ROAM CONSULTING

ENERGY MODELLING EXPERTISE

ROAM Consulting Pty Ltd

A.B.N. 54 091 533 621

Report (Itg00014) to

INTERGEN

NATIONAL ELECTRICITY MARKET FORECASTING

Transmission Security Assessment for Millmerran Power Station

12 December 2007

VERSION HISTORY

Version History					
Revision	**Date Issued**	**Prepared By**	**Approved By**	**Date Approved**	**Revision Type**
1.0	2007-10-12	Andrew Turley			Initial Release of Draft Results
1.1	2007-10-23	Andrew Turley	Ian Rose	2007-10-23	Draft Report
2.0	2007-12-12	Andrew Turley	Ian Rose	2007-12-12	Final Report

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

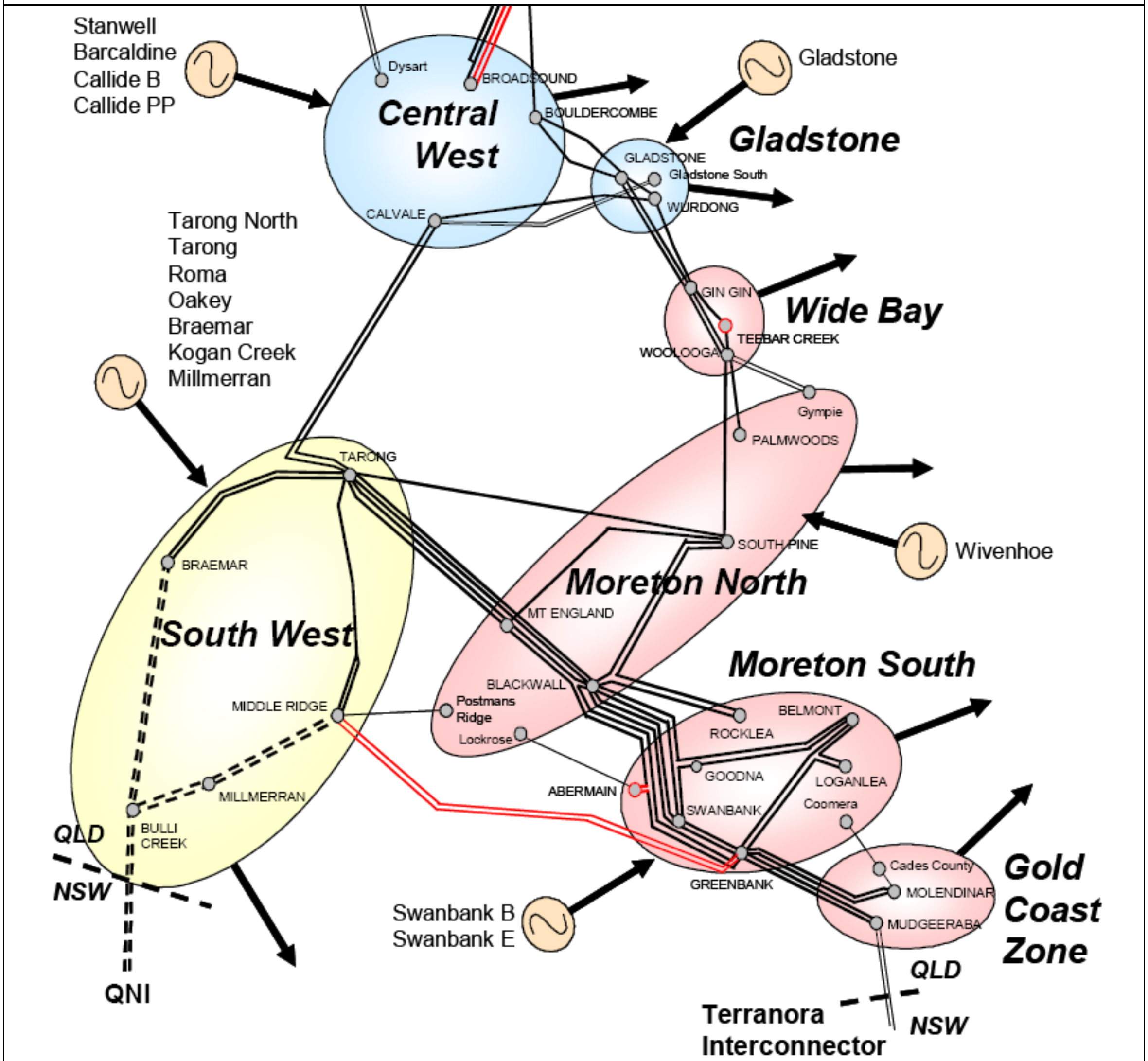
1) INTRODUCTION

