Draft Statement of Principles: Wind Farm Licensing

Assessment of Submissions

Introduction

The Essential Services Commission of South Australia (ESCOSA) released its draft statement of principles for wind farm licensing in June 2005. Consultation closed on 8 August 2005 and submissions were received from the following parties:

AGL
AUSWEA
ElectraNet
Energreen Wind
Hydro Tasmania
International Power Australia
Natalie and Barry Webb
National Generators Forum
National Power/ Babcock and Brown
NRG Flinders
Origin Energy
Outlook Management
Pacific Hydro Limited
Renewable Energy Generators Australia Limited
South Australian Minister for Energy
Southern Hydro
Stanwell Corporation
Tarong Energy (confidential)
TRU Energy
True Friends of the Southern Mt Lofty Ranges
TrustPower
Vestas
Wind Prospect Pty Limited

Although not a formal submission, there was correspondence and discussion with NEMMCO and follow up discussions with a number of parties. ESCOSA requested the Planning Council review the submissions and provide advice.

The Planning Council has reviewed the submissions received and the objective of this document is to categorise and summarise the comments received, assess them and provide advice to ESCOSA as to whether they should consider any amendment of their proposed principles as a result.

Comments received

There were a wide number of issues raised in the submissions. To assist this review, the most salient comments have been grouped and summarised in the 20 issues in the following:

- Position taken by the Planning Council is unnecessarily conservative
- Role of the Commission
- Price Impacts
- Quality Of Supply
- Reliability
    - greater variability and uncertainty in market operations

    - ineffective ramp rate management requiring additional generation commitment
    - system instability arising from credible contingency
    - Fault Ride Through
    - Reactive power
- Requiring a Connection Agreement (Principle 1)
- Automatic Access Standards (Principle 2)
- Scheduled generation (Principle 3)
- Forecasting (Principle 4)
- Ancillary Services (Principle 5)
- Existing Wind Farms Forecasting (Principle 6)
- Sunset Clauses (Principle 7)
- Expiration of license conditions
- Economic Self Regulation of Projects
- Sub 30MW Projects should not have the same license conditions.
- Principles should apply to all wind farm’s

A matrix summarising which parties commented on each issue is appended (Attachment 1).

Both the Planning Council and ESCOSA separately consulted on the Planning Council’s Wind Report to ESCOSA published in April 2005. This document does not seek to review the general background and supporting analysis for the Planning Council’s recommendations in this report but on addressing issues relevant to the development of licensing principles which will allow wind generators to be licensed in South Australia prior to the finalisation and implementation of improved national arrangements.

The following sections discuss in turn the issues raised that relate directly to the licensing principles.

Requirement to have a Connection Agreement (Principle 1)

The majority of respondents had no specific issue with the requirement to have a signed connection agreement as a precursor to considering the license application. The Planning Council recommends that this requirement should be maintained as:

- the presence of a connection agreement indicates the project is at an advanced stage and therefore should be considered under these interim arrangements;

- the development and negotiation of a connection agreement defines the connection arrangements and proposed plant to be connected and provides the supporting analysis to demonstrate the generators technical performance.

The first principle linked the requirement for a connection agreement with a secondary requirement to demonstrate compliance with the automatic access standards required to comply with Principle 2. A number of parties raised significant concerns with this requirement.

The Planning Council notes that the supporting analysis performed by the network service provider (NSP) to assess the adequacy of the equipment proposed by the proponent must be based on the actual equipment proposed. The performance of any generator and its associated connection equipment must be accurately and specifically modelled to determine its performance and impacts on power quality, voltage control and system stability.

The analysis performed by the NSP for connection agreement process should then be based on the actual equipment proposed and the requirements of principle 2 would be automatically met. However, from a drafting point of view it could be argued that this sub-clause be removed from Principle 1 and better incorporated into principle 2 as the principle relevant to technical standards.

Imposition of Automatic Access Standards (Principle 2) – General

This principle attracted considerable interest with quite polarised commentary. The majority of the argument against this principle described it as being discriminatory, inappropriate or too stringent, in excess of what is required of other new entrants and higher than most existing generators could achieve. Others were supportive of a higher connection standard until more definitive and specific standards have been developed and formally adopted in the NER.

A common impression from respondents of the idea that the standard was too high was that both NEMMCO and the Network Service Providers (NSP's) were in the best position to assess and decide the technical requirements that should apply to each wind farm taking into account the specific features of its size, nature and location.

The Planning Council makes a number of observations in this respect. The roles and responsibilities of NEMMCO and the Network Service Provider, as defined under the current National Electricity Rules (NER), are different. Under the connection process defined in the current NER, the NSP leads the negotiation of technical standards between bounds specified in Schedule 5.2. The NSP's primary concern is the protection of the network and to ensure that no party is connected at a standard below the minimum. As defined in *NER Clause 5.3.4.,* the NSP may reject an offer which "in the *Network Service Providers* reasonable opinion, adversely affect quality of *supply* for other *Network Users*".

NEMMCO participates in some parts of the negotiations but can only reject a proposed negotiated access standard on the grounds that it "in NEMMCO's reasonable opinion adversely affects *power system security".* The application of this general provision is in practice limited by the broader requirements in the Rules, and the ability to ascribe any adverse effect which may emerge in the future to a particular connection applicant. It also should be noted that NEMMCO is not a signatory to the connection agreement.

The assessment of an individual application for connection is a complex process and cannot reasonably be expected to test all possible market conditions, network arrangements and power system contingencies to determine its potential impact on system security. The Planning Council notes that the NER only requires the assessment of network faults in respect to fault ride through and only encompasses other projects which are classified as "committed". The assessment of the full impact of a significant and rapid increase in the installed capacity of wind generation is problematic since it can only, by definition, include other projects that already exist or are considered "committed". In a situation such as that which currently exists in South Australia, where there are a large number of new proponents all seeking connection concurrently, there is little or no scope for NEMMCO or the NSP to effectively assess the impact of all of the new projects together in a national market setting. The risk is therefore that without diligence, significant degradation in the overall network and power system performance may result. If problems do occur or inefficiencies develop over time, there is the risk that consumers bear the costs.

Prior to the adoption of new technical standards, the basis for negotiated access standards are those which apply in the existing NER. It was identified by the Planning Council and the WETAG that the current technical standards, as defined in Schedule 5.2 of the NER, do not adequately cover renewable technologies such as wind farms. The Ministerial Council on Energy (MCE) has requested that NEMMCO review these standards and propose modifications that would make them more applicable to all generation technologies. While good progress has been made, this process is by no means complete and it is therefore not possible to judge new wind farms by technical standards which are not yet part of the NER.

The Planning Council approach has therefore been to examine what would appear to be the critical aspects of the performance of the connection of a new generator and attempt to apply the existing NER. The Planning Council acknowledges that requiring generating plant meet higher technical standards will generally impose costs on prospective generators and act to some extent as a barrier to entry. The objective in setting such standards should be to minimise those barriers to entry consistent with ensuring the integrity and stability of the power system. The interim arrangements do not, and should not, consider a “clean sheet” redraft of technical standards. Within that limitation, the Planning Council have attempted to recommend such an outcome.

