Generation Capacity Guide

August 2020

This guide outlines the potential generation capacity which may be available at various locations across Powerlink's transmission network. The data presented is not comprehensive. It is preliminary only and is not intended to replace the existing processes that must be followed to seek connection to Powerlink's transmission network.

The information presented in this document is current at 31 July 2020.

The guide includes a description of the system strength challenges that led to a fault level shortfall being declared by AEMO in April 2020 and then broadly describes the current system strength environment and the opportunities for future investment in inverter-based generation. This guide also provides more information on the local thermal capacity that may be available at different locations within the network and the expected future utilisation of relevant major 'grid sections'.

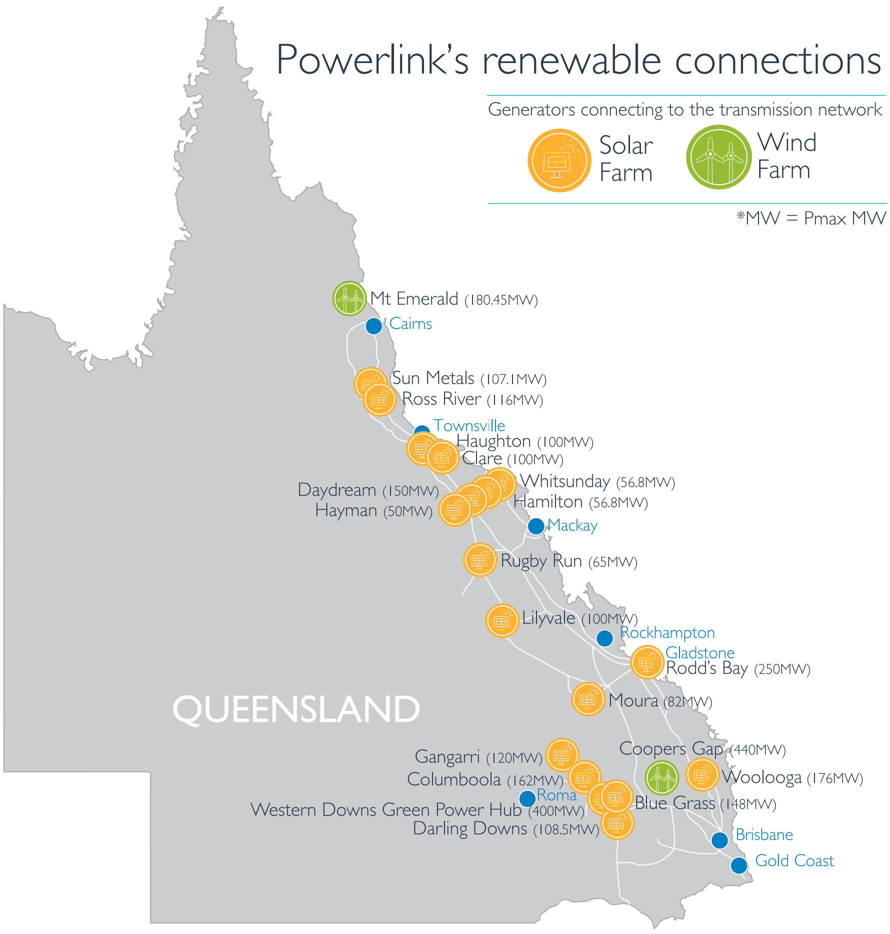
Available capacity is a dynamic concept that changes in response to real time network conditions, environmental conditions, generation dispatch, load levels and the status of transmission equipment. In practice, higher or lower capacities than those listed in Table 2 may be achievable at different points in time. Powerlink encourages interested parties to contact Powerlink's Business Development team by phoning (+617) 3860 2111 during business hours, or by emailing BusinessDevelopment@powerlink.com.au.

Interested parties are also encouraged to refer to Powerlink's Transmission Annual Planning Report (TAPR), which provides information relevant to the development of new generation projects.

Interested parties should check Powerlink's website for updates on network capacity information. To join Powerlink's Non-network Engagement Stakeholder Register (NNESR) and be notified of any updates to this data, please email NetworkAssessments@powerlink.com.au.

Existing and committed inverter-based renewable generation

In the past 12 months Queensland's transmission network has seen more than 1,300 MW of inverter-based renewable generation become committed, adding to more than 1,700 MW that was already connected. Almost all of the most recent committed projects are in southern Queensland.



The success that Queensland's renewable sector has seen over the past three years is a credit to the work of both industry and government, but there is no denying that connecting large-scale inverter-based renewables has been challenging. One of the main contributors to this challenging environment is system strength.

As Queensland's Transmission Network Service Provider (TNSP) Powerlink is responsible for managing system strength throughout the Queensland network, in collaboration with the Australian Energy Market Operator (AEMO).