Millmerran Power Station is owned by Millmerran Power Partnership (MPP). InterGen operates the facility. InterGen has requested ROAM to provide constraint analysis for the network surrounding Millmerran power station.

2) POWERLINK'S TRANSMISSION NETWORK IN SWQ

Millmerran Power Station is located in South West Queensland (SWQ), a major generation region of Queensland. The power station is connected to the major load centres of South East Queensland and New South Wales via the transmission network operated by Powerlink. Figure 2.1 below shows the surrounding transmission network and the critical flow paths between the power station and load centres.

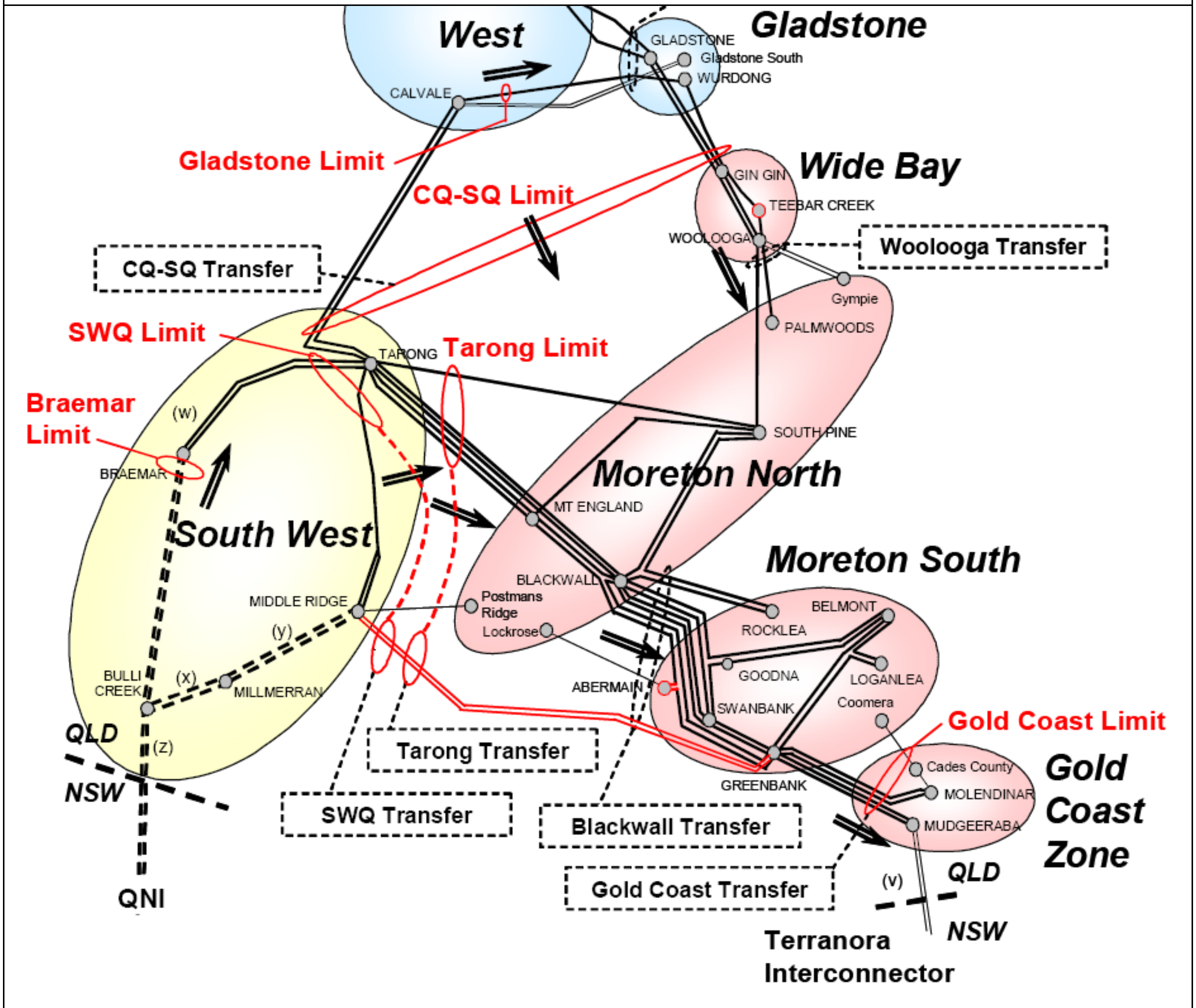
Figure 2.1 – Powerlink's Southern Queensland Transmission Network



