TransGrid

TransGrid's Submission to the Australian Competition & Consumer Commission

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Attachment 6B

Main System Planning Criteria – Application

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MAIN SYSTEM PLANNING CRITERIA – APPLICATION

1. PURPOSE OF THE DOCUMENT

TransGrid's Annual Planning Reports have described TransGrid's planning approach to the NSW network. The planning criteria are set out in broad terms in the APR's.

This document sets out in more detail the planning criteria for the main system and specific aspects of the application of the criteria.

2. SPECIFIC MAIN SYSTEM PLANNING CRITERIA

The main system is planned to provide adequate reliability. In this document the reliability of this interconnected bulk transmission system is defined by the following two categories[1]:

Adequacy

The ability of the power system to supply the aggregate demand and energy requirements of the State loads at all times taking into account scheduled and reasonably expected unscheduled outages of the network and system elements.

Security

The ability of the power system to withstand sudden disturbances, such as short circuits and forced outages of transmission elements and generators.

The specific main system planning criteria are set out in Table 1. These criteria determine the system power transfer capability, the ability to supply the system load and design requirements for the system from a system planning perspective.

2.1 Definitions

The following definitions apply to the categories of load level, the generation dispatch conditions that need to be considered, the level of prior outage and contingency that are assumed in assessing system adequacy, the system capability for power transfer and the reactive capability.

Load Level

This is the forecast probability of exceedence load level, generally under medium economic growth conditions. Other load levels are as specified in the notes to the table. Both summer and winter loading conditions are considered.

The forecast individual substation load levels are assumed as follows:

[1] This definition is found in the practices of many organisations and is referred to for example in CIGRE documents and USA NERC Planning Standards.

- Main Grid – the substation loading at the time of system coincident peak demand
- Areas on interconnections – the substation loading at the time of the coincident area peak demand

Indicative levels of main system losses and power station auxiliaries are assumed in the forecast, and these may vary depending on conditions in the system studies.

All embedded generators within DNSP networks are assumed in service.

Both 10% probability of exceedence (poe) and 50% poe load levels may be considered.

Generation Dispatch

The dispatch of generators and interconnector power flows in the NEM. This is determined by NEMMCO's dispatch systems.

Prior Outage

Any plant that is unavailable for service before the application of the contingency. The plant may be unavailable due to maintenance or as a result of a long-term failure.

The prior outage can be any circuit (defined below) or generator.

There are two transformers at Kemps Creek 500/330 kV and Darlington Pt 330/220 kV. The prior outage of these transformers is not considered, with the view that such outages would not be taken at times where high power transfers are anticipated and constraints would be otherwise covered by limit equations or operational arrangements.

Contingency

This is any single element, which is:

- One circuit of a transmission line
- One transformer (only the 500/330 kV and 330/220 kV transformers are considered at the main grid level)
- One static shunt capacitor bank
- One shunt reactor
- One bus bar section
- One generating unit
- One SVC

A circuit may be one circuit of a double circuit line or a single circuit line.

"N-0" refers to system normal,
"N-1" refers to the outage of a single element
"N-2" refers to the outage of two elements, which may or may not be physically related.

A metropolitan cable (330 kV or 132 kV) is not considered as a contingency from the main system power transfer capability perspective, except where it impinges on reactive power conditions. A cable outage is considered in reactive planning. Cable outages are instead considered in the planning and analysis of the CBD system.

SVC's are treated separately with respect to reactive power capability. They are generally located on interconnectors and their outage is covered by a limit equation. In the Sydney area the system is expected to be able to withstand the outage of an SVC.

Note that the requirement to consider a bus bar section outage impacts on the design configuration of switchyards and is generally not required to be considered from a system study point of view.

Normal operation of any Special Protection Schemes is assumed in the system analysis.

The contingency may be accompanied by a short circuit. The following level of fault is essentially defined in the National Electricity Code:

> *220 kV and above and existing systems below 220 kV*: the most critical two-phase-to-ground fault cleared in primary protection time by the faster of the duplicate protection systems with intertrips available.
>
> *New systems below 220 kV*: the most critical three-phase solid fault cleared in primary protection time by the faster of the duplicate protection systems with intertrips available, where they exist.

<u>System Capability</u>

This is the power transfer capability of the system governed by:

- Line thermal ratings
- Transformer thermal rating
- Transient Stability – within the defined capability
- Damping – within the defined capability

The line thermal ratings applied must be consistent with the situation, covering:

- Continuous Rating,
- Sustained Emergency Rating,
- Short Time Rating

<u>Reactive Capability</u>

This covers the following requirements:

- A margin from the point of voltage collapse.
- Voltages are to be within limits

Voltage limits must cover the following:

- Contractual obligations with customers,
- System Highest Voltage,
- Transformer tap changer limits – tap changers must be within range, allowing the regulated LV bus voltage target level to be reached, unless otherwise to be ignored under a Connection Agreement.

