CHAPTER 8

Renewable energy

8 Renewable energy

Key highlights

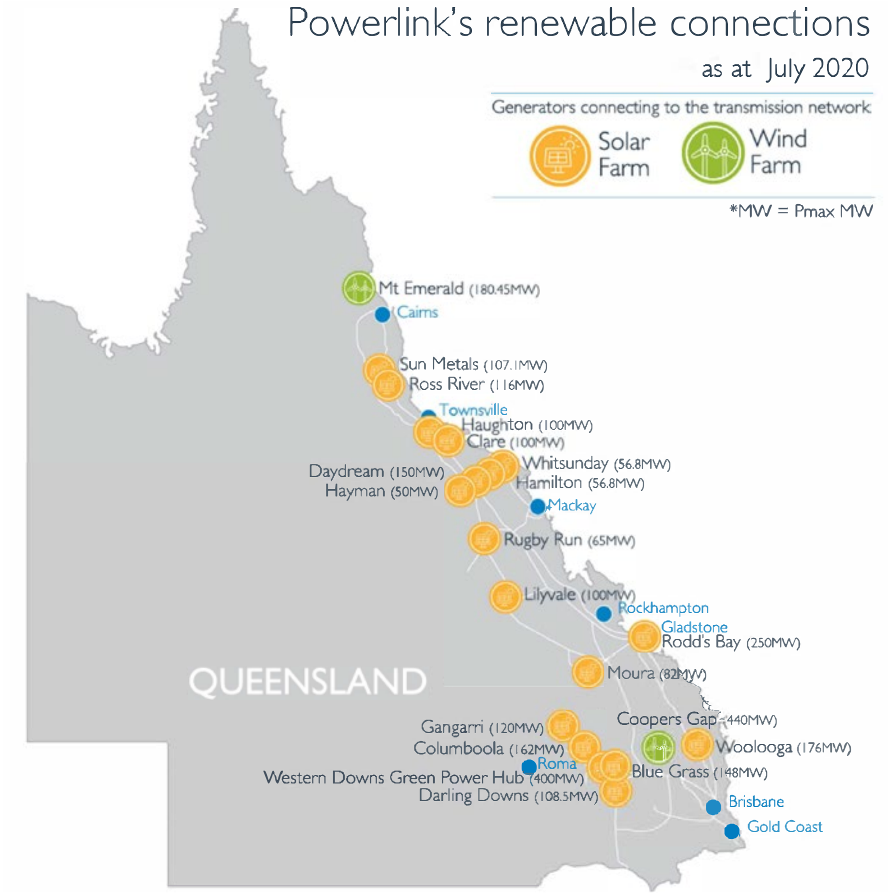
- This chapter explores the potential for the connection of variable renewable energy (VRE) generation to Powerlink's transmission network.
- Powerlink has a central role in enabling the connection of VRE infrastructure in Queensland.
- System strength has been a focus for VRE generators and Powerlink, including development of the Electromagnetic Transient Type (EMT-type) model for Queensland.
- An immediate fault level shortfall has been declared by Australian Energy Market Operator (AEMO) in North Queensland (NQ). Powerlink continues to work with AEMO to develop technical and economic solutions to address the shortfall.
- Powerlink is actively engaging in the Australian Energy Market Commission (AEMC) System Strength Frameworks Review to improve outcomes for connecting parties.

8.1 Introduction

Queensland is rich in a diverse range of renewable resources – solar, wind, geothermal, biomass and hydro. This makes Queensland an attractive location for large-scale VRE generation development projects. During 2019/20, 1,498MW of semi-scheduled VRE generation capacity was committed in the Queensland region, taking the total to 3,960MW that is connected, or committed to connect, to the Queensland transmission and distribution networks (refer to Section 6.2). In addition to the large-scale VRE generation development projects rooftop solar in Queensland exceeded 3,285MW in June 2020.