Millmerran has two main access points with the Powerlink transmission network, from Millmerran to Bulli Creek (with access to the Queensland network via Braemar, or the New South Wales network via QNI), or from Millmerran to Middle Ridge. However, it may be constrained out of the load centres of South East Queensland and New South Wales by a number of constraints. Three major limits may impede Millmerran's ability to transfer energy (see Figure 2.2):

- Tarong Limit – affecting the major SWQ – SEQ flow path between Tarong and Moreton North, and Middle Ridge and Moreton South (upon completion of the Middle Ridge to Greenbank circuit for summer 2007-08);
- SWQ Limit – affecting flows into Tarong and from SWQ to SEQ via Middle Ridge and Moreton South;
- QNI.

Figure 2.2 – Powerlink Transmission Network and Location of Constraints



2.1) SCENARIOS MODELLED - NETWORK DEVELOPMENTS

In its latest 2007 Annual Planning Report, Powerlink has identified a number of committed and routine[1] network upgrades which will significantly affect the flows in and around South West Queensland. Table 2.1 below details each network upgrade to the SWQ network.

Table 2.1 – SWQ Network Upgrades

Project Name	Project Description	Increase to Existing Limits	Timing	Status
MR-GB	New Middle Ridge to Greenbank line. Installation of 330/275kV transformer at Middle Ridge. 200MVAr capacitor bank at Greenbank.	Tarong (Voltage): 250MW SWQ Limit: 300MW Gold Coast (Voltage): 60MW	07-08	Committed
BR–TR	New double circuit line between Braemar and Tarong	SWQ Limit: 1200MW	11-12	Routine
TR–MN	New Halys 275kV substation (near Tarong). New double circuit 500kV line between Blackwall and Halys (initially operated at 275kV)	Tarong (Voltage): 350MW Tarong (Thermal): 2000MW Gold Coast (Voltage): 75MW	11-12	Routine

ROAM has modelled the network with and without the BR-TR and TR-MN upgrades. The MR-GB upgrade is expected to be completed in the very near future, and therefore is included in all studies. The Braemar to Tarong upgrade, ROAM has assumed, would not go ahead were the Tarong (Halys) to Moreton North upgrade not proceeding. Therefore, ROAM has modelled the two cases, with both 2011-12 upgrades either included, or not included.

The two routine upgrades have a significant effect on the limits which impede SWQ generation from flowing to SEQ. The new circuit between Braemar and Tarong will increase the SWQ Limit by approximately 1200MW, whilst the Tarong to Moreton North upgrade is expected to increase the Tarong Voltage Stability Limit by 350MW.

---

[1] Powerlink has three 'Status' indicators:

- ***Committed Augmentation***: Project approved including completion of National Electricity Rules (NER) processes for regulated network augmentations;
- ***Routine Augmentation***: Projects that are not yet committed for which there is a reasonable expectation that the project will be undertaken to maintain network capability, meet mandated standards or to ensure transfer capability is not restricted by equipment that can be installed in a low cost and economic manner;
- ***Conceptual Augmentation***: Projects identified as potential network options to increase the transfer capability of a NTFP (National Transmission Flow Path).

ROAM has not considered a QNI upgrade as part of this study, although a bidirectional expansion of this flow path would be material to Millmerran power station.