Automatic Access Standards (Principle 2.2a) - Fault Ride Through

A number of comments were received arguing that the application of the automatic access arrangements to low voltage fault ride through were onerous and unnecessary. A number of respondents argued that connection agreements negotiated under the current technical standards are adequate and have the approval of both NEMMCO and the TNSP.

While the Planning Council has considered the views submitted it remains convinced of the need for higher standards than those achieved in a number of cases to date. Both NEMMCO and the relevant NSP are obliged to deal with the application at hand in light of the existing NER. The NER does not specifically require the fault ride through capability to be confirmed against actual protection performance, all pre-fault power system configurations and all contingencies or with future configurations including future wind generation investment. The NER requires an assessment of the proposed generators performance against network faults cleared in target primary protection time.

The initial report by DIgSILENT[1] highlights several cases where close in credible faults will cause certain wind farms to trip and other cases where more distant faults causing more

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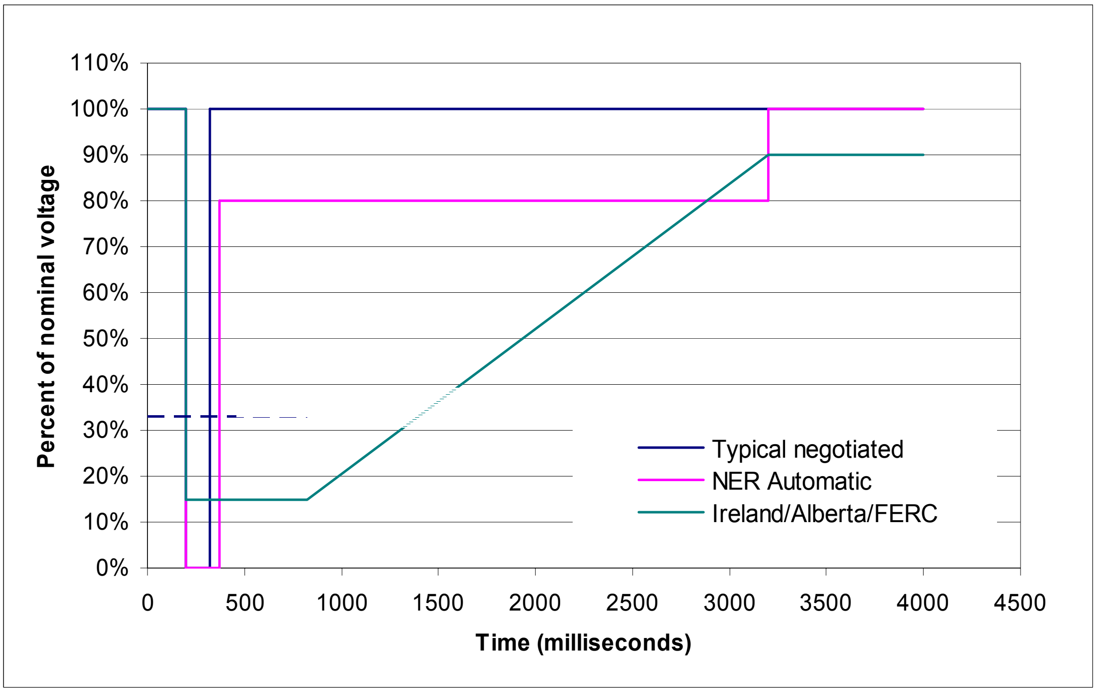
[1] DIgSILENT were commissioned by NEMMCO to assess the potential security risks due to high levels of wind generation in South Australia. This report has not yet been released publicly, however NEMMCO have provided a copy of the results to the Planning Council on a confidential basis.

modest but longer low voltage faults could lead to wind farms tripping. The Planning Council does, however, consider that the simple application of automatic access standard may be difficult and inappropriate and has sought to find a suitable practical interpretation. Such an interpretation was provided in the recent determination on these standards by the National Electricity Tribunal (NET); viz:

"(a) Each *generating unit* must be capable of continuous uninterrupted operation during the occurrence of a *normal voltage fluctuation* caused by a *transmission system* fault involving a single phase or two phase to ground condition with a *loading level* after the fault is cleared that is at, or reasonably about, the *loading level* immediately prior to the fault.

(b) For the purpose of subsection (a), *normal voltage fluctuation* means voltage remaining within a band for 3 minutes, ten seconds and 175 milliseconds following a fault. The band has an upper boundary of 110% of nominal voltage at all times. The band has a lower boundary of 0% of normal voltage for the first 175 milliseconds during the fault, 80% of nominal voltage for the first 10 seconds after the fault is cleared and 90% of nominal voltage for the next 3 minutes."

A graphical representation of this interpretation has been provided in the following figure.



The application of the automatic access standard continues to require a more robust ride through capability which the Planning Council considers necessary with potentially large concentrations of wind energy in the South Australian region. The automatic access standard requires both the ride through of a more severe fault close to the wind farm and a distant fault which could cause a more modest but longer voltage depression at the wind farm's connection point. However the interpretation of the NET clarifies the nature of the ride through characteristic and that only a credible (two phase to ground) fault need be considered.

The ability of wind farms to ride through voltage depressions is internationally recognised and provided for in newer Codes and standards. A number of Codes require generators to ride through a longer fault than proposed here. As such, a number of wind turbine generators available today could meet this standard with the selection of appropriate options and control schemes. For other machines an SVC or STATCOM may need to be included to ensure such a capability. Such a device would also assist in providing the proposed reactive requirement discussed in the following section. The Planning Council would expect compliance with these requirements to be reflected in the connection agreement either by the characteristics of the wind turbines specified alone, or with the assistance of additional connection equipment.

Automatic Access Standards (Principle 2.2b) - Reactive power

A number of comments were received arguing that the application of the proposed requirements with respect to reactive power were also costly, onerous and unnecessary. No submissions provided analytical or quantitative support for this argument, nor did they indicate how much compliance with this requirement might increase a wind farms capital costs.

General information on reactive power and its critical role in AC power systems is outlined in Attachment 2. The DIgSILENT work demonstrates that adding more and more generation capacity to the system which has negotiated access at the minimum, or no reactive capability, will eventually lead to serious voltage control problems. The work demonstrates a particular concern with voltage control on the 275kV transmission backbone of the State. Several respondents argued that these concerns related to cases with a very high concentration of wind generation in South Australia and to particular cases which could be managed by constraints.

On the basis that the Planning Council retains its recommendation that wind farms over 30 MW are scheduled or operate under proposed new arrangements as “semi-dispatched” generators, it is agreed that those should be manageable. However, the use of constraints can only ensure a minimum generation level from plant with a reactive power capability. To actually utilise that capability NEMMCO would need to specify a reactive power requirement as an ancillary service. At this stage, such services are defined as network control ancillary services (NCAS). NCAS are non-market ancillary services the costs of which are recovered from customers. An alternative solution would be network investment which would need to be supported through the economic regulatory mechanisms and again would be charged to customers. Voltage control is also likely to be an issue during, and immediately following, power system faults in cases where South Australia might island from the rest of the National Electricity Market (NEM).