Figure 8.1 shows the location and type of VRE generators connected and committed to connect to Powerlink's network. Department of Natural Resources, Mines and Energy (DNRME) also provides mapping information on proposed (future) VRE projects, together with existing generation facilities (and other information) on its website. For the latest information on proposed VRE projects and locations in Queensland, please refer to the DNRME website.

Figure 8.1 Powerlink's VRE connections as at July 2020



Utility scale and rooftop connections of VRE generation, both in Queensland and the rest of the National Electricity Market (NEM), has brought with it a number of challenges to which Powerlink is responding. One of the main contributors to this challenging environment is system strength. The distributed nature of VRE generation is also changing the way the transmission network is operated, including changes to flow patterns and network utilisation.

This chapter provides information on:

- the current system strength obligations placed on Powerlink and connecting proponents of large-scale inverter-based plant under the National Electricity Rules (NER)
- the objectives of the AEMC's investigation into System Strength Frameworks and Powerlink's perspectives
- how Powerlink has and continues to meet the system strength challenges
- the fault level shortfall declared by AEMO in April 2020 and how Powerlink is addressing this shortfall
- the current system strength environment and the opportunities for future investment in VRE generation.

8.2 Management of system strength and NER obligations

On 1 July 2018, the AEMC rule for 'Managing Power System Fault Levels' came into effect. The Rule provides for a holistic, flexible and technology neutral solution to issues arising from the forecast reduction in system strength.

Under the Rule

- AEMO develops a system strength requirements methodology guideline and determines where the fault level nodes are in each region, plus the minimum three phase fault levels and any projected fault level shortfalls at those fault level nodes.
- Transmission Network Service Providers (TNSPs) or jurisdictional planning bodies, as the System Strength Service Providers for each region, are responsible for procuring system strength services to meet a fault level shortfall declared by AEMO. These services must be made available by a date nominated by AEMO which is at least 12 months from the declaration of the shortfall, unless an earlier date is agreed with the System Strength Service Provider.
- Network Service Providers (NSPs) undertake system strength impact assessments to determine whether a proposed new or altered generation or market network service facility connection to their network will result in an adverse system strength impact.
- Applicants pay for system strength connection works undertaken by a NSP to address an adverse system strength impact caused by their proposed connection to the NSP's network or propose a system strength remediation scheme[1] .

Consistent with this methodology, Powerlink worked with AEMO to determine the required minimum fault level at key 'fault level nodes' within the Powerlink network (refer to Table 8.1). The minimum fault level is used to assess that the system can be operated safely and reliably now and into the future. The initial assessment was completed in mid-2018.

The guidelines require the minimum fault level to be reassessed no more than once in every 12 month period to determine whether a fault level shortfall exists or is likely to exist in the future. This assessment considers the displacement[2] of existing synchronous plant in Queensland.

8.2.1 Investigation into system strength frameworks by AEMC

Powerlink considers that the existing minimum system strength and 'do no harm' framework is at best reactive and does not provide sufficient time to remediate system strength shortfalls. As such the existing framework is not suited to the speed of the energy transformation occurring.

In October 2020 the AEMC concluded an investigation into the effectiveness of the current framework for the management of system strength. The investigation considered whether any improvements could be made to:

- more effectively identify and address low levels of system strength as they arise in NEM regions, to help maintain system security at the lowest possible cost
- allow for the provision of increased levels of system strength to enable greater output from lower cost generation sources, to deliver lower cost electricity for consumers.
- increase the transparency and efficiency for remediating the system strength effects from large numbers of new connecting generators. This will help make the process of connecting generators more effective, to facilitate the transition to the high renewables grid of the future.

Powerlink actively contributed to the AEMC review and consider that any future framework should take into account:

- an increased emphasis on medium to long-term planning for system strength needs

  The energy mix is rapidly transforming and system strength is an issue now but solutions require sufficient time to be delivered. The current short-term reactive approach to deliver a theoretical minimum system strength level is not workable and does not sufficiently enable planning for the long-term management of issues.

[1] Obligation on the connecting generator to 'do no harm' came into effect 17 November 2017 with AEMO publishing the 'Interim System Strength Impact Assessment Guidelines'.