2.2) SCENARIOS MODELLED – NEW ENTRANT PLANT

The location of new entrant generation is particularly important when considering constraints and network congestion. Increased generation in SWQ places more strain on the existing network to deliver energy to the load centres in South East Queensland and across QNI to New South Wales.

ROAM has modelled the following new entrant generators in Queensland. The remainder of the NEM has also been modelled to include the least cost new entrant generators in a timely fashion to ensure that reserve margins are maintained, based on ROAM's latest Integrated Resource Modelling (IRP) outcomes.

Table 2.2 – Installed New Entry Stations

Year	Region	Plant	Max Capacity	Plant Type
2007-08	QLD	Kogan Creek	724MW	Coal
	NSW	Liddell and Munmorah Return to Service	820MW	Coal
	VIC	New Entrant Peaking	400MW	OCGT
2008-09	QLD	Tarong 3&4 Return to Service	700MW	Coal
	NSW	Eraring Upgrade	360MW	Coal
	NSW	Mt Piper Upgrade	100MW	Coal
	NSW	Tallawarra	422MW	CCGT
	SA	Quarantine Upgrade	138MW	CCGT
	NSW	Munmorah Peaker	180MW	OCGT
	QLD	Condamine	135MW	CCGT
	QLD	Darling Downs	630MW	CCGT
	QLD	Braemar Stage 2	450MW	CCGT
2009-10	NSW	Munmorah Peaker	450MW	OCGT
2010-11	VIC	New Entrant Peaking	500MW	OCGT
	SA	New Entrant Peaking	500MW	OCGT
2011-12	QLD	AGL Townsville	400MW	CCGT
2012-13	QLD	Swanbank F	350MW	CCGT
	QLD	Swanbank B Retirement	-480MW	CCGT
	NSW	New Entrant Peaking	500MW	OCGT

The location of the Queensland generators in particular is important given the effect that these will have on network flows. By using advanced and announced proposals, ROAM has ensured that flows are as close to likely future outcomes as possible.

2.3) 2-4-C SIMULATION VERSION

ROAM has used its latest version of the 2-4-C market dispatch software to forecast network congestion for InterGen. This version includes:

- All Powerlink and ANTS constraints and limit equations
- All significant flow path line susceptances and thermal limits
- Minor network upgrades not described previously
- Major network upgrades in SWQ as previously described
- Major network upgrades to other Queensland zones (eg. Broadsound to Ross 275kV CQ-SQ upgrade)

2.4) KEY LIMIT EQUATIONS

As mentioned, ROAM has included in the 2-4-C model all limits as defined by Powerlink and published in the 2007 Annual Planning Report and 2006 NEMMCO Annual National Transmission Statement (ANTS). Powerlink revises these limit equations annually, which are used by NEMMCO as part of the dispatch algorithm.

Of particular importance are the Tarong and SWQ limits. Sections 2.4.1 and 2.4.2 discuss the limit equations for these constraints.

2.4.1) Tarong Limit

Table 2.3 – Tarong Grid Section Voltage Stability Limit Equation

Term	Coefficients (1)	Coefficients (2)	Coefficients (3)	Coefficients (4)	Coefficients (5)
Constant	1202	1158	569	1158	1149
Gladstone_P	-0.03790	-0.04860	0.00000	-0.03160	-0.03040
Callide_B_P + Callide _C_P	0.09950	0.10010	0.09740	0.10490	0.10610
Total Generation at SWQ	0.45780	0.46340	0.70430	0.44430	0.46050
Total Generation at MN + MS	0.00000	-0.34060	-0.17580	-0.32760	0.00000
Swanbank_E_P	-0.5242	0.0000	0.0000	0.0000	0.00000
Total Generation at MN + MS - Swanbank_E_P	-0.35290	0.0000	0.0000	0.0000	0.00000
Highest Wivenhoe Unit Generation	0.00000	0.00000	0.00000	0.00000	-0.60060
Total Generation at MN + MS - Highest Wivenhoe	0.00000	0.00000	0.00000	0.00000	-0.32150
DL_P	-0.1051	-0.1150	-0.1130	-0.1033	-0.10920
Tarong_U	36.92490	33.44030	7.76950	32.76260	36.58520
Tarong_N_U	41.72970	46.54720	12.00000	44.14120	46.43090
Swanbank_B_U	18.55220	14.89480	7.66160	14.60210	13.34600
Wivenhoe_U	48.60820	44.49110	23.19460	42.96700	38.75110
Swanbank_E_U	0.00	78.47	40.97	78.48	75.63450
No. of 120MVAr cap banks available	29.10	28.04	14.34	28.57	28.60510
No. of 50MVAr cap banks available	14.17	14.40	6.40	14.28	14.58130
Equation Floor	2800	3000	2500	3000	2900