2.2 System Conditions and Planning Criteria

The system conditions to be examined and associated planning criteria are set out in the Table below.

Table 1 - Main System Planning Criteria

Load Level	Generation Dispatch	Prior Outage	Contingency	System Capability	Reactive Capability	Comment
Maximum (L1)	All (G1)	-	N-0	Within capability	Margin >0 (R1) Voltages within limits	A
	Limited (G2)	-	N-1	Within capability	Margin >0 (R1) Voltages within limits	A
Range of load to maximum (L2)	Interconnectors at Limits (G3)	-	N-1	Within capability	Normal (R2) or specified	B
10% poe	Limited – Major thermal generators operating and high interconnector flows (G8)	-	N-0	Within capability	Normal (R2)	C
	Limited (G2)	-	N-1	Within capability	Normal (R2)	D
	Limited range after re-dispatch (G4)	-	N-2	Within capability	Normal (R2)	E
50% poe	All (G1)	One reactive source	N-0	Within capability	Normal (R2)	F
	Probable (G5)	One reactive source	N-1	Within capability	Normal (R2)	G
	Limited range after re-dispatch (G4)	One reactive source	N-2	Within capability	Normal (R2)	H
Light load (L3)	All – limited units on line (G6)	-	N-0	Not relevant	Normal with voltage limits (R3)	J
	All – limited units on line (G6)	-	N-1	Not relevant	Normal with voltage limits (R3)	J
Medium load (L4)	Limited off – peak (G7)	One element	N-1	Within capability	Normal (R2)	K

2.3 Comments on the Table

A

This covers the extreme but relatively rare maximum load on the system that exceeds the one in ten year forecast load levels.

Under forecast maximum system load conditions and all dispatch conditions in the system normal state the system is not required to be in a secure state. In general it is expected that the system would be vulnerable to the first contingency for system normal conditions.

Special Protection Schemes are to be applied or a limited dispatch arrangement is to be adopted to bring the system to a secure state under system normal conditions. This yields the limited dispatch conditions that are to be tested under 'N-1'.

It is necessary to achieve a positive margin from the point of voltage collapse and voltages are to be within limits. It is not expected that all generators would have spare reactive capability at the system normal operating point.

The system is able to withstand a single contingency under a limited range of dispatch conditions, thereby in principle allowing the load to be served. This range of conditions may be very limited. The system voltages are to be stable (without any margin from the point of collapse) under N-1 conditions.

B

The interconnector capability is defined according to a N-1 criterion and the dispatch process adopts this capability. The capability is specified as a limit equation or technical envelope which provides the interconnector capability across a range of conditions. The limit equation includes terms relating to system or area load, generation dispatch etc.

The limit equation may assume that the normal system reactive margins have been applied but may also have a separately specified safety margin. The margin and its basis is specified when the limit equation is derived.

Interconnector capability is determined by consideration of:

- Line thermal ratings;
- Transient stability – with modelling prescribed by the considerations of the Plant Modelling Working Group;
- Voltage control; and
- System Damping – with modelling in accordance with the workings of the interconnector testing working group.

C

At the 10% probability of exceedence (poe) forecast load level (or one in ten year load) and system normal conditions it is necessary to be able to operate the NSW major thermal units at rated output and have high power transfers into NSW over the interconnectors whilst also achieving an acceptable voltage profile with all elements within their continuous rating.

This requirement stems from the point of view of system economy and to ensure that the operation of one generator does not preclude the operation of another for the want of relatively low cost reactive support. The aim is to ensure the ongoing reliability of supply to the NSW loads.

Normal reactive power margins and voltage control margins apply. These are set out in following sections below.

In practice it is the N-1 considerations that will determine the feasibility of a dispatch pattern. A range of generation dispatches should be feasible under system normal conditions. However not all dispatch conditions and interconnector flow levels may be feasible. A set of limit equations will define the feasible dispatch patterns. The limit equations may need to cover line thermal limits, transient stability limits and reactive conditions.

D

Under N-1 conditions (where limit equations define the capability) where it is feasible, reactive plant will be installed such that the reactive capability is less restrictive than the line rating or transient stability limitations. This is in recognition of the relatively low cost of static shunt reactive plant. All plant installations are however subject to the requirements of the Regulatory Test.

E

Within 30 minutes of a contingency, generation will be re-dispatched so as to bring the system to a secure state in anticipation of the next contingency. The feasible range of dispatch conditions may be very limited to satisfy the N-2 reliability level.

Normal reactive margins continue to apply. As in D the reactive power limitations should not be more restrictive than other limitations.

F

Under 50% poe load level conditions (a one in two year load) the system is to be within capability and have normal reactive margins under N-0 conditions, with one critical item of reactive power support out of service.