[2] Displacement may occur for periods when it is not economic for a synchronous generator to operate, and is distinct from retirement which is permanent removal from the market.

- the adoption of suitable margins for system strength requirements whilst ensuring efficient outcomes

  This includes the need to securely operate the power system under a wide range of operating conditions. To facilitate this the frameworks need to provide for a degree of headroom and inclusion of a stronger operational overlay on the forward planning requirements.

Given the AEMC investigation has only just been finalised, Powerlink is currently reviewing the AEMC recommendation. Powerlink will continue to contribute to the development of new Rules to give effect to changes to the framework. Draft Rules are expected in December 2020.

8.3 Developing an understanding of the system strength challenges

Powerlink continues to better understand the system strength challenges and has worked closely with AEMO, Australian Renewable Energy Agency (ARENA) and inverter manufacturers to maximise the VRE generation hosting capacity of the Queensland transmission network.

Fundamental to the understanding of system strength challenges has been the development of a system-wide EMT-type model. This has allowed the study of system strength and its impact on the stability and performance of the power system.

Powerlink has developed an EMT-type model that extends from Far North Queensland (FNQ) to the Hunter Valley in New South Wales (NSW). It includes plant specific models for all VRE and synchronous generators (including voltage control systems) and transmission connected dynamic voltage control plant (Static Var Compensators and Statcoms). This is the most detailed modelling possible with the inverter-based plants modelled at the controller level and with time steps required in micro-seconds.

AEMO's System Strength Impact Assessment Guidelines introduced a Preliminary impact assessment (PIA) screening based on fault level calculation in 2018. This methodology was developed based on the best available knowledge of system strength at that time. During the last 24 months, Powerlink has gained a greater understanding of system strength related issues and now believes that this fault level based methodology does not provide sufficient confidence as a screening methodology, as intended.

Powerlink now understands 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. 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. The only way to gain an understanding of these oscillations is through detailed, EMT-type system-wide modelling.

8.3.1 Australian Renewable Energy Agency (ARENA) Project

Powerlink received funding from the ARENA to investigate technical, commercial and regulatory solutions to address system strength challenges. The study looks at addressing system strength challenges by exploring the merits of several technical solutions, as well as business and regulatory models to facilitate lower cost solutions and remove commercial barriers. The study is occurring over a number of stages.

For stage 1 Powerlink partnered with GHD to prepare an initial report on system strength. The purpose of the report was to promote better understanding on how system strength can impact investment in generation and transmission network assets. The report targets a broad audience to establish a base level of understanding between all stakeholders involved in the power system and serve as a basis for informing the ongoing development of regulatory frameworks. Solar farm operators Pacific Hydro and Sun Metals also supported the report's development. The 'Managing System Strength during the Transition to Renewables' report was published in May 2020 (refer to Powerlink's website[3]).

3 Powerlink, Managing System Strength During the Transition to Renewables, May 2020.

Subsequent stages of this project build on these foundations. Powerlink will publish a stage 2 report 'PSCAD Assessment of the effectiveness of a centralised synchronous condenser approach'' in early November 2020 which demonstrates the potential benefits of connecting proponents sharing a scale-efficient synchronous condenser to meet their individual system strength remediation obligations. This technical viability was demonstrated in a system-wide EMT-type case study, which compared distributed, project specific, synchronous condenser installations to a centralised shared scale-efficient synchronous condenser.

Further stages focus on building understanding of the role 'grid forming' (GFI) inverter technology, can play in contributing to system strength. The aim is to determine whether advanced inverter controls can facilitate a higher penetration of inverter-based renewable generation (e.g. wind and solar) without compromising grid stability.

Initially Powerlink invited inverter manufacturers to test the ability of their product(s) to mitigate system strength challenges. Powerlink provided a simulation test case and defined a range of system and plant conditions and disturbances under which the plant was to be tested for plant stability. For most of the GFI inverters investigated stable operation was simulated down to low Short Circuit Ratios (SCR).