Table 2.3 above shows the limit equation for the Tarong Limit. The limit is the minimum of five separate equations, each of which may or may not be applicable depending upon the availability of key generating units (such as Swanbank E and Wivenhoe), or key transmission lines (such as Calvale – Tarong and Tarong – Blackwall). The limit increases where more energy is generated in SWQ, and where more SWQ generating units are online. The amount of energy generated in SEQ reduces the limit, however it also reduces the amount of energy which must be transferred across the constraint. SEQ generation therefore has a net positive effect on the Tarong Limit.

2.4.2) SWQ Limit

The SWQ Limit equation is not explicitly published in Powerlink's Annual Planning Report, however it is part of the ANTS Constraint Workbooks. The ANTS constraint workbooks provide limit equations for each region in the NEM, however the constraints are referred to the inter-connectors such that only inter-regional limits exist. In the case of the SWQ Limit, the constraint applies to the flow across QNI into Queensland. The flow is limited and the constraint is bound when Queensland imports will cause more energy to flow across SWQ to SEQ than the network is capable of transmitting.

The SWQ network will allow up to approximately 2400MW of energy to flow into South East Queensland from South West Queensland. This includes energy generated within SWQ and energy imported from NSW. However, as Figure 2.2 demonstrated previously, energy generated at Tarong or Tarong North is excluded, being downstream of the SWQ constraint.

Table 2.4 – SWQ Limit Equation

Term	Coefficients (1)	Coefficients (2)	Coefficients (3)
Constant	1700	2000	3200
QLD Demand	0.03700	0.03700	0.03700
Total Generation at Millmerran	-1.00000	-1.00000	-1.00000
Kogan + Wambo + Braemar Stage 2	-0.96000	-0.96000	-0.96000
Total Generation at Oakey	-1.10000	-1.10000	-1.10000
Other SWQ New Entry	-1.0000	-1.0000	-1.0000
Equation Floor	n/a	n/a	n/a

Table 2.4 shows three limit equations for the SWQ Limit; each of these are only different by the constant. Prior to the Middle Ridge to Greenbank upgrade (which is committed for completion in time for the 2007-08 summer), the constant is 1700MW. After the Middle Ridge upgrade but prior to the routine Braemar to Tarong upgrade, the constant is 2000MW, increasing 300MW due to the MR-GB development.

As mentioned, the limit is referred to the flow from Armidale (NSW) to Bulli (QLD) across QNI. That is, the flow north into Queensland must be less than, or equal to, the result of the above equation. The result is approximately 2400MW of either locally generated, or imported, energy. Local generation in excess of 2400MW must be exported across QNI into NSW.

Network Upgrades and the SWQ Limit

As discussed in Section 2.1, ROAM has incorporated committed and routine upgrades as announced by Powerlink for the SWQ network. These have a significant effect on the SWQ Limit.