This guide is designed to provide proponents with an understanding of the current situation in Queensland with regard to system strength and to outline what it means for project planning.

Powerlink has also recently partnered with ARENA to produce the 'Managing System Strength During the Transition to Renewables' report. The report captures recent learnings about system strength and how to manage it.

National context

Managing system strength is a challenge being faced by every jurisdiction in the National Electricity Market (NEM). Fault level shortfalls have been declared in South Australia, Victoria and Tasmania, indicating how widespread these challenges are.

Approaches to managing system strength are continuing to evolve. For example, a recent rule change aimed at increasing transparency requires TNSPs to share basic connection information about new generation projects with AEMO. AEMO must then publish this data on the generator information page. The aim of this rule is to promote awareness of other projects and facilitate more efficient system strength remediation for proponents looking to connect in the same area.

The AEMC is also currently undertaking an investigation into the effectiveness of the current frameworks for the management of system strength. The investigation is examining whether improvements can be made to more effectively and efficiently address system strength issues in the NEM.

The journey so far

The Minimum Fault Level rule change that was introduced in 2018 required Powerlink to build a system-wide model to study system strength and its impact on the stability and performance of the power system. Through our work on this model, our understanding of system strength has grown and evolved. Initially system strength was understood in terms of the fault level required for individual inverter-connected generators to be able to operate stably and to ride through system faults.

That is why AEMO's System Strength Impact Assessment Guidelines introduced a Preliminary Impact Assessment (PIA) screening methodology based on the available fault level at the point of connection of new inverter-based generation. We have previously leveraged off this methodology (i.e. the available fault level) when providing general advice on the hosting capacity in different parts of the network.

However, we now understand that the dominant limitation to hosting capacity is the potential for multiple generators — and other transmission-connected dynamic plant — to interact in an unstable manner. It is our experience that the PIA screening methodology cannot be used to understand and predict the onset of these interactions.

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 12Hz. The only way to gain an understanding of these oscillations is through detailed, PSCAD system-wide modelling.

Fault level shortfall in North Queensland

In April 2020, AEMO declared a fault level shortfall in North Queensland. As Queensland's TNSP – and therefore System Strength Service Provider – it is Powerlink's responsibility to ensure the minimum fault level is maintained at key nodes as defined by AEMO. In the short term Powerlink has achieved this by entering into an interim arrangement with CleanCo to draw on their hydro power stations at Barron Gorge and Kareeya for system strength support. Powerlink is now working towards a longer term arrangement.

While this shortfall indicates the challenges faced for inverter-based connections in this part of the network, it does not mean that new connections are not possible. Where system strength remediation is required by new connecting proponents, Powerlink will work with proponents to explore whether a more efficient and cost effective solution is through a shared service (System Strength as a Service).

Renewable projects throughout Queensland

Powerlink works closely with AEMO – and inverter manufacturers – to maximise the inverter-based generation hosting capacity of Queensland's network.

Underlying system strength is now limited throughout the state and there are still a large number of enquiries and applications under consideration.

Phase	Projects	Estimated MW capacity
Enquiry	56	~15,000
Application	37	~8,000
Offer made	1	250
Committed Projects	7	1,338
Completed Projects	6	1,001
Fully Operational	7	629

As such, all proponents should consider the strong possibility that system strength support will be required no matter where the project will be located. Most commonly this support comes in the form of a synchronous condenser, but it can also include retuning of the plant's control systems and other technology solutions.

Synchronous condensers come in a variety of sizes and costs. Unfortunately it is not possible to provide advice on whether or not system strength remediation will be required – or how large it may need to be – without undertaking a Full Impact Assessment (FIA) for a project-specific inverter-based plant.

Full Impact Assessment

Powerlink now undertakes an FIA for all inverter-based generation applying to connect to the Powerlink network regardless of the size of the proposed plant and available fault level indicated from the PIA. This is because only an FIA can provide information on the impact of potentially unstable interactions with other generators.

To carry out an FIA, Powerlink uses its PSCAD system-wide model and the individual plant models provided by the project proponents. It is vital that proponents provide high-quality models for the FIA process. One of the most common delays to project assessments is the need to request changes to proponents' models.

Once an acceptable PSCAD plant model is submitted by the proponent, the typical timeframe for a FIA is at least six weeks. Typically a number of iterations are required before the PSCAD models are ready for use.

All FIAs are undertaken assuming "system intact" conditions. Even when an FIA produces a positive result, it is still possible for generators to be constrained under "outage" conditions.

It should be noted that if another generator becomes committed while a project is going through the FIA process, the analysis will need to be repeated with the newly committed plant included in the system-wide model. This has led to a significant amount of rework and delays in processing connection applications.