The next step is for Powerlink (in consultation with ARENA and AEMO) to select a promising GFI technology, based on the initial preliminary assessment, and complete a more rigorous system-wide EMT-type analysis. The purpose of this analysis is to evaluate and verify the effectiveness of GFI technology in a 'real world' case and determine their potential to increase the VRE hosting capacity of an area of the Powerlink network. Powerlink anticipate publishing a report on the outcome of this assessment in early 2021.

8.3.2 Retuning of transmission connected Static VAr Compensators (SVCs)

Powerlink has redesigned and commissioned changes to the voltage controller at nine SVCs in North and Central Queensland (CQ). In some cases the structure of the voltage control itself was modified to allow the existing plant to support more VRE generation. In other cases, the gain of the voltage controller was changed to minimise the control interactions. These changes have materially increased the renewable energy hosting capacity of the network. This has reduced proponent's connection costs that would have otherwise been required to provide system strength remediation.

8.3.3 Inverter level retuning of VRE plant

In late-2019 Powerlink developed a methodology to assess the damping provided by a VRE generator at different oscillation frequencies using an EMT-type model that could be shared with inverter manufactures but still preserve the confidentiality of their propriety information.

This work allowed Powerlink to partner with an inverter manufacturer to investigate changes to the plant voltage control strategy. The outcome of this work recommended that the bandwidth of the voltage control system be higher to counter the 8Hz to 15Hz control interactions that have been observed in Powerlink's network. Powerlink tested this revised control strategy in the state-wide EMT-type model and confirmed its effectiveness.

This approach, initiated by Powerlink in partnership with an inverter manufacturer, has been adopted in the North West Victoria area where five fully commissioned plants were being heavily constrained due to control interactions identified post their commissioning. Powerlink is also leveraging off this development. Powerlink has entered into a contract with Daydream, Hamilton, Hayman and Whitsunday Solar Farms (connected to the Strathmore Substation) to help address the declared fault level shortfall in north Queensland (refer to Section 8.4.1).

8.4 Declaration of fault level shortfall

During early 2020, Powerlink and AEMO reviewed the minimum fault level requirements within the Powerlink network. As a result of this review, AEMO published (9 April 2020) a report 'Notice of Queensland System Strength Requirements and Ross Fault Level Shortfall' to the NEM under Clause 5.20C.2(c) of the NER.

The report identified that the fault level nodes for Queensland remain the same as those determined in mid-2018, except for the replacement of the Nebo 275kV node with the Ross 275kV node. The Ross 275kV node is now considered to be a better representation for system strength conditions in north Queensland compared to the Nebo 275kV node.

The minimum three phase fault levels were also determined for all of the Queensland fault level nodes. Powerlink and AEMO carried out detailed EMT-type analysis to determine these system strength requirements for the Queensland region. Using the outcomes from these studies (for example, minimum required synchronous generator combinations), Powerlink and AEMO calculated a new minimum three phase fault level of 1,300MVA at the Ross 275kV fault level node. The updated minimum three phase fault levels for the Queensland fault level nodes are shown in Table 8.1.

Table 8.1 Three phase fault levels for Queensland fault level nodes

Fault level node	2020 minimum fault level (MVA) (post-contingency)
Gin Gin 275kV	2,250
Greenbank 275kV	3,750
Lilyvale 132kV	1,150
Ross 275kV	1,300
Western Downs 275kV	2,550

Based on the minimum fault level review and assessment of the projected fault levels based on dispatch outcomes from the Draft 2020 Integrated System Plan (ISP) Central scenario market modelling results, AEMO declared an immediate fault level shortfall of 90MVA at the Ross 275kV fault level node. AEMO projected that, if not addressed, this fault level shortfall will continue beyond 2024-25.