Whilst the Planning Council remains concerned at the potential for voltage control issues in the future, the broader problems associated with reactive power are generic to the current NER and it is not reasonable to impose the global solution on wind generators. The more specific requirements to deliver voltage control to the 275kV system should therefore be removed. However, prospective generators should take into account the commercial risk that they may be constrained at times in future to maintain voltage control. In such cases, the ability to contribute to voltage control would be advantageous.

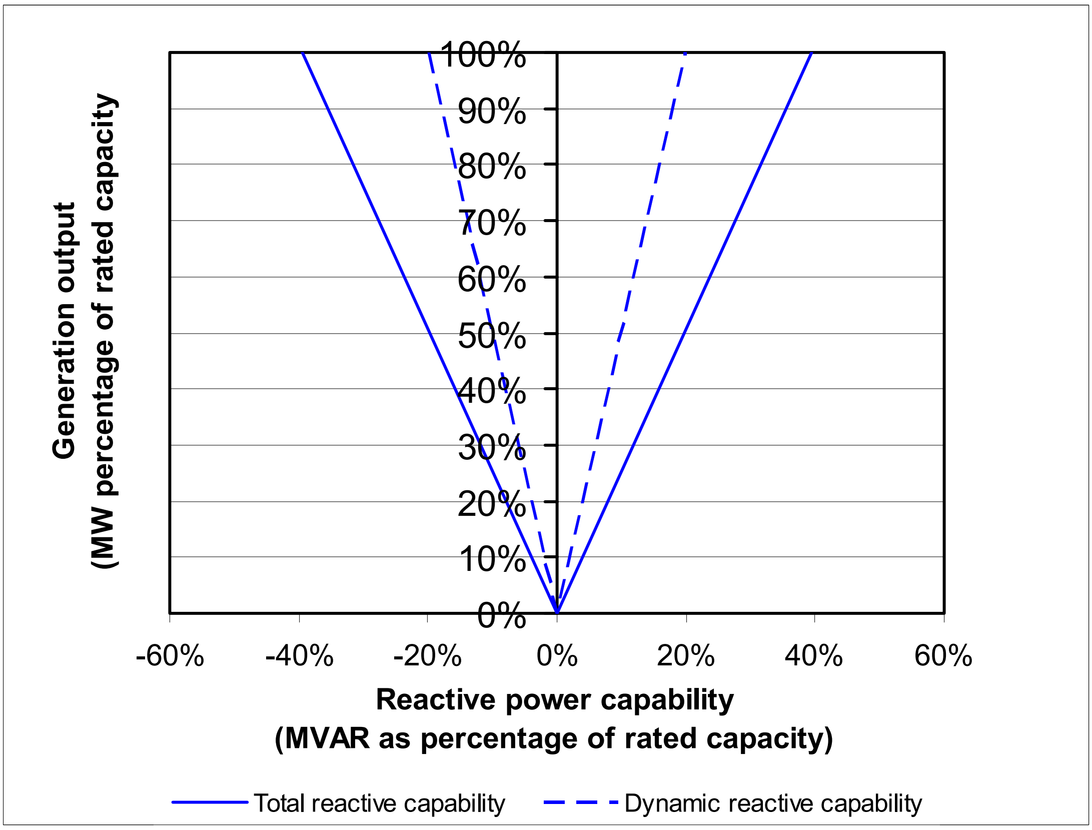
The Planning Council remains convinced that wind farms should have a reactive power capability significantly in excess of the current minimum technical standard to:

- contribute to local voltage control especially during and immediate following a fault; and
- minimise the impact of the addition of further wind generators on the power system and defer the point at which voltage control becomes a significant issue.

The automatic access standard, from which the proposed licence condition was lifted, represents a relatively high level of reactive power generation and absorption being equivalent to operating over a power factor of ±93% at maximum output. As written, the standard may be read as requiring this level of reactive capability across the full output range. This is well in excess of the capabilities of conventional synchronous generators and is more onerous than any international standard that has been reviewed by the Planning Council. On the other hand, the current automatic access standard does not make it clear how this reactive capability needs to be delivered. A number of International Codes specify such characteristics, specifically requiring fast acting automatic voltage control capability.

The Planning Council therefore considers that a prudent way forward, as an interim standard, is to require the plant to be capable of delivering or absorbing reactive power of 0.395 times its nominal power output **at rated power output.** At generation levels below full rated output the reactive capability should be at least pro-rata to that of full output. The NER also does not make it clear how much of the reactive capability in the automatic access standard ought to be provided dynamically. Whilst the Planning Council recognises that shunt reactive plant can provide some of these requirements at a lower cost, there are limitations. The Planning Council considers that at least half of that reactive power capability should be dynamically variable with the balance able to be provided by non-dynamic plant such as shunt capacitors and inductors if preferred. The reactive power capability should be controlled by a fast acting continuously variable, voltage control system which is able to receive a voltage set point. The wind farm should also be capable of operating to a set power factor if that is the preferred mode of control at any time.

The dynamic capability is considered mandatory to contribute toward maintaining voltage control under normal operating conditions, during contingencies and in the immediate post-contingency recovery period. Any static capability supplied to complement the dynamic reactive capability and meet the overall requirement should be designed in close cooperation with the network service provider and aimed at ensuring the full range of the dynamic capability is available under various network loading conditions. Any static capacity should be supplied in appropriate sized blocks with suitable switching and damping to limit transient effects and harmonics. It is possible to contemplate network locations where some of the static reactive capability, either inductance or capacitance, may not be required in the foreseeable future. The Commission might consider applications where the network service provider certified that this was the case and the proponent undertook to construct additional static capacity any time in the future should requirements change. The proposed requirement is shown graphically in the following chart.



Some other subclauses of Principle 2 also require some clarification.

Principle 2.3 which covers the provision of real time data to NEMMCO has to some degree been advanced by NEMMCO recently. It is appropriate that NEMMCO request and are now receiving data on at least temperature at hub height, wind speed and direction, active and reactive power output from the wind farm, number of turbines available and dispatch limits as required by NEMMCO or the TNSP. In line with the requirements for forecasting in Principle 4, other data may also be needed and the proponents should be prepared to provide additional information as required.

From the submissions received, Principle 2.4 would appear to require some additional clarification. This clause is designed to ensure that the wind farm will be able to continue to receive and act on dispatch instructions and provide SCADA to NEMMCO for 3 hours in the event of a prolonged system failure. The Planning Council does not consider this to be a particularly onerous requirement.

Small generators

Some respondents questioned whether the higher Technical Standards should be applied to small wind generators. The NER in these respects would normally only apply to registered generators. NEMMCO has established a standing exemption from registration for generators with a nameplate rating of less than 5 MW. The Planning Council considers that it would be appropriate that the higher technical standards should also only apply to wind farms with a total rating of 5 MW or more.

Requirement to register as a Scheduled generator (Principle 3)

The submissions on this license condition varied, but certainly most of the wind farm proponents were not in favour of being classified as "scheduled". Among the many reasons offered, the most commonly presented were:

- concerns about the cost of systems to provide offers to NEMMCO;
- difficulties in providing meaningful input into MTPASA, STPASA and pre-dispatch processes as to future generation output; and
- the risks of penalties as a result of not delivering the output accepted in the dispatch offer and therefore being considered as non-conforming.

