constrain operation during 2021/22. Information pertaining to the historical duration of constrained operation for the SWQ grid section is summarised in Figure 8.20.

Figure 8.20 Historical SWQ grid section constraint times

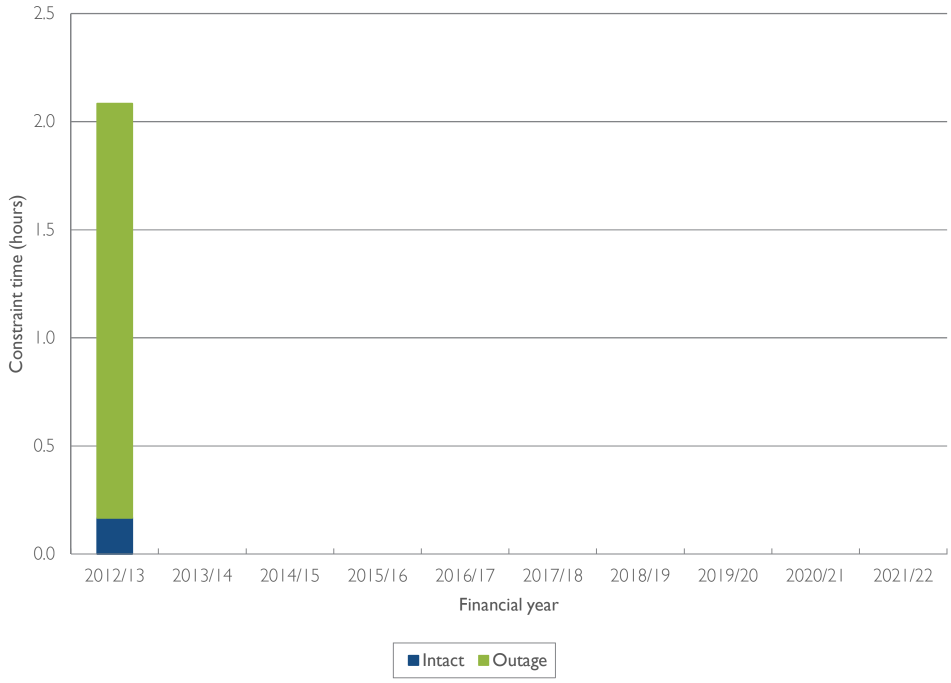
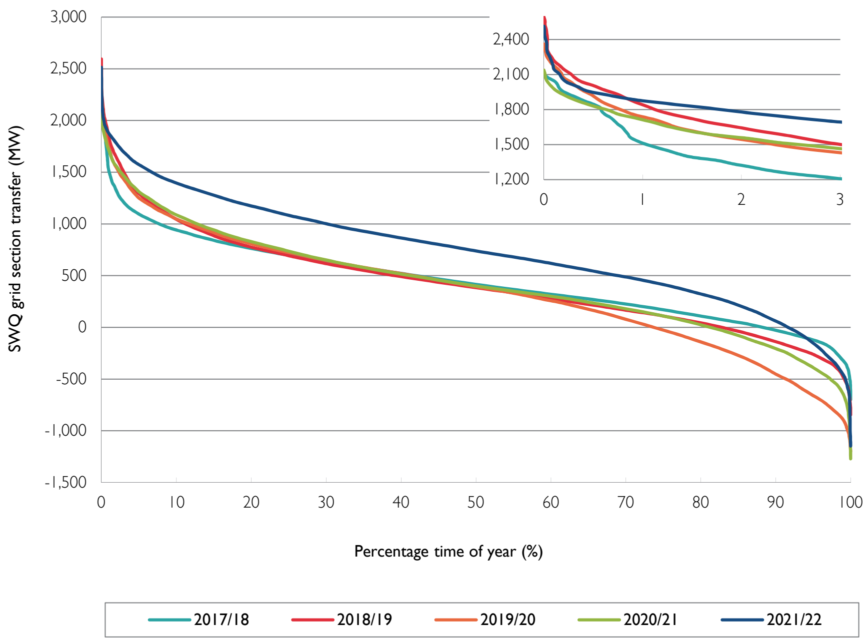


Figure 8.21 provides historical transfer duration curves showing an increase in energy transfer in 2021/22.This is predominantly due to a shift in generation from central Queensland coal to Bulli zone gas generation and reductions in interconnector flows to NSW (refer to figures 8.6, 8.7 and 8.8).

Figure 8.21 Historical SWQ grid section transfer duration curves



AEMO's 2022 Integrated System Plan[8] (ISP) required stage 1 of the Darling Downs REZ Expansion by 2028/29 in its most likely scenario. This project involves a possible upgrade to transformer capacity at Middle Ridge Substation. AEMO has requested Powerlink undertake preparatory activities for this future project by 30 June 2023.

[8] AEMO, 2022 Integrated System Plan (ISP), June 2022.

8.6.8 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.5 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 was constrained for 10 minutes in 2021/22. This occurred during planned maintenance work. Information pertaining to the historical duration of constrained operation for the Tarong grid section is summarised in Figure 8.22. Constraint times have been minimal over the last 10 years.