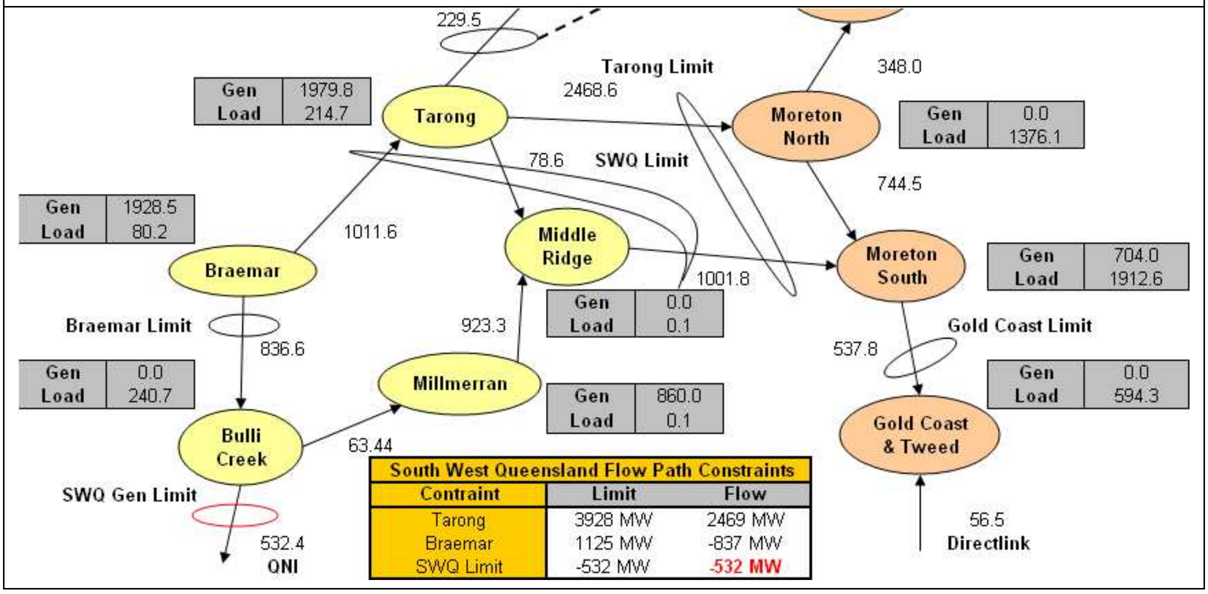
Although it is not included in the SWQ Limit Equation, the Tarong (Halys) to Moreton North upgrade is equally important to the SWQ region. Alleviating constraints on the SWQ grid section would increase constraints on the Tarong grid section without network enhancements on this network flow path. The proposed upgrade will increase the Tarong Voltage Stability Limit by approximately 350MW, as stated in Table 2.1.

The Braemar to Tarong double circuit line is a significant development for SWQ, particularly for generators upstream of the SWQ Limit. The upgrade increases the SWQ Limit by 1200MW, all but eliminating constraints on this grid section. This effectively allows up to 3600MW of generation to flow between SWQ and SEQ (excluding that generated by Tarong and Tarong North). Given that there is forecast to be approximately 3600MW of installed and new entrant generation in SWQ (excluding Tarong and Tarong North), most of which is baseload or intermediate plant, the upgrade is necessary in order to ensure that constraints in the region are not unnecessarily high.

Example of an SWQ Constraint

Figure 2.3 below demonstrates an individual period where the SWQ Limit is binding, causing a constraint. The example shows that the SWQ Limit is -532MW. That is, the flow along QNI must be no more than -532MW, or 532MW to the South. As the SWQ Limit is oriented to the inter-connector, the flow along QNI is always the binding limit, although the constraint is designed to limit the flow across SWQ – SEQ.

Figure 2.3 – Example of an SWQ Constraint



If the binding constraint will create negative settlement residues across QNI, then SWQ generation, including Millmerran will have to reduce output so as to reduce flows south on QNI and remove the negative settlement residues. It should be noted that the auxiliary losses on Millmerran Power Station has been placed at the Bulli Creek node for convenience, rather than at the Millmerran node.

3) RESULTS

Powerlink has advised InterGen that network congestion becomes material to the Millmerran Power Station in the next five years. ROAM Consulting concurs with that assessment.

3.1) FREQUENCY OF CONSTRAINTS IN SOUTH WEST QUEENSLAND

Given the new entrant stations which are anticipated to enter the market, taking into account all recent market announcements and commitments, ROAM concludes that the South West Queensland network will begin to become significantly constrained from 2009-10, even with the Middle Ridge to Greenbank upgrade in service.