Several respondents commented that wind farms should be registered as "semi-dispatched" rather than "scheduled". The category "semi-dispatched" not part of the NER with NEMMCO and an industry reference group working to propose suitable rule changes. The WETAG acknowledged that it was inevitable that there would need to be some controls over the dispatch of wind farms to ensure that an optimal market outcome was achieved. The WETAG introduced the concept of a "semi dispatch" category of generation to accommodate some but not all of the requirements of a scheduled generator. The proposed principle makes it clear that when such provisions are in place, this licence condition will be removed. In the interim the only choice apparent to ensure the power system is effectively and efficiently managed with a larger concentration of wind generation is for wind farms to be "scheduled". This requirement would bring wind farms under the same central dispatch control as other generators and include them in the security constrained optimised dispatch. Constraints would only be employed in the dispatch process if they were deemed necessary to ensure secure operation. The balance of this section then examines how well the use of the "scheduled" classification could work as an interim solution.

As a scheduled generator a wind energy generator would need to submit offers to the central dispatch price. The offers envisaged would include the expected available capacity and an offloading price. The NER allows considerable flexibility to bid and rebid available output and to move capacity within pricing bands including negatively priced bands, or offloading prices. Automated bidding systems can be used. The Planning Council is aware of one example where an existing generator used a basic automated system to reoffer the capacity of the generator into the market every 5 minutes based on variations in key inputs.

The Planning Council believes that any generator with an automated reoffer system, which provides NEMMCO with a soundly based indication of their likely capacity and generation over the next dispatch interval is unlikely to be judged as not offering in "good faith".

The provisions in the NER relating to non-conformance allow NEMMCO discretion to decide what constitutes reasonable conformance to dispatch. NEMMCO has published guidelines on this matter which they update from time to time and these provide scope for a generator to routinely diverge from their target by modest amounts and by a larger amount for a limited number of dispatch intervals especially if their non-conformance is not driving security risks.

NER Clause 4.8.9 (c) specifies that

(c) "A *Registered Participant* must use its reasonable endeavours to comply with a direction or Clause 4.8.9 instruction unless to do so would, in the *Registered Participant's* reasonable opinion, be a hazard to public safety, or materially risk damaging equipment, or contravene any other law."

(c1) Subject to clause 4.8.9(c) a *Registered Participant* must use its best endeavours to comply with a *direction* or *clause 4.8.9 instruction* in accordance with the timeframe specified by *NEMMCO* in the *direction* or *clause 4.8.9 instruction*.

(c2) A *Market Participant* must not by any act or omission, whether intentionally or recklessly, cause or significantly contribute to the circumstances causing a *direction* to be issued, without reasonable cause.

NER Section 4.9.8. describes the general responsibilities of registered participants and particularly

(a) A *Registered Participant* must comply with a dispatch instruction given to it by *NEMMCO* unless to do so would, in the *Registered Participant's* reasonable opinion, be a hazard to public safety or materially risk damaging equipment.

(b) A *Scheduled Generator* must ensure that each of its *scheduled generating units* is at all times able to comply with the latest generation *dispatch offer* under Chapter 3 in respect of that generating unit.

While NER Clause 4.9.9 states:

A *Scheduled Generator* must, without delay, notify *NEMMCO* of any event which has changed or is likely to change the operational availability of any of its *scheduled generating units*, whether the relevant *generating unit* is *synchronised* or not, as soon as the *Scheduled Generator* becomes aware of the event.

Under NER Clause 3.8.23.(a) which deals with not following instructions and states:

"If a *scheduled generating* unit, *scheduled network service* or *scheduled load* fails to respond to a *dispatch instruction* within a tolerable time and accuracy (as determined in NEMMCO's reasonable opinion), then:

(1) the *scheduled generating unit, scheduled network service* or *scheduled load* (as the case may be) is to be declared and identified as non-conforming; and

(2) the *scheduled generating unit, scheduled network service* or *scheduled load* (as the case may be) cannot be used as the basis for setting *spot prices."*

Power System Operating Procedures SO_OP3705 published by NEMMCO Principle 4.6 defines the methodology for calculation of non-conformance. NEMMCO defines 3 categories of error trigger; Small, Large and Gross. Assuming ramp rates are not defined for wind farms then :

- a small error trigger is the larger of 6 MW or 3% of the bid unit availability measured over 6 dispatch intervals;

- a large error trigger is the larger of 6 MW or 5% of the bid unit availability measured over 3 dispatch intervals; and

- a gross error trigger is the larger of 20MW or 10% of the bid unit availability monitored in approximately 10 second cycles. (The gross error trigger or "MW Discrepancy" alarm alerts NEMMCO staff for situations where there are major deviations from targets or say, a scheduled unit has tripped but the bid is not yet updated to reflect this situation.)

An alarm will alert NEMMCO staff when any trigger level is exceeded for the prescribed count of dispatch intervals. The count is reset to zero if, prior to the prescribed count, the scheduled unit moves within the trigger level. For consecutive dispatch intervals the count will be reset to unity and the alarm reset, if the exceeded trigger level of the scheduled unit is in the opposite direction of the exceeded trigger level on the previous dispatch interval. The expectation in such circumstances is that these movements in different directions will, to some degree, cancel out. Once a trigger has occurred for a generator, NEMMCO would advise the generator of the situation and seek a reason for their non-responsiveness. The generator then has another two dispatch periods to correct the situation prior to being classified as non-conforming."

From this procedure it is clear that in most occasions if the wind farm provides a forecast of its likely output based on persistence for each dispatch interval it is un-likely to be deemed non-conforming. The Planning Council notes that in its statistical analysis the majority of 5 minute variations were zero or very small.

Section 5.6.1 Power System Operating Procedures SO_OP3705 defines the procedures to be followed for a non-conforming scheduled generator providing the non-conformance does not cause a system security violation. At its worst this process may result in the participant being constrained to a particular operating level.

A number of respondents also indicated that the connection agreements executed between the proponent and the TNSP provided for mechanisms that allow the output of the wind farms to be limited by the TNSP. The Planning Council agrees that while these facilities would provide a mechanism for controlling the wind farms it does not provide NEMMCO with the rights to adjust limits on wind farm outputs in response to system security or reliability issues nor does it provide an opportunity for wind farm generation to be included in the market optimisation or constraints.

The use of NEMMCO powers to direct registered participants (NER Clause 4.8.9 and Clause 3.8.2(e)) is a very coarse approach to a problem that can be optimised effectively in the normal market dispatch process. Directions and Instructions to registered participants are inefficient in terms of market optimisation and potentially costly to South Australia customers. In order to minimise errors and exposure of the market to insecure conditions and because of the coarse nature of these instruments, the result, while maintaining system security is unlikely to be optimal with respect to economic efficiency.

The Planning Council recommends that this principle be applied to all wind farms that are greater than 30 MW.

Wind Generation Forecasting (Principle 4)

The submissions for this indicate that there is some confusion with respect to the purpose of the forecasting and the models required.

- This clause was designed to ensure that all licensees provide information to facilitate the successful development of a wind forecasting system. This part of the principle received broad support and should apply to all wind farms in the network. This principle was not designed to get each wind farm to develop comprehensive individual wind forecasting software.