All reasonable dispatch patterns are to be covered.

G

Under N-1 contingency conditions the probable generation dispatch patterns (but not all dispatch patterns) are covered.

As in D and E the reactive power limitations should not be more restrictive than other limits, where this is feasible and subject to the Regulatory Test.

H

A more limited range of dispatch patterns, following re-dispatch within 30 minutes, is to be covered when testing for N-2 adequacy.

J

At light load all generation patterns should be feasible. System capability is not an issue. Upper voltage limits are the prime concern.

Under light load conditions the NSW thermal generators are assumed to be operating at high output with spinning reserves provided by interstate reserves and Snowy.

It is assumed that generators would not be dispatched purely to control system voltage.

Generator dispatch and pump allocation may be judged from historical recordings.

The sensitivity of reactor requirements to the generators in-service should be tested.

All reactors are generally assumed available for service on the 220, 330 and 500 kV system. Exception must be made where supply and secure operation would be jeopardised by a prolonged reactor outage. In such cases consideration should be given to the most critical reactor being unavailable. An outage of one critical SVC or syncon and the sensitivity to varying levels of Snowy syncon availability should be considered.

K

There needs to be sufficient windows of opportunity for line and switchbay maintenance. Hence it is assumed that maintenance will be carried out under medium load conditions. A limited range of generation dispatched may apply. Normal reactive margins are to apply under N-1 conditions.

Operational arrangements can often be made to facilitate maintenance. Often interconnector and generation restrictions apply during maintenance.

This loading level is not usually an issue at the planning stage and is unlikely to be a driver for network augmentation.

Under circumstances where lines need to be removed from service for upgrading or uprating a detailed assessment by operational staff is required to ensure that the development plan is feasible. Works may need to be advanced to ensure that line reconstruction is possible.

2.4 Notes on the Table

Load Level

L1:

The maximum load is defined at the 1% poe level under medium growth conditions. Present load statistics show that this is up to approximately 10% above the 10% poe level.

L2:

Load terms are included in the interconnector capability limit equations.

L3:

The system capability at light load is tested at system minimum load, which is approximately 40% of system peak load.

L4:

Medium load applies to day-time loads in the autumn and spring seasons.

Generation Dispatch:

The dispatch of frequency control plant and spinning reserve needs to be considered. NSW may not be carrying any generation reserves (it may be negative at time of peak demand) at times.

G1:

All dispatch patterns are to be feasible without violating system capability or reactive limits.

G2:

Limited dispatch implies that not all interconnectors may be able to operate to their usual limits and generator output may be limited.

G3:

Interconnector loading is up to the limits defined by limit equations.

G4:

Generation is re-dispatched so that within 30 minutes of the first contingency the system is secure.

G5:

A probable dispatch is based on experience of normal dispatch patterns, taking into account merit-order dispatch. Hence reactive limitations should not normally impact on the economic operation of generators. The present probable pattern is:

Hunter Valley	Four Bayswater units and two to three Liddell units – with four Liddell units to operate as the supply / demand situation deteriorates
West:	Up to all four units at Mt Piper and Wallerawang
Central Coast	Four units at Eraring, up to two units at Vales Pt
Munmorah	Both units off-line. They may return to service if required for supply / demand reasons
Redbank	in service
QNI and NSW/Vic interconnectors	loaded to balance to supply the state load

Allowance needs to be made for the impact of having some central coast units (Vales Pt and Eraring) off line.

G6:

Minimum units are assumed to be on line and they are assumed to be fully loaded. The MW dispatch is a probable one with a bias to having only base-load units operating.

G7:

At off-peak times only the base load units are assumed operating with a relatively low Snowy draw. QNI may be moderately loaded.

G8:

The conditions to be covered include:

- All thermal units operating and high import over QNI, with Victorian export or Snowy generation to balance (it is assumed that NSW is not exporting); and
- All thermal units on and high import from the south, with QNI power transfer to balance. It is assumed that NSW is not exporting over QNI.

If necessary, to achieve a reasonable dispatch, the lower-priority units (Munmorah) may be taken off-line.

<u>Reactive Capability</u>

R1:

The operating point has a margin from the point of voltage collapse according to the reactive power analysis process. This applies in the system normal state, immediately after a contingency and in the long-term.

For R1 the reactive margin is to be >0, ie the system voltages are at least marginally stable.

In the system normal condition it is accepted that some generators may be operating on their var limits.

R2:

A reactive margin form the point of voltage collapse is to be maintained. The reactive margin requirement is set out in Section 2.6 below.

Voltages are to be within limits, this is discussed in Section 2.5 below.

R3:

System highest voltage limits are to be observed as the prime concern.