The South West Queensland Limit, which is included in the ANTS Constraints Workbook 1[2], limits flow between SWQ and SEQ. This limit is of particular importance to Millmerran, as the power station is 'upstream' of the limit in relation to the Queensland load centre. The limit is significantly affected by the proposed development of the Braemar to Tarong and Tarong (Halys) to Moreton North lines. ROAM has found that the proposed network upgrade, for which Powerlink estimates completion by 2011-12 (coinciding with Powerlink's anticipated emergence of material network constraints in the region), effectively eliminates the possibility for constraints on the SWQ grid section.

Figure 3.1 below shows the number of periods in which the SWQ Limit binds, causing a constraint along the SWQ – SEQ flow path, from 2008-09 to 2012-13.

Figure 3.1 – South West Queensland Network Congestion

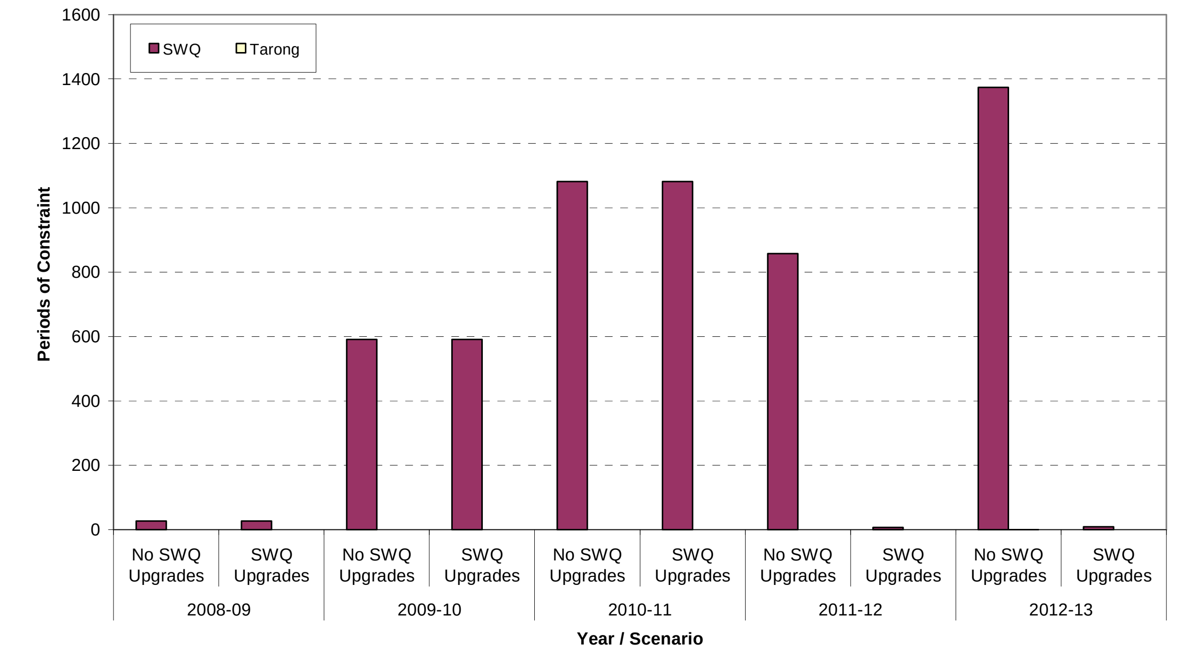


Figure 3.1 demonstrates the effectiveness of the proposed SWQ network upgrades. The BR-TR and TR-MN upgrades increase the SWQ Limit and Tarong Voltage Stability Limit by 1000MW and 350MW respectively. These upgrades, when installed in tandem, effectively reduce congestion along the SWQ flow paths into SEQ to very low levels at that time.

[2] The ANTS Constraints were developed for the 2006 ANTS Market Simulations Scoping Studies Case. There are three books of constraints. The SWQ Constraint Equation is located in Workbook 1.

3.2) MAGNITUDE OF CONSTRAINTS TO MILLMERRAN POWER STATION

Section 3.1 has demonstrated that there are a significant number of periods where the SWQ grid section is constrained out from SEQ. However, the cost of the high degree of constraints to Millmerran Power Station is as yet unknown. Millmerran will be disadvantaged by the constraint where the transmission network is unable to allow a full dispatch from the station, that is, where Millmerran is not allowed to generate at full output. Given that the pool price during these periods of constraint is on average very high ($500-1000/MWh depending on the marginal generator downstream of the constraint), the loss of generation during these periods will have a large impact on the revenues of the generator.