Figure 8.22 Historical Tarong grid section constraint times

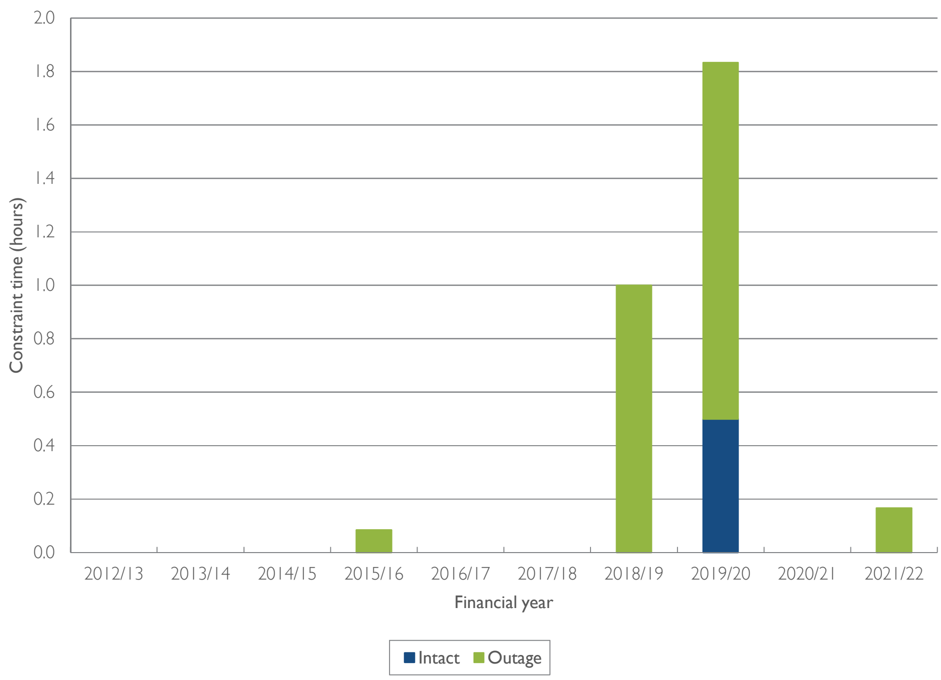
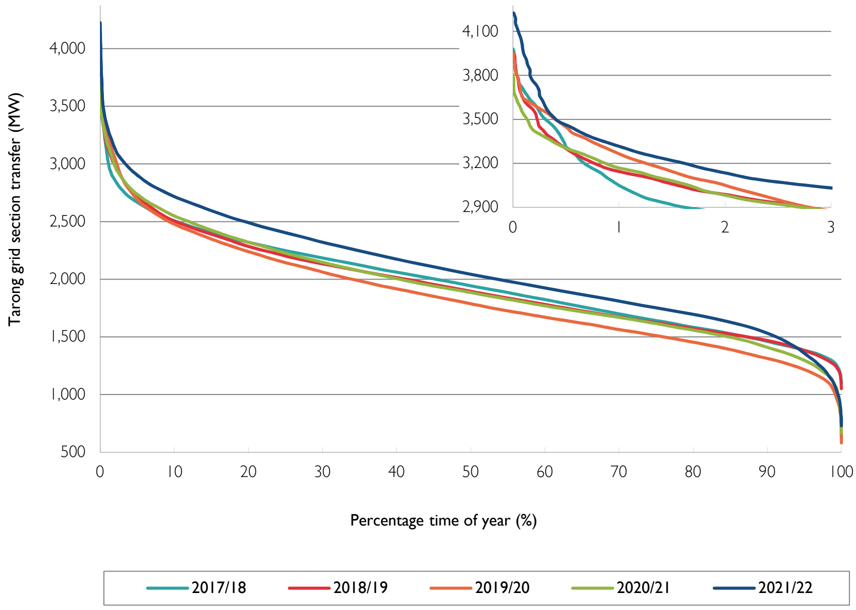


Figure 8.23 provides historical transfer duration curves showing an increase in flows in 2021/22. This is predominantly due to a reduction in net generation in the Moreton zone (refer to figures 8.6, 8.7 and 8.8). The reduction in generation is predominantly due to an unplanned outage of the Swanbank E generator between December 2021 and September 2022 and higher utilisation of Wivenhoe pumped hydro (refer to figures 8.6, 8.7 and 8.8).

Figure 8.23 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.

8.6.9 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.

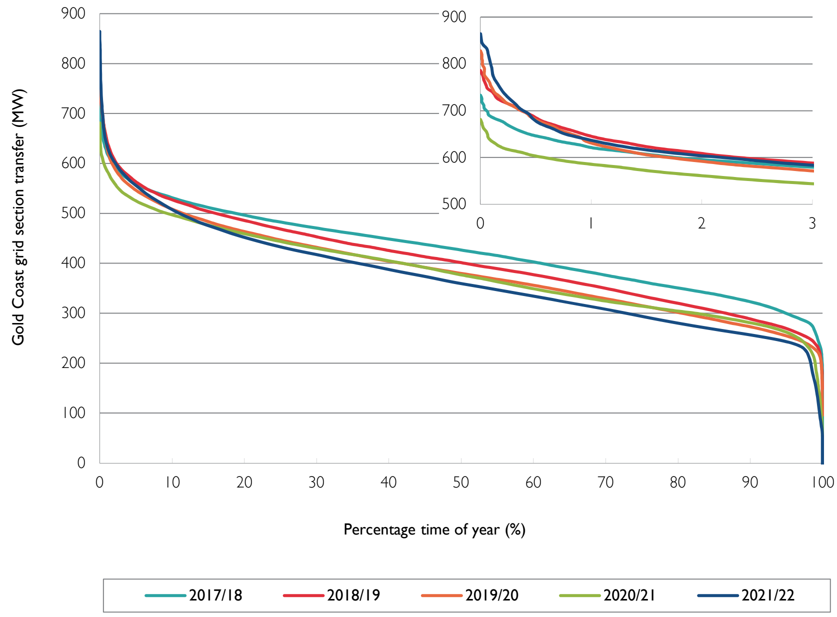
The limit equation in Table D.6 of Appendix D shows that the following variables have a significant effect on transfer capability:

- 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. There have been no constraints on the Gold Coast grid section over the last 10 years.

Figure 8.24 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. Northern NSW transfers and Gold Coast zone demand were lower in 2021/22 compared to 2020/21 (refer to figures 8.6, 8.7 and 8.8).

Figure 8.24 Historical Gold Coast grid section transfer duration curves



Due to condition drivers, Powerlink is retiring one of the aging 275/110kV transformers at Mudgeeraba Substation by June 2025. This is listed in Table 11.7.

8.6.10 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 Monthly Constraint Reports which includes a section 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 Monthly Constraint Reports. The Monthly 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 Dumaresq and Armidale in NSW
- oscillatory stability upper limit of 1,450MW.

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 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 December 2019, Powerlink and Transgrid finalised a PACR on 'Expanding NSW-Queensland transmission transfer capacity', identifying the preferred option which includes uprating the 330kV Liddell to Tamworth 330kV lines, and installing Static VAr Compensators (SVC) at Tamworth and Dumaresq substations and static capacitor banks at Tamworth, Armidale and Dumaresq substations. The project is complete and inter-network testing activities, as required by NER 5.7.7, are progressing.

Associated with high penetration of rooftop PV installations, Powerlink is reviewing the transient stability limit for QNI southerly transfer. The review includes dynamic load models that include rooftop PV behaviour. Powerlink will update this limit advice by April 2023.