- The provision of fit for purpose, verifiable models of the wind farm performance can be interpreted in several ways. There is a need for accurate and verifiable models to be used in the connection process to determine if a number of the technical requirements will be met with a proposed wind farm configuration. Whilst the importance of such models should not be downplayed, they remain an issue for the connection process. Tests during commissioning and subsequent performance in the market should hold all generators accountable for their modelling projections. In regard to wind forecasting there is a need for models to calculate the expected generation of the wind array from metrological data. This clause was intended to ensure that the models provided by the participant are appropriate representations of the conversion of wind at the site to the power output.

- Input into the ST and MT PASA processes for wind farms would appear on the surface to be problematic, however the NER only requires the generator to provide input into these systems that is the best indicator of their future performance. Clearly, because of the stochastic nature of the resource, any input from wind farms into these processes can only ever be indicative. Given that weather forecasting is not precise over long time frames it would not be unreasonable to use the typical seasonal or monthly patterns for these longer time frames. Shorter time frames such as pre-dispatch can be accommodated using information from the available Bureau of Meteorology forecasts or more site specific analysis. NEMMCO has issued a tender seeking forecasting software to assist them in this task. This in conjunction with the mathematical model of wind farm performance with respect to wind would enable the development of a more effective input into the NEM systems until a more elaborate and comprehensive system has been completed.

The Planning Council recommends that this principle be applied to all wind farms that are greater than 5 MW as the diversity and spread of data it might provide could be expected to improve the quality, and hence value, of the future forecasting systems.

Ancillary Services (Principle 5)

The suggestion that wind farms be involved in the ancillary services market received mixed responses, the majority of which were supportive of the principle. Some suggested not making this principle part of the license condition but ensuring that modifications to the NER included a specification suitable to encompass its inclusion. Other issues raised were specifically related to ensuring that the actual causer pays applies more broadly to ancillary service costs. Some respondents considered it would be difficult to calculate precisely which generators contributed to frequency deviations and to what extent and that because of the variable nature of wind the contribution to frequency variation of all wind farms should be considered before allocation to an individual, or that the cost should be averaged across all wind farms in the region.

The Planning Council does not consider any changes are necessary to this principle.

The arrangements in the market for the allocation of costs to generators and customers are recognised to be imperfect. However, they are much more efficient and equitable than generators avoiding any payment and the "causer pays" regime applying to regulating services provide efficient incentives on generators. The Planning Council believes that if wind farms are scheduled generators as proposed the application of causer pays to wind farms can be done appropriately with the existing tools and methodology applying to other generators.

A number of new International standards require wind farms to provide an active frequency response to contribute toward frequency control. Variable speed wind turbines can be configured to provide such a function within a limited range. If a very high concentration of wind generation does eventuate in South Australia and ancillary services costs become material, then these arrangements provide the incentive for generators to change their behaviour.

The allocation of specific "causer pays" factors necessarily relies upon appropriate metering. The metering specified is generally required anyway to support the management and control of the wind farm and is the same as the SCADA data envisaged under other principles. The Planning Council understands that NEMMCO already requires such metering on all larger wind farms. To participate in market settlements a generator must be classified as "market".

Imposition of Existing Wind Farms Forecasting (Principle 6)

The submissions on this were again somewhat variable. The essence of this principle was that the requirements for the provision of data for forecasting, the obligation to participate in the development of central forecasting software should all apply to existing wind farms as well as new wind farm's currently seeking licenses.

The management of existing licences is clearly a matter for the Commission. However, the Planning Council agrees that the imposition of these requirements on all wind farms in the State would be of considerable value to the efficient operation of the market. Most existing windfarm operators have voluntarily cooperated with NEMMCO and the Planning Council with the supply of such data and a suitable outcome may be able to be negotiated through a separate process.

Sunset Clauses (Principle 7)

The submissions on this licence condition argued that there may need to be some discretion from ESCOSA in the actual application of this principle. They argued that the demonstration of project commencement may need interpretation as to what constitutes progress with a project and also the time frame over which it was acceptable to have demonstrated progress.

The Planning Council would prefer proponents who do not intend commencing a project in the near future not to use the interim measures proposed but rather negotiate connection through the final national rules when they have been amended. This would generally be advantageous to proponents as wind turbine technology continues to develop. On the other hand, the principles as set out have been devised to ensure efficient and effective operation with a larger concentration of wind energy in the system. As such, the Commission could reconsider the need for this principle.

Attachment 1

Issues matrix – Tabular summary of issues raised

The following table provides a list of the issues raised in ESCOSA's consultation on the draft principles for granting generating licences and assigns a letter of the alphabet to each issue. The table on the following pages outlines which respondents raised each issue.

	Issue
A	Position taken by the Planning Council is unnecessarily conservative
B	Price Impacts
C	Reliability and Quality Of Supply
D	Reliability – greater variability and uncertainty in market operations
E	Reliability – ineffective ramp rate management requiring additional generation commitment
F	Reliability – system instability arising from credible contingency
G	Commission Role
H	Requiring a Connection Agreement (Principle 1)
I	Automatic Access Standards (Principle 2)
J	Reliability – Fault Ride Through
K	Reliability – Reactive power
L	Scheduled generation (Principle 3)
M	Forecasting (Principle 4)
N	Ancillary Services (Principle 5)
O	Existing Wind Farms Forecasting (Principle 6)
P	Sunset Clauses (Principle 7)
Q	Expiration of license conditions
R	Economic Self Regulation of Projects
S	Sub 30MW Projects should not have the same license conditions.
T	Principles should apply to all wind farm's

Proponent (abbreviation	Interest in specific project	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
AUSWEA (AUSWEA)	All in General ✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓			
Wind Prospect Pty Limited (WPPL)	Numerous							✓	✓			✓		✓					✓	✓	
Energreen Wind (EG)	Worlds End Wind Farm									✓			✓		✓	✓	✓				
NRG Flinders (NRG)	No projects							✓					✓	✓	✓		✓	✓			
True Friends of the Southern Mt Lofty Ranges (TFSMLR)	No projects		✓					✓					✓	✓	✓						
Stanwell Corporation (SC)	Barn Hill Wind Farm							✓	✓				✓	✓	✓		✓				
NP Babcock and Brown (BB)	Lake Bonney Stage 2	✓	✓	✓				✓	✓				✓	✓	✓	✓	✓				
Hydro Tasmania (HT)			✓	✓					✓		✓	✓	✓	✓	✓	✓	✓				✓
International Power Australia (IPRA)									✓	✓			✓	✓	✓	✓	✓				
Minster Conlon (MC)																					
Tarong Energy	Confidential Submission																				
Renewable Energy Generators Australia Limited (REGA)	All in General								✓				✓	✓	✓	✓	✓				
Origin Energy (OE)	Various							✓											✓		
AGL (AGL)	Brown Hill /The Bluff WF							✓	✓				✓	✓	✓		✓				
National Generators Forum (NGF)								✓						✓				✓			
TrustPower (TP)	Snowtown and Myponga WF	✓		✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓		✓		
Southern Hydro (SHP)								✓						✓		✓		✓			
TRU Energy (TRU)								✓		✓			✓		✓	✓	✓	✓			
Pacific Hydro Limited (PHL)		✓	✓					✓	✓		✓	✓	✓	✓	✓	✓	✓				
Vestas (VES)	All in General							✓	✓		✓	✓	✓	✓							
Natalie and Barry Webb (WEB)		✓						✓													
ElectraNet (EN)		✓							✓	✓			✓	✓	✓	✓	✓				

Attachment 2

Reactive-Power and Voltage control in an AC Power System

Introduction

An important factor in the consideration of technical standards for all generators in an AC power system is setting the level and nature of their reactive power capability. This is particularly important in the South Australian power system as we contemplate high levels of wind generation in the system.