During periods of constraint, it is typical that generators upstream of the constraint bid at the market price floor in order to ensure that their available capacity is dispatched and therefore the generator is dispatched during the constrained period. Due to the intra-regional constraint, the generator has no risk with bidding in below marginal cost, as the constraint ensures it cannot be the marginal generator and hence set price.

Where more generation is bid at equivalent price than is capable of transmitting across the constrained flow path, NEMMCO dispatches each generator such that the dispatched capacity is the proportion of available capacity to total capacity bid in at the market floor upstream of the constraint. The example below demonstrates the price setter 'tie-breaking' method:

Tie-Breaking Example

1. Constraint occurs between SWQ and SEQ;
2. QLD Pool Price increases above $1000/MWh;
3. All SWQ generators which are not offline or on maintenance bid in all available capacity at the market price floor (-$1000/MWh);
    a. Kogan Creek has 724MW available;
    b. Condamine has 135MW available;
    c. Wambo has 300MW available (one unit offline);
    d. Darling Downs has 630MW available;
    e. Braemar 2 has 300MW available (one unit offline);
    f. Oakey has 0MW available;
    g. Millmerran has 860MW available;
    h. Total available SWQ generation is 2949MW.
4. Total available energy which can be transmitted to SEQ is 2434MW
5. Resulting dispatch is in proportion to total price-tied generation:
    a. Kogan Creek will be dispatched for 724/2949*2434MW = 597.6MW;
    b. Condamine will be dispatched for 135/2949*2434MW = 111.4MW
    c. Wambo will be dispatched for 450/2949*2434MW = 247.6MW;
    d. Darling Downs will be dispatched for 630/2949*2434MW = 520.0MW;

e. Braemar 2 will be dispatched for 450/2949*2434MW = 247.6MW;
f. Oakey will be dispatched for 0/2949*2434MW = 0MW;
g. Millmerran will be dispatched for 860/2949*2434MW = 709.8MW

In the above example, no mention is made on the effect of the SWQ Limit to the flow on QNI. The SWQ Limit is referenced to the interconnector, such that the flow on QNI is capped by the SWQ Limit. The tie-breaking methodology does not influence the flows along QNI as the limit itself controls the flow. The most recent congestion management protocol addresses the context of QNI with regards to constraints on the SWQ network. The protocol is designed to alleviate congestion without changing the flow on QNI. This has implications for all SWQ generators, including Millmerran.

3.3) IMPORTANCE OF THE BRAEMAR – TARONG AND TARONG (HALYS) – MORETON NORTH UPGRADES

Total South West Queensland generation (summer) capacity is approximately 2300MW at present, of which approximately 1600MW is high capacity factor, low cost plant. Prior to the Braemar to Tarong and Tarong (Halys) to Moreton North upgrades, the total capacity of the SWQ to SEQ flow path is approximately 2000MW, depending upon demand. This increases by 1MW for each 1MW flowing south along QNI (and likewise decreases by 1MW for each 1MW flowing north along QNI).

With the introduction of Darling Downs, Condamine and Braemar Stage 2, there is an additional 1200MW of both intermediate and peaking plant. The installation of Darling Downs in particular, which is anticipated to be a moderate-high capacity factor plant, will put further strain on the operation of the SWQ grid section, as over 2800MW of low cost plant will be installed in the region. After strategic withdrawal of capacity, there is little headroom on the network capability to SEQ, which is demonstrated by the significant increase in constrained periods from 2009-10.

In 2011-12, when the upgrade is scheduled for completion, constraints are all but eliminated.

4) CONCLUSIONS

ROAM has modelled the Queensland transmission network, including all committed and routine upgrades along Powerlink network, from 2008-09 to 2012-13, in order to identify whether the South West Queensland network faces congestion during this period. ROAM has been able to identify that a considerable number of periods are expected to bind the SWQ Constraint, from 2009-10 and in 2010-11, although Powerlink's proposed upgrades of the major flow paths (Braemar to Tarong and Tarong – Moreton North) should alleviate most constraints upon completion.