AEMO's 2022 Integrated System Plan[9] (ISP) considered the QNI Connect project that would increase transfer capacity between Queensland and New South Wales. The ISP identified that QNI Connect may be required as early as 2029/30 (based on the Hydrogen Superpower scenario). AEMO has requested Powerlink and Transgrid undertake preparatory activities for a 500kV QNI Connect option by 30 June 2023.

8.7 Zone performance

This section presents, where applicable, a summary of:

- the capability of the transmission network to deliver loads
- historical zonal transmission delivered loads
- intra-zonal system normal constraints
- double circuit transmission lines categorised as vulnerable by AEMO[10]
- 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 (where its magnitude or degree is not considered an Exceptional Event[11]) 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.

Statewide delivered energy has not materially changed from 2020/21 to 2021/22. However, there are some zones where delivered energy has increased and others where it has decreased (refer to Figure 8.8). Despite the flat state-wide delivered demand, there has been significant increases in embedded VRE generation. The Queensland region's installed rooftop PV has increased by approximately 730MW over the year, reaching approximately 4,808MW by 30 June 2022[12]. Figure 3.11 provides annual transmission delivered demand load duration curves for the Queensland region.

[9] AEMO, 2022 Integrated System Plan, June 2022.
[10] AEMO, List of Vulnerable Lines, effective May 2022.
[11] An Exception Event is defined in AEMO's Power System Security Guidelines (SO_OP_3715) as a simultaneous trip of a double circuit transmission line during a lightning storm caused by an event that is far beyond what is usual in magnitude or degree for what could be reasonably expected to occur during a lightning storm.
[12] Clean Energy Regulator, Postcode data for small-scale installations – all data, data as at 31/08/2022, September 2022.

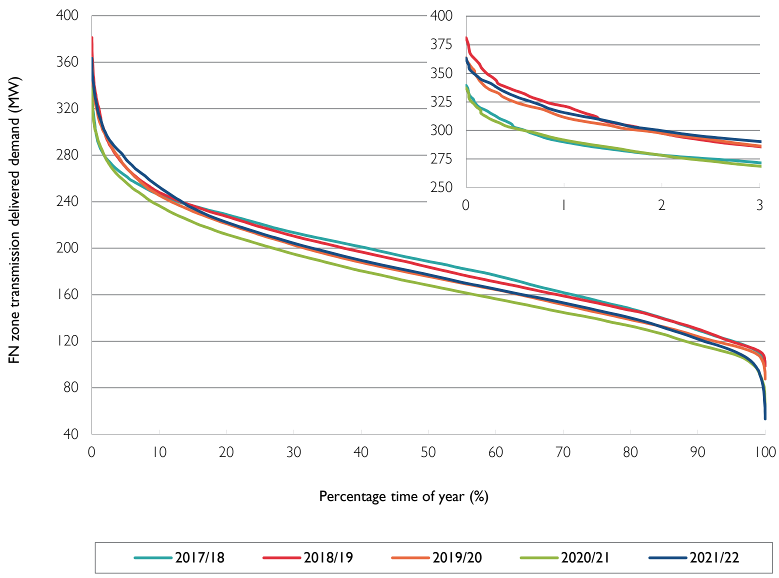
8.7.1 Far North zone

The Far North zone experienced no load loss for a single network element outage during 2021/22.

The Far North zone includes the non-scheduled embedded generator Lakeland Solar and Storage as defined in Figure 3.5. This embedded generator provided approximately 20GWh during 2021/22.

Figure 8.25 provides historical transmission delivered load duration curves for the Far North zone. Energy delivered from the transmission network increase by 5.4% between 2020/21 and 2021/22. The maximum transmission delivered demand in the zone was 363MW, which is below the highest maximum demand over the last five years of 381MW set in 2018/19. The minimum transmission delivered demand in the zone was 53MW, which is the lowest minimum demand over the last five years.

Figure 8.25 Historical Far North zone transmission delivered load duration curves



High voltages associated with light load conditions continue to become increasingly challenging for longer durations. Energy Queensland will, over time, lower off-load tap settings on many distribution transformers. This requires localised network outages, and in many instances will be set to the last remaining tap setting.

There are currently no double circuits in the Far North zone in AEMO's lightning vulnerable transmission line list.

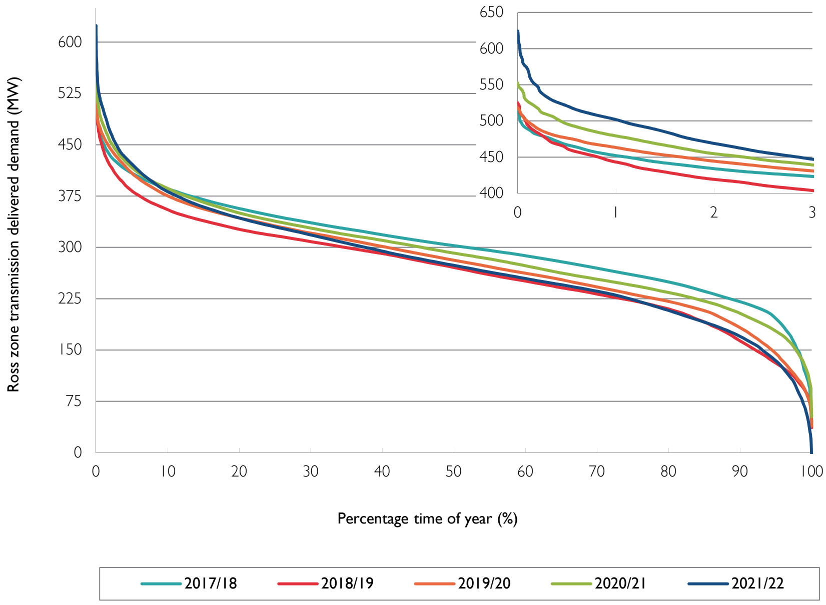
8.7.2 Ross zone

The Ross zone experienced no load loss for a single network element outage during 2021/22.

The Ross zone includes the scheduled embedded Townsville PS 66kV component (steam turbine component of the CCGT), semi-scheduled distribution connected embedded Kidston Solar Farm, Kennedy Energy Park and direct connected embedded Sun Metals Solar Farm, and the significant non-scheduled embedded generators Hughenden Solar Farm and Pioneer Mill as defined in Figure 3.4. These embedded generators provided approximately 482GWh during 2021/22.