Under the NER the responsibility to resolve a fault level shortfall lies with the System Strength Service Provider, which is the TNSP or Jurisdictional Planning Body (JPB) for the region. In Queensland, Powerlink is the System Strength Service Provider which must address these technical issues as efficiently as possible. In accordance with clause 5.20C.2(c) of the NER, AEMO specified 31 August 2021 as the date by which Powerlink should ensure that the necessary system strength services to address the fault level shortfall are available.

8.4.1 Options to address the fault level shortfall

Immediately following the fault level shortfall declaration, Powerlink commenced an Expression of interest (EOI) process for both short and long-term solutions seeking offers for non-network solutions to address the fault level shortfall at Ross. Submissions closed on 13 May 2020 (refer to Section 5.7.1).

Powerlink received a very positive response to the EOI with counter parties offering a range of system strength support services to address the fault level shortfall at Ross and have worked closely with AEMO on the proposed remediation approach.

In the short-term, Powerlink with AEMO's approval, has entered into an agreement with CleanCo Queensland to provide system strength services through utilising its hydro generation assets in FNQ. These short-term support services are in place until 31 December 2020. These services, whilst not fully meeting the fault level shortfall, provide additional hosting capacity. Through the development of system strength constraint advice (refer to Table D.3) the hosting capacity has been determined for various synchronous generator dispatches in Central and NQ. These system strength services from the CleanCo hydro generators, together with the system strength limit equations, reduce the incidence of constraints on the inverter-based generation in NQ.

This partial short-term solution allows Powerlink to continue to work on assessing long-term solutions to address the fault level shortfall. Given the impact of system strength on the hosting capacity in NQ, it is very important for Powerlink to implement additional solutions (or combination of solutions) as soon as possible to minimise the constraints on NQ renewable plants.

Offers received as part of the EOI process included inverter tuning to reduce the interactions currently occurring between renewable generation and other control systems, as noted in Section 8.3.3. This included an offer to modify inverters at Daydream, Hamilton, Hayman and Whitsunday Solar Farms connecting to Powerlink's Strathmore Substation. As a result of the modelling by Powerlink, and the subsequent due diligence by AEMO, there is confidence that this inverter retuning will assist with the daytime solution. On this basis Powerlink has entered into an agreement to retune the four plants. These changes are expected to be finalised and commissioned by the end of 2020.

Powerlink will continue to work closely with AEMO to develop more complete and technically feasible short and long-term solutions to the system strength shortfall and undertake the relevant formal approval process in accordance with the NER when the optimal solution has been identified.

8.5 Transmission connection and planning arrangements

In May 2017, the AEMC published the Final Determination on the Transmission Connections and Planning Arrangements Rule change request. The Rule sets out significant changes to the arrangements by which parties connect to the transmission network, as well as changes to enhance how transmission network businesses plan their networks.

Since the implementation of the Rule from July 2018, Powerlink has continued to enhance the documentation available and processes used to meet Powerlink's obligations under the NER. Documents updated include the 'Network Configuration Document – Selection for New substations'. Parties seeking connection to Powerlink's network should ensure that they are referencing the most up to date documentation.

During 2018/19, connection activity at both the enquiry and application stages decreased. Powerlink considers that this is not a result of the new connection arrangements, but rather the market reaching a point where the developments already under consideration are focussing on the impact of the Rule changes and the obligations under the Generator Performance Standards (GPS) on their pending investment decisions, and the moderating forward price of electricity and large-scale generation certificates.

Powerlink is focussed on delivering a timely and transparent connection process to connecting generators including coordination of the physical connection works, GPS and system strength.

8.6 Indicative available network capacity – Generation Capacity Guide (GCG)

Powerlink provides a significant amount of information for parties seeking connection to the transmission network in Queensland, including the GCG. 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. Proponents are encouraged to utilise this information to make informed proposals, however we encourage early engagement with Powerlink's Business Development team.

The GCG is published on Powerlink's website separate to the Transmission Annual Planning Report (TAPR) to facilitate updates to the GCG as required to make available the most up to date data for VRE developers. The GCG also includes thermal capacity and congestion information for customers seeking to connect to Powerlink's transmission network.