In order for Powerlink to present an Offer to Connect, including a Connection Agreement capable of execution, an FIA resulting in no adverse system strength impact, with Powerlink and AEMO's acceptance in accordance with 5.3.4B of the National Electricity Rules (NER), along with agreed performance standards in accordance with clauses 5.3.4 and 5.3.4A of the NER will be required. It should be noted that if another generator becomes committed prior to Powerlink making an Offer to Connect, the FIA analysis will need to be repeated with the newly committed plant included in the system-wide model. This has led to a significant amount of rework and delays in processing connection applications.

AEMO's System Strength Impact Assessment Guideline provides additional details regarding the assessment process and methodology, while AEMO's Power System Model Guidelines provides additional information regarding modelling requirements.

Thermally supportable generation

Powerlink has assessed the available thermal generation connection capacity at a number of locations across the network, predominantly at the 275kV and 132kV level. Locations close to major urban areas were considered less likely to host a large large-scale inverter-connected project and were excluded from the assessment.

Analysis is based on the existing and committed transmission network arrangements. The analysis also takes account of recent generator commitments. Possible (uncommitted) future network changes – including those outlined in chapters five and seven of Powerlink's 2019 TAPR – may alter the level of supportable generation.

Thermal capacity relates to the highest level of generation that can be exported through a connection point without exceeding the rating of a transmission circuit following the loss of a network element. This capacity is applicable to all forms of generation.

The thermally supportable generation capacity only relates to constraints on the local network, including the network adjacent to the connection point and between the connection point and the main transmission system. Generators may be required to implement a mitigation scheme if seeking to operate in a constrained network area.

The information presented is not intended to provide information on intra-network or inter-network constraints. Further information on this can be found in the following section and in chapter six of Powerlink's 2019 TAPR.

The capacities of thermally supportable generation reported in Table 2 are based on the single generation dispatch shown in Table 1. This generation profile is applied to a typical winter noon load and coincident output for the existing and committed scheduled and semi-scheduled generation projects.

Within a zone the available thermal capacity can vary significantly due to the local network topology and rating and substation connection configurations. The thermally supportable generation at a connection point may be substantially greater or lower with different generation patterns and load levels.

Table 1 Base winter noon generation dispatch assumptions for the maximum available thermal capacity guide

Zone/Interconnector	Generation sent out (MW)
Far North	203
Ross	429
North	375
Central West	907
Gladstone	942
Wide Bay	158
Surat	387
Bulli	1,272
South West	1,308
Moreton	18
Qld-NSW Interconnector Southerly Flow (swing)	840
Terranora Interconnector Southerly Flow	60

Each connection point's thermal capacity was calculated by iteratively applying increasing levels of generation to the connection point (balanced by changing power flows on the Queensland to New South Wales Interconnector) and performing contingency analysis. The thermal limit of a connection point was assessed as being reached when a rating breach was identified within the local network.

It may be possible for generation to be exported in excess of the thermally supportable generation capacity if a mitigation scheme is agreed that limits generation output in the event of local network contingency events.

Powerlink has assessed each connection point individually and has not assessed whether multiple generators in a region are likely to result in congestion on the backbone transmission network.

Major 'grid section' congestion and Marginal Loss Factors

The location and pattern of generation dispatch influences power flows across most of the Queensland system. 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 demand or generation, and/or when embedded generation output is lower.

Maximum power transfer capability may be set by transient stability, voltage stability, thermal plant ratings (transformer and conductor ratings) or protection relay load limits. System strength may also be a constraint that limits the output from large-scale inverter-based generation in an area of the network.

Where constraints occur on the network, AEMO will constrain generation based on the market system rules within the National Electricity Market Dispatch Engine (NEMDE) to maintain system security.

Rapid changes in demand and generation patterns will likely result in transmission constraints emerging over time. Forecasting these constraints is not straightforward as they depend on generation development and bidding patterns in the market. For example, with the existing and committed inverter-based renewable generation in North Queensland, the utilisation of the Central West to Gladstone and Central to South Queensland grid sections are expected to further increase over time.

Powerlink monitors the potential for congestion to occur and assesses the need for network investments using the Australian Energy Regulator's (AER) Regulatory Investment Test for Transmission (RIT-T). Where found to be economic, Powerlink may augment the network to ensure the electricity market operates efficiently and at the lowest overall long run cost to consumers.

Generator proponents are encouraged to refer to Chapter 5 and Chapter 7 of Powerlink's TAPR for more detail on potential future network development as well as emerging constraints.

Marginal Loss Factors (MLFs) have also emerged as an important consideration for new entrant generators, especially for photovoltaic generators in North Queensland. MLFs adjust the spot price to account for the marginal impact of losses from additional generation. They are calculated as a volume-weighted average for the full year and are determined based on historical generation and demand profiles adjusted for known forward commitments.