Figure 8.26 provides historical transmission delivered load duration curves for the Ross zone. Energy delivered from the transmission network has reduced by 5.9% between 2020/21 and 2021/22. The reduction in energy delivered is predominantly due to the increase in energy from embedded generation. The peak transmission delivered demand in the zone was 624MW, which is the highest maximum demand over the last five years. The minimum transmission delivered demand in the zone was -6MW, which is the lowest demand over the last five years and the first time that the Ross zone has become a net exporter.

Figure 8.26 Historical Ross zone transmission delivered load duration curves



High voltages associated with light load conditions are managed with existing reactive sources.

As a result of double circuit outages associated with lightning strikes, AEMO includes the Ross to Chalumbin 275kV double circuit transmission line in the vulnerable list. This double circuit tripped due to lightning in January 2020.

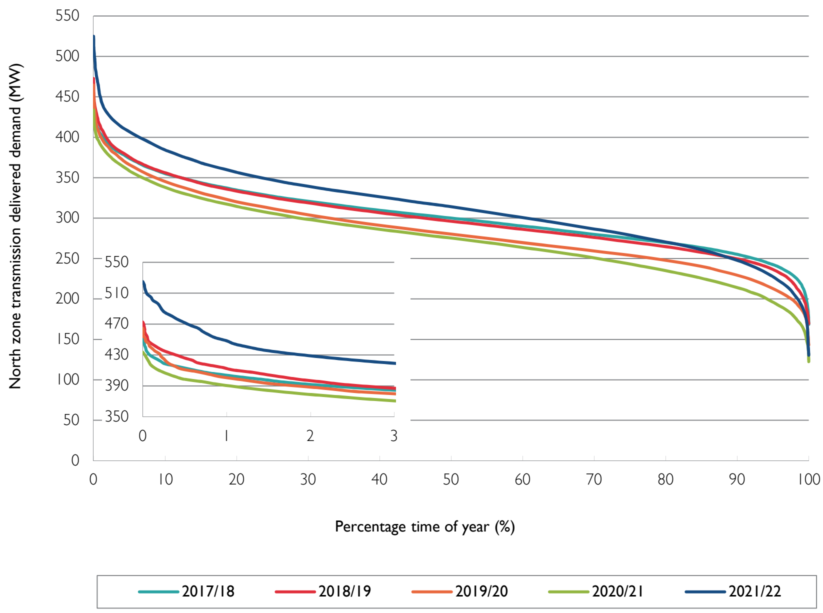
8.7.3 North zone

The North zone experienced no load loss for a single network element outage during 2021/22.

The North zone includes semi-scheduled embedded generator Collinsville Solar Farm and significant non-scheduled embedded generators Moranbah North, Moranbah and Racecourse Mill as defined in Figure 3.4. These embedded generators provided approximately 457GWh during 2021/22.

Figure 8.27 provides historical transmission delivered load duration curves for the North zone. Energy delivered from the transmission network has increased by 14.2% between 2020/21 and 2021/22, to the highest level in the last decade. The peak transmission delivered demand in the zone was 525MW, which is the highest maximum demand over the last decade. The minimum transmission delivered demand in the zone was 130MW, which is slightly higher than the lowest minimum demand in the last five years of 122MW, recorded in 2020/21.

Figure 8.27 Historical North zone transmission delivered load duration curves



High voltages associated with light load conditions are currently managed with existing reactive sources. However, midday power transfer levels continue to reduce as additional rooftop PV is installed in NQ. As a result, voltage control is forecast to become increasingly challenging for longer durations. This is discussed in Section 8.6.2.

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

- Collinsville North to Proserpine 132kV double circuit transmission line, last tripped February 2018
- Collinsville North to Stoney Creek and Collinsville North to Newlands lines, last tipped November 2021.

The following double circuit has, this year, been removed from 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.

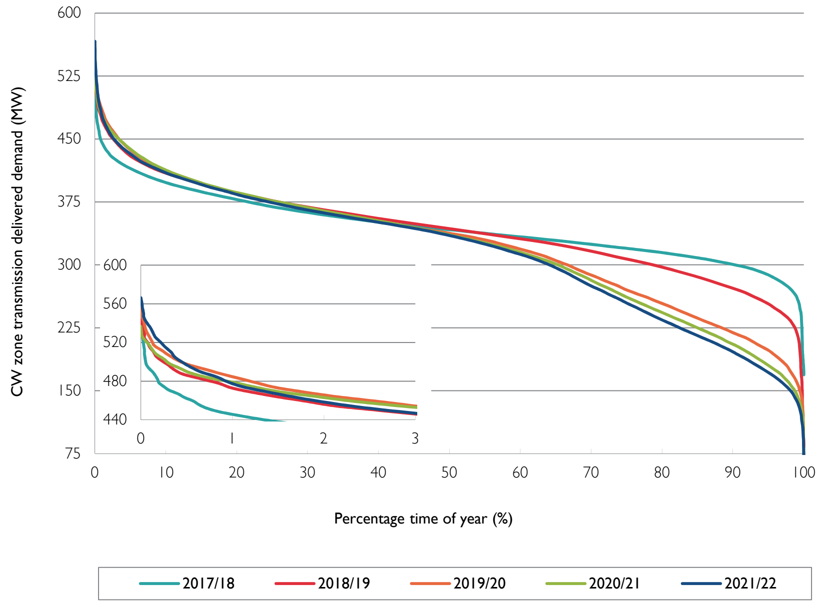
8.7.4 Central West zone

The Central West zone experienced one load loss for a single network element outage during 2021/22. The duration of the outage was less than two hours and approximately 35MWh of energy was lost. The loads impacted by this outage are supplied by a single radial connection under normal system conditions.

The Central West zone includes the scheduled embedded Barcaldine generator, semi-scheduled embedded generators Clermont Solar Farm, Emerald Solar Farm and Middlemount Solar Farm and significant non-scheduled embedded generators Barcaldine Solar Farm, Longreach Solar Farm, German Creek and Oaky Creek as defined in Figure 3.5. These embedded generators provided approximately 739GWh during 2021/22.

Figure 8.28 provides historical transmission delivered load duration curves for the Central West zone. Energy delivered from the transmission network has reduced by 1.3% between 2020/21 and 2021/22, to the lowest level in the last decade. This is a continuation of the trend seen in recent years. The peak transmission delivered demand in the zone was 566MW, which is the highest maximum demand over the last five years. The minimum transmission delivered demand in the zone was 65MW, which is slightly higher to the lowest minimum demand over the last decade, which was 64MW recorded in 2020/21.