Whilst the consideration and analysis of reactive power is integral to the work of power engineers, it is a complex issue to understand and convey to other interested parties. The objective of this section is to:

- provide an overview of what reactive power is;
- how it arises through the nature of capacitors and inductors;
- the relationship between real (or active) power and reactive power in a system and the concept of the power factor;
- how real power is balanced in a power system and frequency is maintained within standards;
- how reactive power balance in a network also must be maintained and how the voltage profile across a network is controlled by the injection or absorption of reactive power at each point on the network;
- the difference between static (or passive) reactive devices and their contribution to voltage control and dynamic reactive sources such as generators and their importance in voltage control and voltage stability.

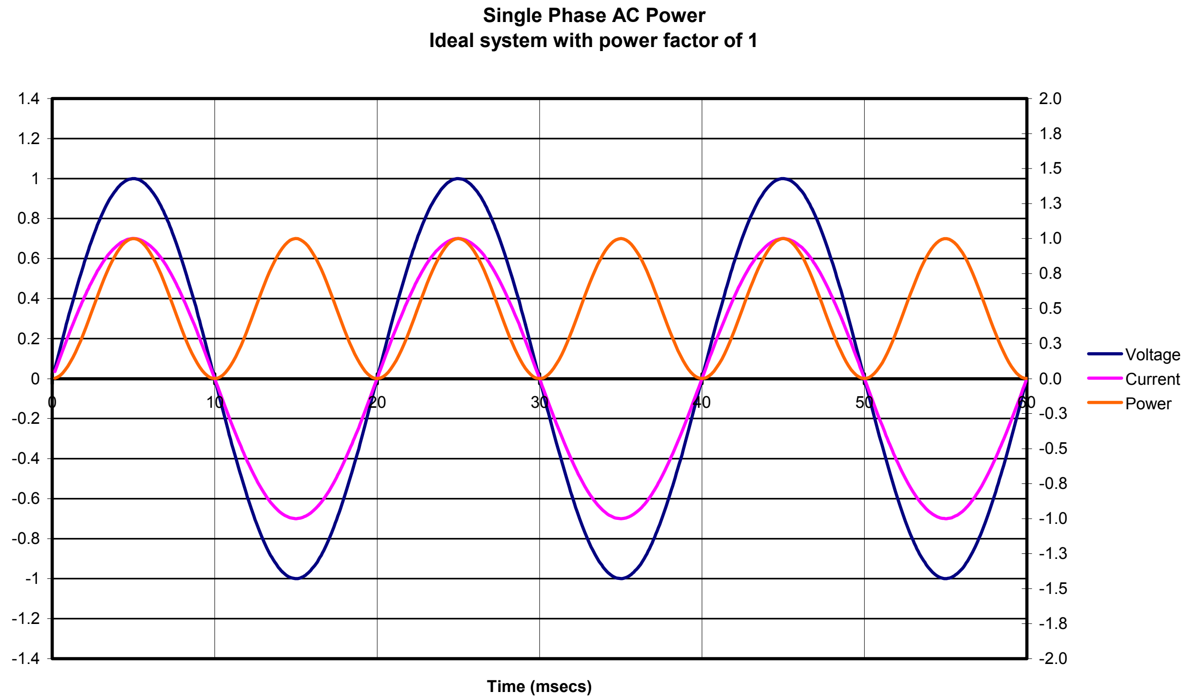
This section cannot be a complete treatise on reactive power but should hopefully assist others to understand the importance of the consideration of reactive power in this context. The paper concludes by noting the relevance of some of this discussion to wind generators in South Australia.

What is reactive-power?

To understand reactive power and the relationship between power factor and voltage control, one must understand alternating current (AC). The voltage and current produced by a generator in the Australian power system oscillates 50 times a second with the shape of a sine wave. The following graph shows a single phase system where the sine wave of the voltage is in perfect synchronism with the sine wave of the current. The power (P) at any instant is the product of voltage (V) and current (I) at that instant, that is:

$$P = V \times I.$$

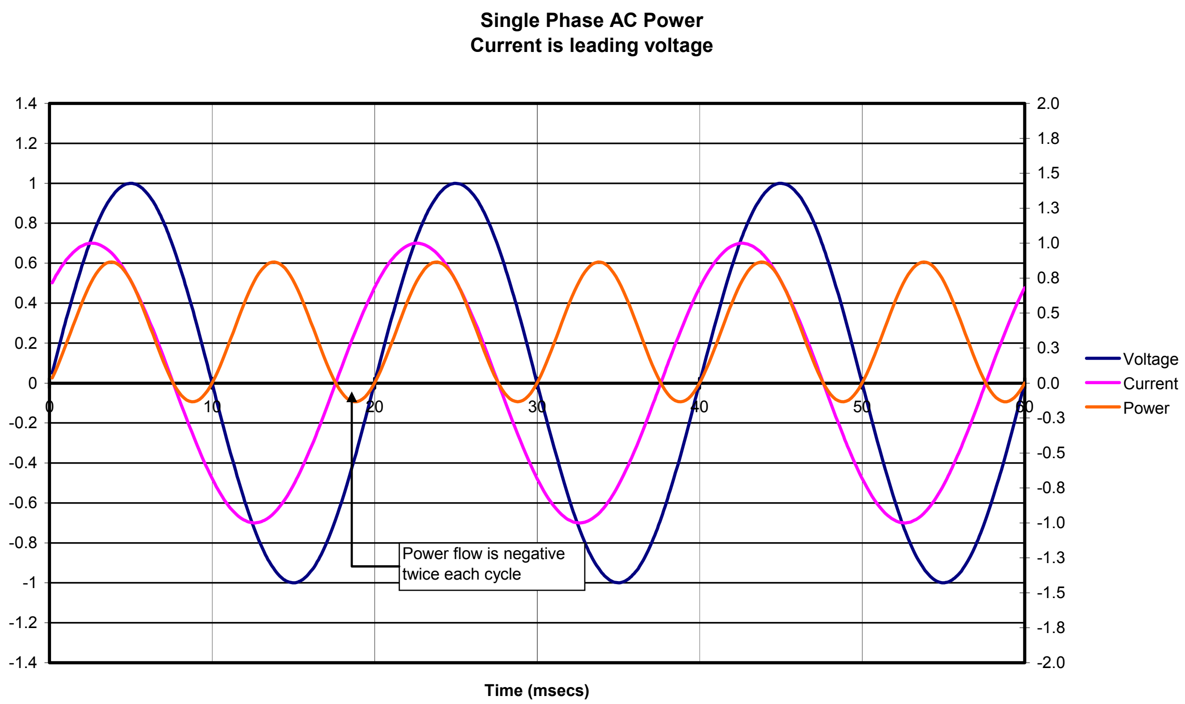
As shown in the graph, the power is always positive if the voltage and current oscillate together, even though both the voltage and the current are negative half the time. The power pulsates for a single phase at twice the frequency of the voltage and current.