Under the NEM's open access regime, it is possible for generation to be connected to a connection point in excess of the network's capacity, or for the aggregate generation within a zone to exceed the capacity of the main transmission system. Where this occurs, the dispatch of generation may need to be constrained. This congestion is managed by AEMO in accordance with the procedures and mechanisms of the NEM. It is the responsibility of each generator proponent to assess and consider the consequences of potential congestion, both immediate and into the future.

As outlined in Section 8. 4, AEMO declared a fault level shortfall in NQ. 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. However, the underlying system strength is now limited throughout the state and there are still a large number of enquiries and applications under consideration. As such, all proponents should consider the strong possibility that system strength support will be required no matter where the project will be located. This support may be provided by a synchronous condenser. However, retuning of the plant's control systems and other technology solutions could be equally effective.

To determine if system strength remediation is required a system-wide EMT-type assessment for a project-specific inverter-based plant must be undertaken. If this assessment identifies an adverse system strength impact then there is an obligation on the VRE proponent to provide system strength remediation. Powerlink will work with the proponent to explore the most cost-effective solution. This may include a shared system strength service.

8.6.1 Full Impact Assessment (FIA)

Powerlink now undertakes an FIA for all VRE 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.

The FIA is carried out as part of the connection process as per AEMO's System Strength Impact Assessment Guidelines. This is to ensure that any adverse system strength impact is adequately identified and addressed as part of the connection application either via a system strength remediation scheme or through system strength connection works.

It is vital that proponents provide high-quality EMT-type models as per AEMO's Power System Model Guidelines[4] for the FIA process. One of the most common delays to project assessments is the need to request changes to proponents' models. Generation must meet the NER GPS, and generation proponents are required to demonstrate that their proposed generation technology is able to meet these standards during the connection process.

AEMO's System Strength Impact Assessment Guidelines[5] provides additional details regarding the assessment process and methodology, while AEMO's Power System Model Guidelines provides additional information regarding modelling requirements.

8.7 System strength during network outages

Throughout the year, it is necessary to remove plant in the transmission network from service. In the majority of circumstances planned outages are necessary to maintain or replace equipment. It may also be necessary to remove plant from service unexpectedly. During these planned and unplanned outages, Powerlink and AEMO must ensure that the system continues to be operated in a secure state.

Network outages may lead to reductions in system strength. While this may be a localised issue, outages on key 275kV corridors, as well as some 275/132kV transformers, may impact the system strength of a number of VRE generators. To address this, Powerlink is working with AEMO to develop constraint equations to be implemented in the National Energy Market Dispatch Engine (NEMDE). The purpose of these equations is to maximise the dispatch of VRE generators in the Queensland system within the available system strength.

8.8 Transmission congestion and Marginal Loss Factors (MLF)

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.

4 AEMO, Power System Model Guidelines, July 2018.
5 AEMO, System Strength Impact Assessment Guidelines, July 2018.

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 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 NQ, 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 (AER)'s Regulatory Investment Test for Transmission (RIT-T). Where found to be economic, Powerlink will 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.

MLFs have also emerged as an important consideration for new entrant generators, especially for photovoltaic (PV) generators in NQ. 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 NQ 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 PVs has resulted in large drops in the MLFs for PV generators in NQ over recent years. The situation is not as significant for wind generators in NQ 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 NQ provide an opportunity for additional loads (or storage) to locate in NQ.

8.9 Further information

Powerlink will continue to work with market participants and interested parties across the renewables sector to better understand the potential for VRE generation, and to identify opportunities and emerging limitations as they occur. The NER (Clause 5.3) prescribes procedures and processes that NSPs must apply when dealing with connection enquiries. Should an interested party wish to utilise the connection framework referred to in Section 8.4, it will be necessary to submit a new connection enquiry.

Figure 8.2 Overview of Powerlink's existing network connection process

Proponents who wish to connect to Powerlink's transmission network are encouraged to contact BusinessDevelopment@powerlink.com.au. For further information on Powerlink's network connection process please refer to Powerlink's website.