Figure 8.28 Historical Central West zone transmission delivered load duration curves



EDL has advised AEMO of its intention to retire Oaky Creek non-scheduled embedded generators in 2025.

There are currently no double circuits in the Central West zone in AEMO's lightning vulnerable transmission line list.

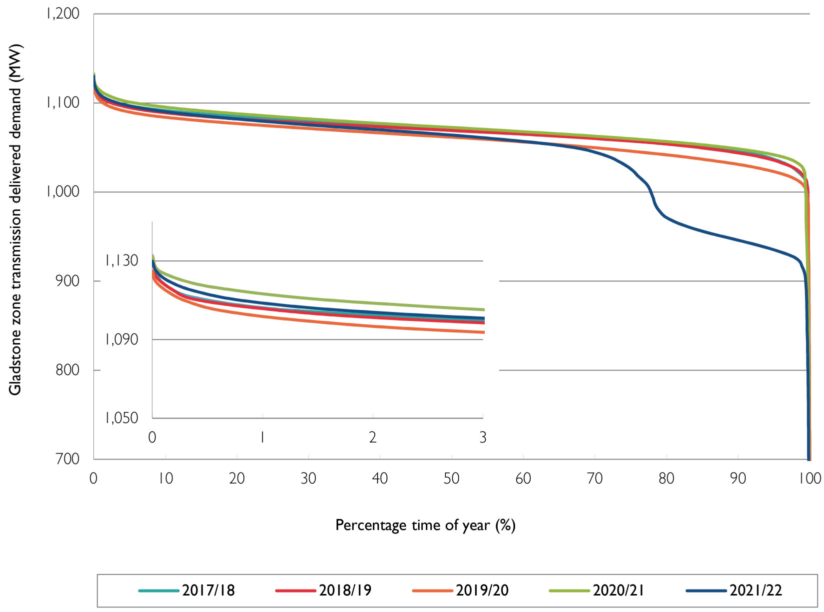
8.7.5 Gladstone zone

The Gladstone zone experienced no load loss for a single network element outage during 2021/22.

The Gladstone zone contains no scheduled, semi-scheduled or significant non-scheduled embedded generators as defined in Figure 3.4.

Figure 8.29 provides historical transmission delivered load duration curves for the Gladstone zone. The figure clearly shows a reduction in demand during 2021/22 due to unplanned outages by Boyne Smelters Limited (BSL). Energy delivered from the transmission network has reduced by 2.8% between 2020/21 and 2021/22. The peak transmission delivered demand in the zone was 1,130MW, which is close to the highest maximum demand over the last five years of 1,133MW set in 2017/18. Minimum demand coincides with small periods when one or more smelter potlines are out of service. The minimum transmission delivered demand in the zone was 632MW.

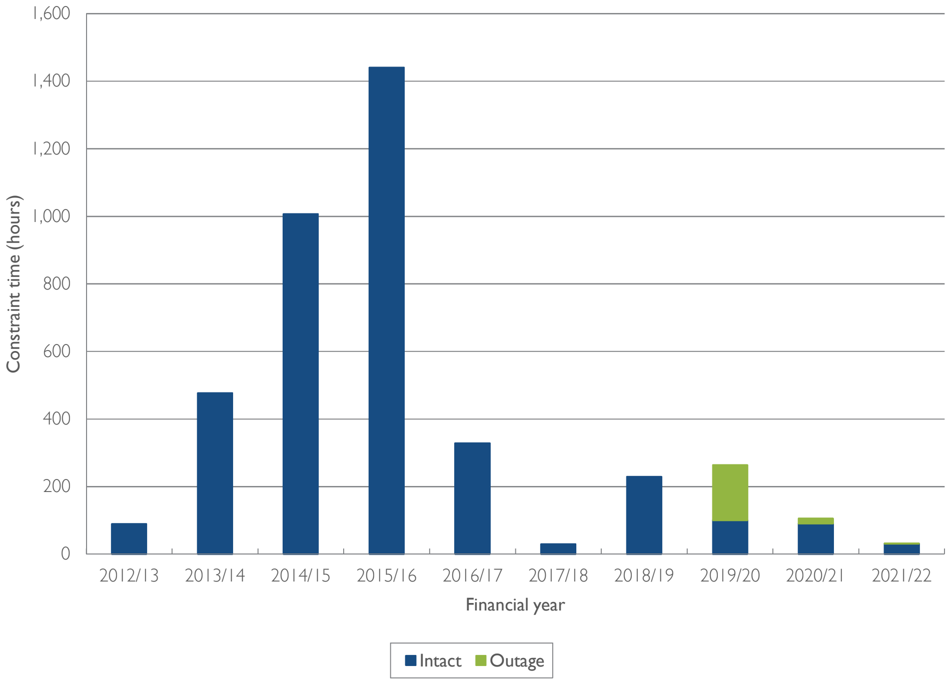
Figure 8.29 Historical Gladstone zone transmission delivered load duration curves



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 BSL's substation. The constraint limits generation from Gladstone PS, mainly from the units connected at 132kV. AEMO identifies the system normal 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 8.30. During 2021/22, the feeder bushing constraint experienced 32 hours of constrained operation, 1 hour during the planned outage of 275kV feeders between Calliope River and Woolooga.

Figure 8.30 Historical Boyne Island feeder bushing constraint times



There are currently no double circuits in the Gladstone zone in AEMO's lightning vulnerable transmission line list.

8.7.6 Wide Bay zone

The Wide Bay zone experienced no load loss for a single network element outage during 2021/22.

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 3.4. These embedded generators provided approximately 260GWh during 2021/22.

Figure 8.31 provides historical transmission delivered load duration curves for the Wide Bay zone. Wide Bay zone is one of three zones in Queensland where the delivered demand reaches negative values, meaning that the embedded generation exceeds the native load, the transmission network supplying the zone is often operated at zero and near zero loading, and the embedded generation makes use of the transmission network to feed loads in other zones. Figure 8.32 provides the daily load profile for the minimum transmission delivered days over the last five years.

While energy has seen significant reductions, the peak demand, which occurs at night, remains at similar levels. Energy delivered from the transmission network reduced by 6.8% between 2020/21 and 2021/22, to the lowest level in the last decade. The peak transmission delivered demand in the zone was 277MW, which is below the highest maximum demand of 316MW recorded in 2020/21. The minimum transmission delivered demand in the zone was -106MW, which is the lowest demand on record.