The current and the voltage will oscillate together if all components in a power system are of a purely resistive nature. Resistors dissipate electrical energy normally by converting electrical energy to heat and do not change the relationship between the current and the voltage.

If some components in the power system have a more complex character, the current and voltage may not oscillate together. If the current wave is delayed slightly from the voltage wave, the two are no longer in phase, and the current is said to lag the voltage. The current will lag the voltage where there is an inductance (also called reactance) in the power system. Similarly the current can lead the voltage where there is capacitance in the power system. These cases are important to understand as all real world power-systems include components that have capacitance and/or inductance associated with them. In fact, inductance is a dominant characteristic of many power-system components (e.g. generators, overhead lines and transformers) and of motors used by customers. The demand for reactive power from customers in South Australia and Victoria has in fact risen over recent decades as a result of the greater use of induction motors particularly with increased air-conditioning loads. Underground cables and, to a lesser extent, overhead lines have significant capacitance, as well.

The following graph shows a case where the current leads the voltage. In this, and all cases where the voltage and current are out of synchronism, the resulting power is sometimes positive (the generator is delivering power to the load) and sometimes negative (the generator is taking power from the load).

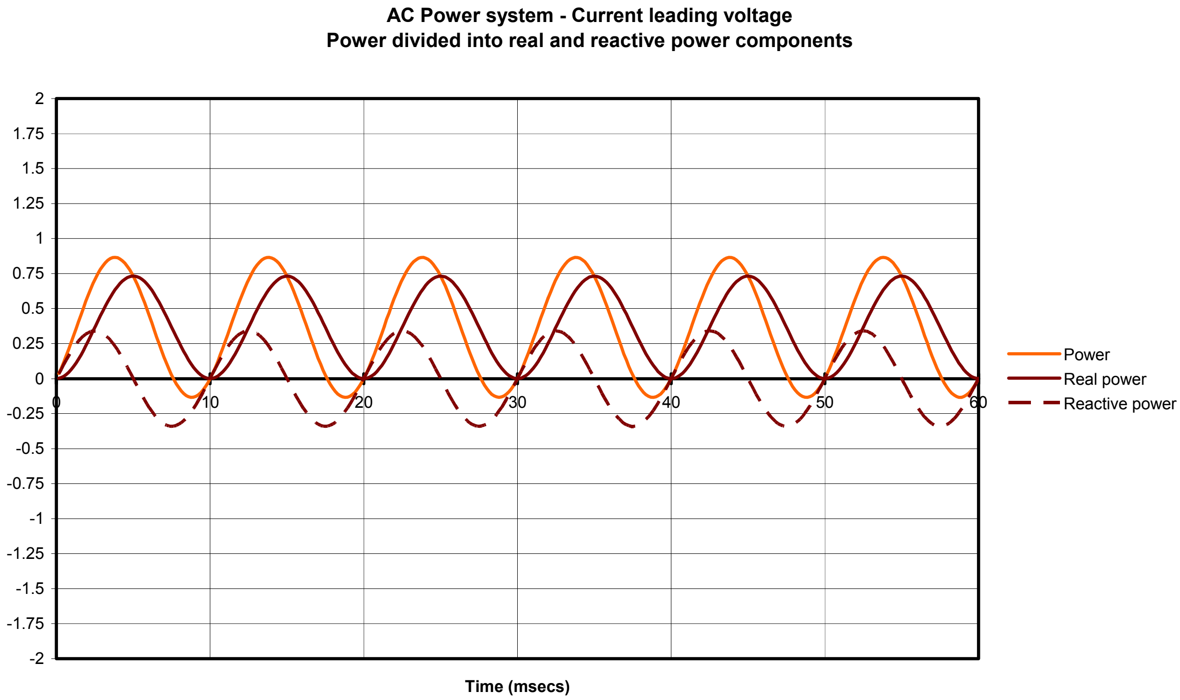


In this case, whilst most of the energy transfer is positive (that is, is being transferred from the generator to the load) some is not. In fact if the current led (or lagged) the voltage by 90 degrees, all the power would oscillate with no net energy transfer from the generator to the load occurring over a full cycle. In the above situation, the power shown in the orange line is the total or apparent power.

This apparent power could be divided into two components:

- **Real power** or that component which transfers real power as in the case above where the voltage and current are in synchronism; and
- **Reactive power** or that component which oscillates 100 times a second between the generator and the load but transfers no real power.

The real power is sometimes referred to as the active power. The graph below shows the apparent power in the case above divided into those two components.



The nature of inductors and capacitors

For power oscillations to occur between the generator and the load, the load or some system elements need to be able to instantaneously store energy. Both inductors and capacitors store energy during the cycling of current and voltage:

- inductors store energy in, and release energy from, a magnetic field which results from the current flowing in the wire of the inductor.
- capacitors store energy in, and release energy from, an electrostatic field which results from the voltage difference between the plates of the capacitor.

This storage of energy and oscillation of power in these cases is analogous to the storage of energy and oscillation of a weight on a spring where the weight was subject to a cyclical force.

This phenomenon is important because nearly all power-system components have capacitance and/or inductance associated with them. In fact, inductance is the dominant characteristic of most power-system components (e.g., generators, overhead lines, transformers, and motors). Underground cables and, to a lesser extent, overhead lines have significant capacitance, as well. Consequently, these oscillations occur all the time.

Power factor

The current associated with transferring energy back and forth between the AC generator and an inductor or capacitor does not deliver useful energy to the load. The concept of power factor was developed to express how much of the total current supports the transfer of useful energy to the load (real power) and how much supports oscillations (reactive power). Real power is measured in megawatts (MW), reactive power is measured in volt-amps reactive (MVAR), and apparent power is measured in volt-amps (MVA). The power factor can be calculated by dividing the real power by the apparent power. It is better defined though as, the cosine of the phase angle between the voltage and current. When the load is inductive (e.g., an induction motor), the current lags the applied voltage and the power factor is said to be a lagging power factor. When the load is capacitive (e.g. an underground cable), the current leads the applied voltage and the power factor is said to be a leading power factor.

Although reactive power does not transfer useful energy, it is important to the operation and efficiency of AC power systems. Reactive power reduces the real power transfer for a given voltage and current. With a given voltage, a load will draw more current for the same power if it has a low power factor. Higher currents will increase losses in a system and use the capacity of key transport infrastructure like lines and transformers (A poor power factor lowers the capacity of the transmission system to move useful energy to the load by consuming some of the limited current-carrying capacity of this plant with reactive current).

The connection arrangements for customers under the National Electricity Rules or the specific requirements of the network service provider would normally limit the range of power factors within which a customer must keep their load. Some network service providers also use kVA tariffs or penalty payments for power factors outside an acceptable range to provide an incentive for customers to operate with a power factor near to 1.

Real power management and frequency control

The real power consumed in a power system must be balanced at all times with the real power generated. In an AC power system if the real power generated is higher than that consumed, the frequency of the power system will increase. Conversely if the real power generated is less than that consumed, the frequency of the power system will decrease.