In North Queensland the local supply and demand balance is significant due to the long distances of the transmission system from North to South Queensland. The coincident generation from photovoltaics has resulted in large drops in the MLFs for photovoltaic generators in NQ over recent years. The situation is not as significant for wind generators in North Queensland as a large amount of the wind export is not coincident with the photovoltaic output and hence does not coincide with the large demand and supply imbalance in the region.

MLF reductions across North Queensland provide an opportunity for additional loads (or storage) to locate in North Queensland.

Engage early

This information is provided as a guide only and is not a substitute for the information obtained during the connection process.

Generator proponents are also encouraged to refer to Powerlink's 2019 TAPR, which provides more detail on these issues, particularly:

- Chapter six presents existing capacity and performance of the main transmission network backbone.
- Chapter five describes possible and proposed changes to the network in the five-year and 10-year outlook period.
- Chapter seven identifies network limitations that may arise within the 10-year outlook period due to new loads within the resource rich areas of Queensland or at the associated coastal port facilities whose development status is not yet at the stage that they can be included (either wholly or in part) in the medium economic forecast of Chapter two.
- Chapter seven also provides a summary of the technical challenges due to the changing mix of generation and the impact this may have on the operation and utilisation of major grid sections and the role Powerlink will play in facilitating an efficient energy transformation.
- Appendix D provides the Powerlink derived intra-regional limit equations, which are implemented in the national electricity market dispatch engine to constrain the generation dispatch within the technical capabilities of the network.
- Appendix E provides indicative minimum and maximum short circuit currents and lowest plant rating at connection points providing an indication of required switchgear ratings.

We encourage all proponents to engage with Powerlink as early as possible in the development of new projects - it is vital that all parties have a firm understanding of everyone's roles and responsibilities throughout the process.

Powerlink is happy to provide guidance on how best to deliver all the information needed for a smooth, efficient connection application process.

Table 2 Indicative connection point supportable generation capacities by zone (based on local thermal capability only)

Zone	Voltage Level (kV)	Thermally supportable generation (MW)	Includes the substations
Far North	275	300-500	Chalumbin, Walkamin
	132	150-250	Chalumbin, Edmonton, Innisfail, Turkinje
Ross	275	800+	Ross
	132	150-400	Cardwell, Clare South, Ingham South, Tully, Yabulu South
North	275	800+	Nebo, Strathmore
	132	50-200	Alligator Creek, Bowen North, Collinsville North, Kemmis, Mackay, Moranbah, Newlands, Peak Downs, Pioneer Valley, Proserpine, Strathmore
Central West	275	200-800	Bouldercombe, Broadsound, Calvale, Lilyvale, Stanwell, Raglan
	132	100-300	Blackwater, Bouldercombe, Lilyvale, Bluff, Dysart
Gladstone	275	500-800	Calliope River, Larcom Creek, Wurdong
	132	300-400	Calliope River, Gladstone South, Larcom Creek
Wide Bay	275	600-800	Gin Gin, Teebar Creek, Woolooga
	132	150-400	Gin Gin, Teebar Creek, Woolooga
Bulli	330	800+	Braemar, Bulli Creek, Millmerran
	275	800+	Braemar, Western Downs
Surat	275	800+	Columboola, Wandoan South
	132	300-400	Columboola, Wandoan South
South West	330	800+	Middle Ridge
	275	800+	Halys, Middle Ridge, Tarong
	110	200-400	Middle Ridge, Tangkam
Moreton	275	500-800	Mt England, Palmwoods
	132	250-400	Palmwoods

Key modelling assumptions

1. Thermally supportable generation capacity has been assessed using a single, indicative, winter midday pattern of load and generation, taking account of constraints on the local network only. The thermally supportable generation at a location may be substantially greater and/or lower with different load and generation patterns, and does not take account of intra-regional or inter-regional constraints on the main transmission network.
2. All analysis is based on the existing configuration of the transmission network with committed changes to the network applied. Possible future network changes, including those outlined in chapters 5 and 7 of Powerlink's TAPR may alter the level of supportable generation.

General notes

1. The provided figures are indicative. Detailed and project specific analysis is undertaken as part of the connection application process, including an assessment of stability, network congestion and compliance with the generator performance standards.
2. Generation opportunities presented in this section are not cumulative. If a new generator commits, it may impact the supportable generation at multiple locations.
3. Transmission network connections do not confer firm access to the National Electricity Market (NEM). The dispatch of generation within the NEM, including management of any congestion, is the responsibility of the Australian Energy Market Operator (AEMO). Powerlink proactively monitors the potential for congestion to occur in accordance with the National Electricity Rules (NER), and will assess the potential network augmentations and/or non-network options to maximise market benefits using the Australian Energy Regulator's (AER) Regulatory Investment Test for Transmission (RIT-T). Where augmentations are found to be economic, Powerlink may augment the network or implement non-network solutions to ensure that the electricity market operates efficiently and at the minimum overall long run cost to consumers.

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