Figure 8.31 Historical Wide Bay zone transmission delivered load duration curves

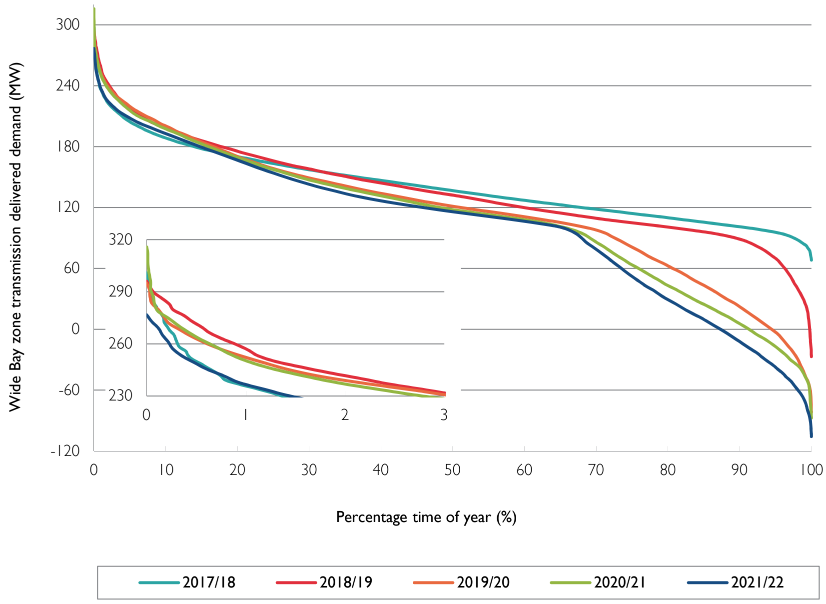
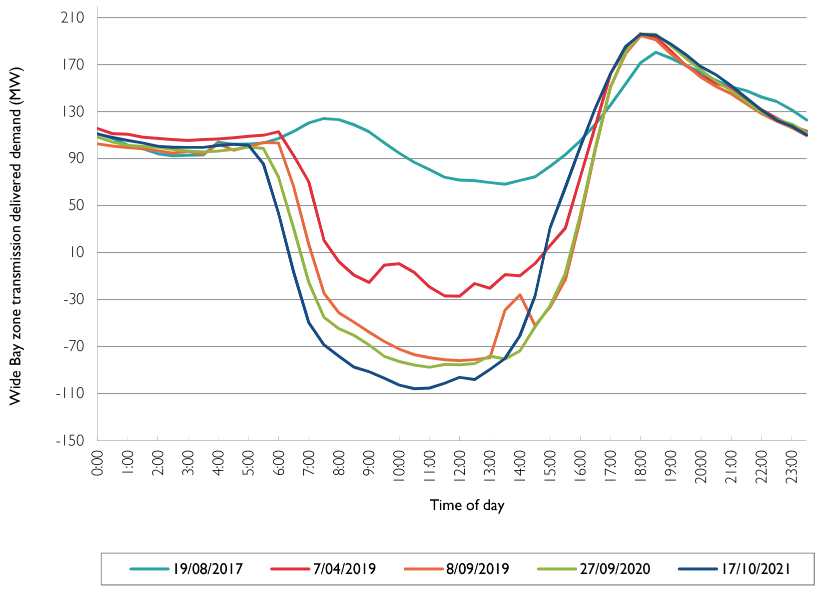


Figure 8.32 Historical Wide Bay zone minimum transmission delivered daily profile



There are currently no double circuits in the Wide Bay zone in AEMO's lightning vulnerable transmission line list.

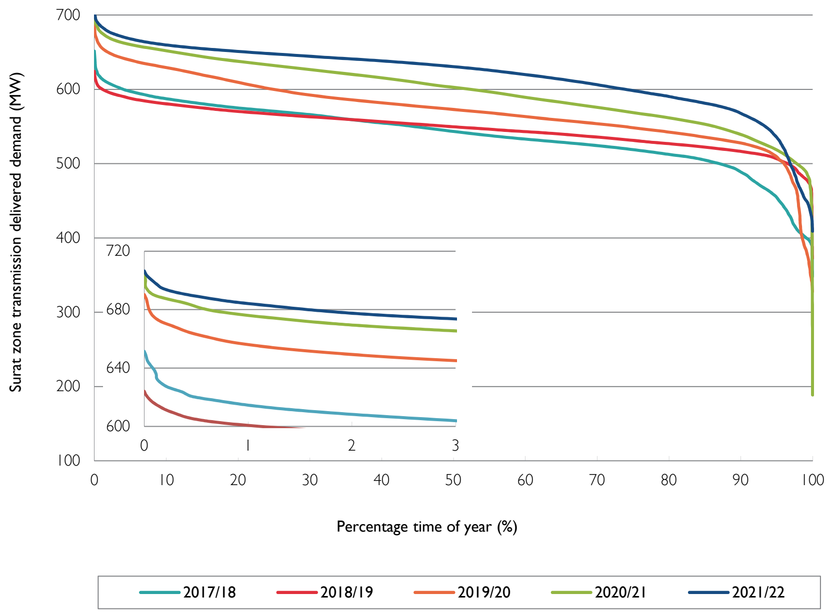
8.7.7 Surat zone

The Surat zone experienced no load loss for a single network element outage during 2021/22.

The Surat zone includes the scheduled embedded Roma and direct connected embedded Condamine generators and significant non-scheduled embedded generator Baking Board Solar Farm as defined in Figure 3.4. These embedded generators provided approximately 206GWh during 2021/22.

Figure 8.33 provides historical transmission delivered load duration curves for the Surat zone. Energy delivered from the transmission network has increased by approximately 3.4% between 2020/21 and 2021/22. The peak transmission delivered demand in the zone was 707MW, which is the highest maximum demand over the last five years but only a slightly higher than 706MW recorded in 2020/21. The minimum transmission delivered demand in the zone was 409MW. The minimum demand over the last five years of 189MW was a result of load disconnection following the Callide C unit 4 incident on 25 May 2021.

Figure 8.33 Historical Surat zone transmission delivered load duration curves



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

- Tarong to Chinchilla 132kV double circuit transmission line, last tripped October 2020
- Condabri North to Condabri Central 132kV double circuit transmission line, last tripped January 2020.