2.5 Limits to Busbar Voltage Levels and Reactive Power Conditions

The following considerations apply in establishing the adequacy of reactive power conditions:

Consideration 1:

To ensure the economy of system operation and to maximise power transfer capability the pre-contingency power station 330 kV and 500 kV bus voltage levels are to be at the highest practical levels bearing in mind system highest voltage limits (at the power stations and all other buses) and post contingency reactive power reserve sharing between stations at varying distances from major load centres. The voltage profile shall be optimised to minimise the requirement for new reactive power sources.

Target voltage levels are set out in Operating Manual 530. Generally an upper limit of 108% applies (where SHV is 110%) to allow for metering and state-estimation errors.

It is generally necessary in the modelling of the system normal state that all generators are able to be operated with some spare reactive reserve. It is necessary that at least 1pu volts is able to be maintained at the terminal buses. With respect to the system studies it is generally sufficient if the reactive output of the generators in an area is less than the capability of the area. This avoids the need to optimise voltages at the HV buses of the power stations to accurately share the reactive burden in the reactive study. The areas are:

Hunter Valley:	Bayswater and Liddell
Central Coast:	Eraring 1-2, Vales Pt, Munmorah
West:	Mt Piper and Wallerawang
Snowy:	Combined Snowy units

It is difficult to schedule the voltage at Eraring 500 kV versus Eraring 330 kV to equalise the var loading across the four Eraring units, hence Eraring 3-4 units are not included in the Central Coast area from the point of var sharing.

Consideration 2

Post-contingency, the reactive power loading of all generators, synchronous condensers and static var compensators to remain at or within proven reactive capability. Continuous and short time (e.g. 1 hour) reactive capabilities can be utilised.

It is necessary to recognise the potential variability in generator var capability. In assessing the need for relatively low cost reactive support plant a conservative approach to the modelling of generator var capability is warranted, based on judgement. The sensitivity of the reactive margin to the generator var capability or voltage profile should be examined.

Consideration 3

The target post-contingency voltage at any point in the main grid is generally to be not less than 95% of nominal in the steady-state after all transformer taps have settled and after supply point loads have returned to their pre-contingency levels. This is a target only.

On some sections of the 220 kV and 330 kV system a lower standard has been accepted due to contractual or economic considerations. The locations are:

Broken Hill system
System north of Liddell

At Tomago 330 kV there is a contractual obligation to achieve a minimum 0.95 pu voltage in the steady-state under contingency conditions.

The post-contingency voltage is to be not less than the level at which the 330kV transformer tap range permits control of the LV busbar to reasonable voltage levels or to voltage levels agreed to with Distributors or direct customers.

Consideration 4

The change in voltage, at any point on the main grid, between pre-contingency and post contingency levels (both in the immediate post-contingency state and steady- state) is to be limited, with a target of not greater than 5%. Radial sections of the main grid may be subjected to greater voltage changes.

Overall the voltage change is to be not greater than 10% in the immediate post-contingency state ie:

- Loads modelled as composite loads or with voltage indices of np=1 and nq=3;
- Taps unchanged from the pre-contingency state; and
- No switching of reactive plant.

In the long-term post-contingency state the voltage change at the EHV level is to be not greater than 10%. Supply point voltages must be able to be restored to their pre-contingency minimum level set out in the Connection Agreements.

Consideration 5

In general, it is assumed that no reactive plant is switched between the immediate post-contingency state and long-term steady-state.

Exceptions may apply where appropriate, especially where SVC's or Special Control Schemes are applied.

Another exception is where reactor switching is used to control the voltage at the ends of open-ended lines following operation of a circuit breaker.

Consideration 6

System Highest Voltage limits are generally 110% but there exceptions as set out in the Operating Manuals (OM530).

Consideration 7

In the analysis it is assumed that there will be no under-voltage load shedding, unless it is part of Special Protection Scheme. It is ensured that voltage levels will not fall to the point where UVLS operates and this may set a minimum voltage limit.

Consideration 8

SVC’s and Sydney South syncons can be assumed to be floating at near zero Mvar output before a contingency.

System reactors are assumed switched out as appropriate to the location. Not all main grid reactors will generally be switched off at peak load. Typically the Wellington reactor, some of the reactors in the far north and some of the reactors in the western 220 kV system may be in-service at time of peak load.

2.6 Reactive Power Margins

The following margins from the post-contingency system reactive power limits (knee point of QV curve for example) or voltage collapse point are to be met. The margins apply under long-term system response conditions.

Sydney area: 200 Mvar

This exceeds the NEC requirement (1% of the fault level) and has been broadly established from long-term voltage stability simulations. It is also equivalent to about the rating of the largest capacitor bank in the area.

For other areas of the system - the larger of:

- The NEC Code 1% of fault level; or
- The rating of the largest capacitor bank at the critical bus or nearby site in the area.

The margins above may be altered if long-term voltage response simulations show that other levels are required or are sufficient.