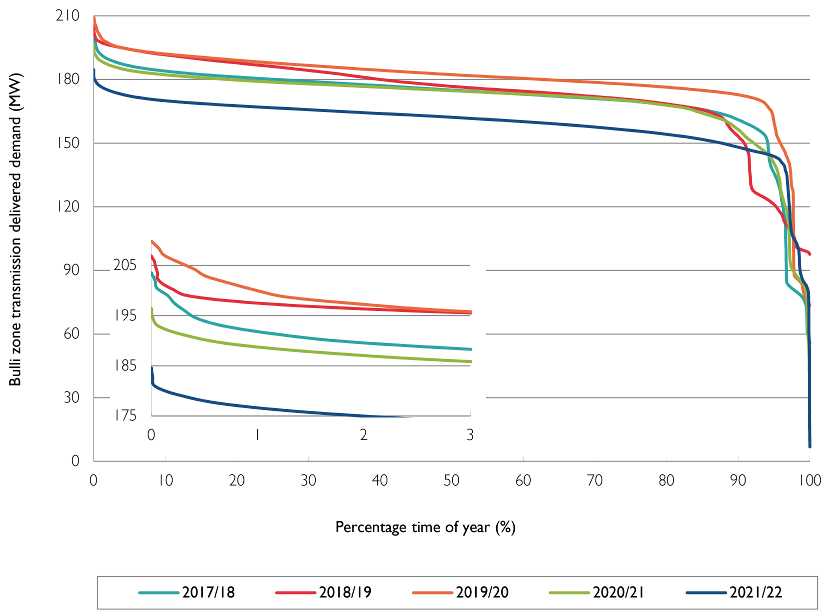
8.7.8 Bulli zone

The Bulli zone experienced no load loss for a single network element outage during 2021/22.

The Bulli zone contains no scheduled, semi-scheduled or significant non-scheduled embedded generators as defined in Figure 3.4.

Figure 8.34 provides historical transmission delivered load duration curves for the Bulli zone. Energy delivered from the transmission network has reduced by approximately 6.4% between 2020/21 and 2021/22. The peak transmission delivered demand in the zone was 185MW which is below the highest maximum demand over the last five years of 210MW set in 2019/20. The minimum transmission delivered demand in the zone was 7MW, which is the lowest demand over the last five years and was a result of an unplanned network outage.

Figure 8.34 Historical Bulli zone transmission delivered load duration curves



There are currently no double circuits in the Bulli zone in AEMO's lightning vulnerable transmission line list.

8.7.9 South West zone

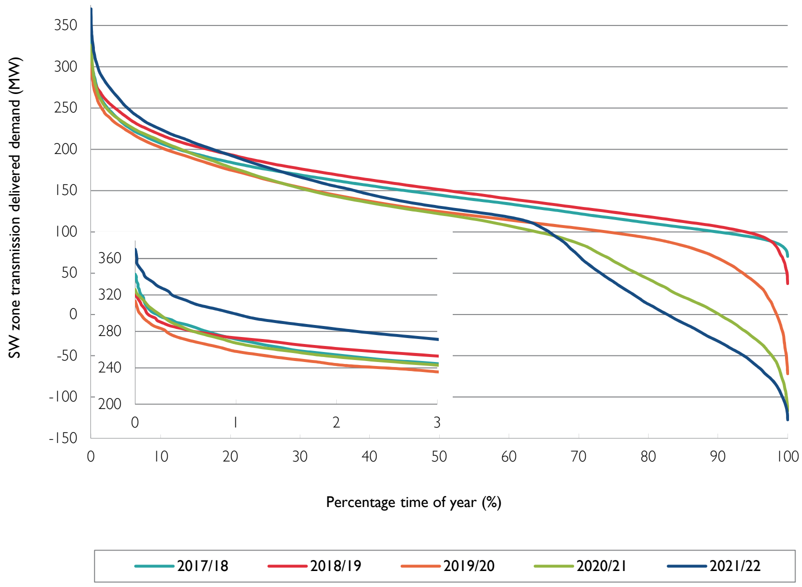
The South West zone experienced no load loss for a single network element outage during 2021/22.

The South West zone includes the semi-scheduled embedded generators Oakey 1 Solar Farm, Oakey 2 Solar Farm, Yarranlea Solar Farm, Maryrorough Solar Farm and Warwick Solar Farm as defined in Figure 3.4. These embedded generators provided approximately 464GWh during 2021/22.

Figure 8.35 provides historical transmission delivered load duration curves for the South West zone. The South West zone is one of two zones in Queensland where the delivered demand reaches negative values, meaning that the embedded generation exceeds the native load, the transmission network supplying the zone is often operated at zero and near zero loading, and the embedded generation makes use of the transmission network to supply loads in other zones.

Energy delivered from the transmission network has reduced by 0.3% between 2020/21 and 2021/22, to the lowest level in the last decade. The reduction in energy delivered is slightly lower than the 2020/21 figure, which was the previous record minimum. The peak transmission delivered demand in the zone was 370MW, which is the highest demand over the past five years. The minimum transmission delivered demand in the zone was -128MW, which is the lowest demand on record.

Figure 8.35 Historical South West zone transmission delivered load duration curves



The significant non-scheduled embedded Daandine PS was retired in March 2022.

There are currently no double circuits in the South West zone in AEMO's lightning vulnerable transmission line list.

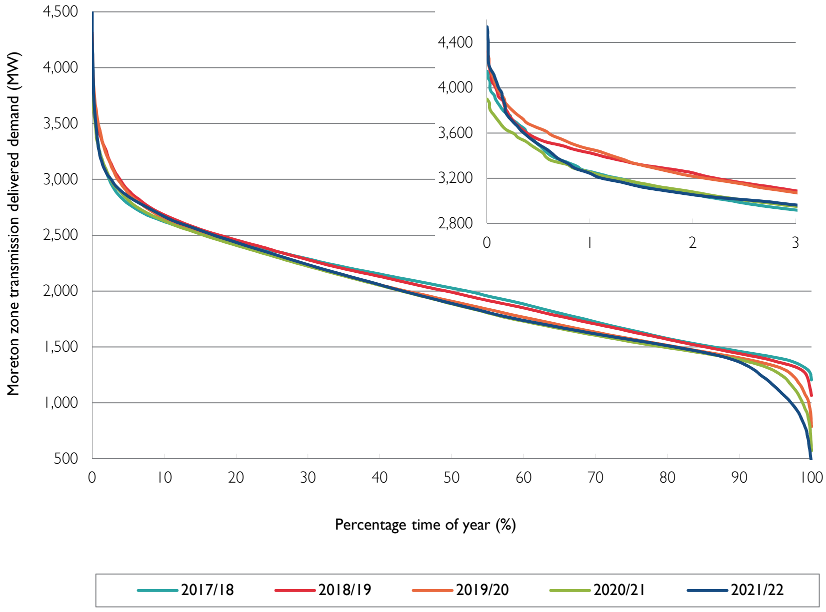
8.7.10 Moreton zone

The Moreton zone experienced no load loss for a single network element outage during 2021/22.

The Moreton zone includes the significant non-scheduled embedded generators Sunshine Coast Solar Farm, Bromelton and Rocky Point as defined in Figure 3.4. These embedded generators provided approximately 48GWh during 2021/22.

Figure 8.36 provides historical transmission delivered load duration curves for the Moreton zone. Energy delivered from the transmission network has increased by 0.1% between 2020/21 and 2021/22. This is a slight increase on the record minimum delivered energy of 17,087GWh recorded in 2020/21. The peak transmission delivered demand in the zone was 4,539MW, which is the highest maximum demand over the past five. The minimum transmission delivered demand in the zone was 451MW, which is the lowest demand on record.

Figure 8.36 Historical Moreton zone transmission delivered load duration curves

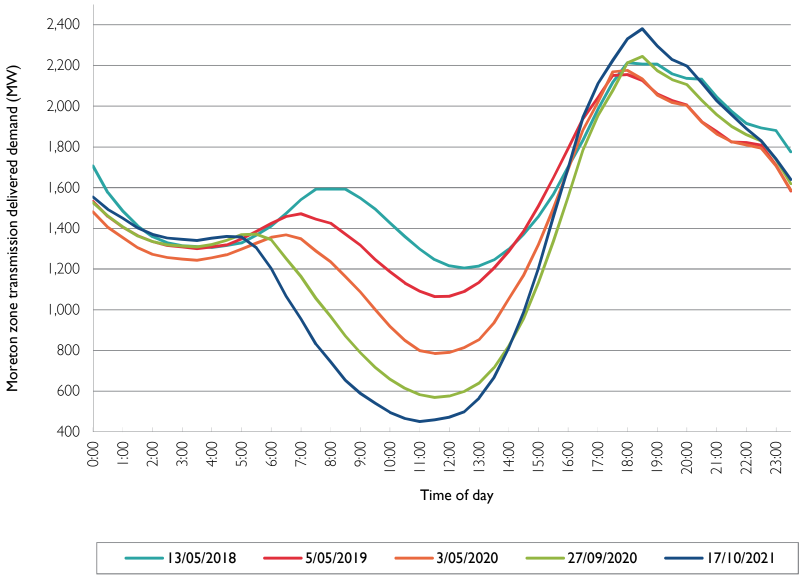


High voltages associated with these light load conditions are currently managed with existing reactive sources. However, voltage control within Powerlink's and Energex's network is forecast to become increasingly challenging for longer durations. This is discussed in Section 6.11.4. In 2021, AEMO identified an NSCAS gap of up to 250 MVAr of reactive power absorption in the southern Queensland. Due to this gap, Powerlink initiated an EOI to identify network and non-network options to address this gap[13].

Figure 8.37 provides the daily load profile for the minimum transmission delivered days for the Moreton zone over the last five years. This figure highlights the steady decrease in minimum demands but also shows the minimum demands days are shifting to later in the year, as the impact of greater rooftop PV yield outweighs the impact of higher native loads in the warmer weather. This is a trend observed across several zones with high levels of rooftop PV generation. The figure also highlights the increase gap between minimum and maximum demand on these days.

13 Powerlink, Request for power system security services in central, southern and broader Queensland regions, May 2022.

Figure 8.37 Historical Moreton zone minimum transmission delivered daily profile



There are currently no double circuits in the Moreton zone in AEMO's lightning vulnerable transmission line list.

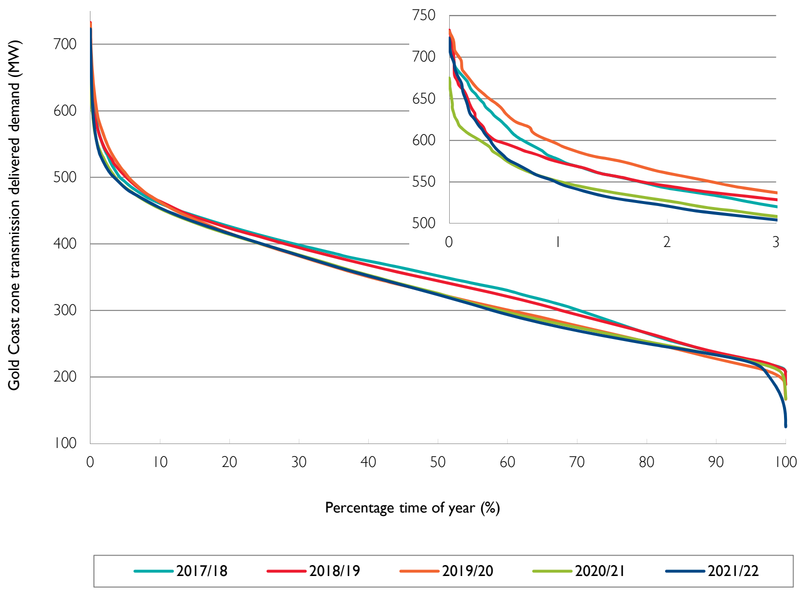
8.7.11 Gold Coast zone

The Gold Coast zone experienced no load loss for a single network element outage during 2021/22.

The Gold Coast zone contains no scheduled, semi-scheduled or significant non-scheduled embedded generators as defined in Figure 3.4.

Figure 8.38 provides historical transmission delivered load duration curves for the Gold Coast zone. Energy delivered from the transmission network has reduced by 0.6% between 2020/21 and 2021/22, to the lowest level in the last decade. The peak transmission delivered demand in the zone was 723MW, which is below the highest maximum demand over the last five years of 732MW set in 2018/19. The minimum transmission delivered demand in the zone was 125MW which is the lowest demand on record.

Figure 8.38 Historical Gold Coast zone transmission delivered load duration curves



There are currently no double circuits in the Gold Coast zone in AEMO's lightning vulnerable transmission line list.

8 Network capability and performance