In the National Electricity Market, the frequency is set at 50 Hz and the dispatch engine seeks to balance supply and demand to achieve that outcome. As the load from customers, the output from some generators and the system losses are always changing, the frequency must be maintained within acceptable bounds using regulating ancillary services. Regulating ancillary services are supplied by generators fitted with automatic generator control (AGC) which can be driven by NEMMCO's systems to continuously balance supply and demand and maintain the frequency at 50 Hz.

The balance between supply and demand of real power also needs to be maintained through events such as the tripping of generators or loads or the failure of transmission elements. The NEM purchases contingency ancillary services to meet this need from either loads that can trip or generators that can quickly respond when the system frequency moves outside its normal operating band.

Reactive power management and voltage control

In an alternating-current (AC) power system, voltage is controlled by managing production and absorption of reactive power. A key objective in managing a power system is to maintain adequate voltages throughout the transmission system under both normal operating and contingency conditions.

There are three reasons why it is necessary to control voltage:

1. Both customer and power-system equipment are designed to operate within a range of voltages. At low voltages, many types of equipment perform poorly; light bulbs provide less illumination, induction motors can overheat and be damaged, and some electronic equipment will not operate at all. High voltages can damage equipment and shorten their lifetimes.
2. Reactive power consumes transmission resources. To maximize the amount of real power that can be transferred across a transmission line or through a transformer, reactive-power flows must be minimized.
3. Moving reactive power on the transmission system incurs real-power losses. Both capacity and energy must be supplied to replace these losses.

In the same manner as real power supply and demand must be balanced, reactive power supply and demand in a power system must also be balanced. The choice of where reactive power is supplied and absorbed in a network will change the voltage profile across the network. If we took a power system where real and reactive power was in balance and stable, it would have a given voltage profile. If at any node in that network we now increased the reactive power input, the voltage at that node would need to rise to transport that reactive power to other areas in the grid. Conversely a reduction in reactive power injection at a node would require the voltage at that point to drop to draw replacement reactive power from the grids to that point.

Injecting reactive power into the system then raises voltages at the point of injection whilst absorbing reactive power lowers voltages. Voltage-support requirements are a function of the locations and magnitudes of generator outputs and customer loads and of the configuration of the transmission system. These requirements can differ substantially from location to location and can change rapidly as the location and magnitude of generation and load change. At very low levels of system load, transmission lines act as capacitors and increase voltages. At high levels of load, however, transmission lines absorb reactive power and thereby lower voltages. These effects are especially pronounced in the NEM because of the length of transmission lines.

Reactive power can be produced and absorbed by both generation and transmission equipment. Reactive-power devices differ substantially in the magnitude and speed of response and in their costs. Most transmission-system equipment (capacitors, inductors, and tap-changing transformers) is relatively static and can respond to changes in voltage support requirements only slowly and in discrete steps. Capacitors and inductors are passive devices that generate or absorb reactive power with few losses. They are therefore relatively cheap sources of reactive power and are able to provide something akin to a baseload supply of reactive power. Some transmission-system equipment SVCs (static VAR compensators), and STATCOMs (static synchronous compensators) and certain generators can generate or absorb reactive power and continuously vary their output to maintain a given voltage at their connection point. These are essential to provide something akin to the load following response of generators supply regulating ancillary services in the real power market.

Dynamic voltage control

Voltage control in a power system is complicated by two additional factors;

1. The transmission system itself is a nonlinear consumer of reactive power, depending on system loading. At very light loading the system generates reactive power that must be absorbed, while at heavy loading the system consumes a large amount of reactive power that must be replaced. The system's reactive-power requirements also depend on the generation and transmission configuration. Consequently, system reactive requirements vary in time as load levels and load and generation patterns change.
2. Second, the bulk-power system is composed of many pieces of equipment, any one of which can fail at any time. Therefore, the system is designed to withstand the loss of any single piece of equipment and to continue operating without impacting any customers. That is, the system is designed to withstand a single contingency.

Taken together, these two factors result in a dynamic reactive-power requirement. Just as an power system requires real-power reserves, or contingency ancillary services, to respond to sudden changes in the system so too it must maintain dynamic reactive-power reserves. The loss of a generator or a major transmission line can have the compounding effect of reducing the reactive supply and, at the same time, reconfiguring flows such that the system is consuming additional reactive power. In extreme cases, voltage collapse can occur.

Voltage instability or voltage collapse occurs on a power system when voltages progressively decline until stable operating voltages can no longer be maintained. This is precipitated by an imbalance of reactive power supply and demand, resulting from one or more changes in system conditions including increased real or reactive loads, high power transfers, or the loss of generation or transmission facilities. Unlike the phenomenon of transient instability, where generators swing out of synchronism with the rest of the power system within a few seconds or less after a critical fault, voltage instability can occur gradually within tens of seconds or minutes.

The voltage point corresponding to the transition from stable to unstable conditions is known as the "critical voltage," and the reactive power level at that point is the "reactive margin." Voltage collapse occurs below the critical voltage when an increase in load or loss of generation or transmission facilities causes dropping voltage, which causes a further reduction in reactive power from capacitors and line charging, and still further voltage reductions. The result is a progressive and uncontrollable decline in voltage, all because the power system is unable to provide the reactive power required to supply the reactive power demand.

To ensure voltage stability is maintained, the desired operating voltage level should be well above the critical voltage. To ensure this is maintained through changes in system conditions and contingencies, a power system needs sources of reactive power which can respond quickly to changes in voltage support requirements. Conventional generators, synchronous condensers, SVCs and STATCOMs all provide fast, continuously controllable reactive support and voltage control.

A power system should have a mix of static and dynamic reactive support to provide satisfactory voltage profiles during normal operating conditions. This though needs to be supplemented by sufficient dynamic support from these sources to ensure there is adequate reactive power available during contingencies to maintain voltage stability.

Wind farms and reactive power

Manufacturers employ several different technologies in their wind turbine generators. In South Australia we have examples of each of the major technologies namely:

- induction generators;
- doubly fed induction generators;
- converter driven synchronous generators.

Early wind turbine generators were all induction generators. Induction generators are simpler and more robust generators but have limited speed control capability and no ability to generate reactive output. Some of these generators are able to switch the number of poles in the generator to provide for two speed operation. All such generators absorb reactive (or are an inductive load on the system) and hence at least some power factor correction through switched capacitors is specified. In several cases, wind farms of these types of machine are supplemented by an SVC at their connection point to assist with both ttheir ride through capability and the local need for reactive support.

Converter driven synchronous generators utilise a synchronous generator but the generator is not synchronous with the power system frequency. The synchronous generator will be designed to operate over a range of frequencies to allow the wind turbine to operate at its most efficient rotational speed for a given wind speed. Power electronics are then used to convert all the output power generated from the generated frequency to the power system frequency. Reactive power output or absorption can be delivered in this case through both the excitation of the generator and the power electronics. Properly designed and configured, these generators can provide a very flexible and controllable source of reactive capability.

Doubly fed induction generators (DFIG) are a popularly used technology which seeks to combine some of the features of the converter driven synchronous machine with the lower cost induction generators. The use of a DFIG generator allows variable speed operation of the turbine to enhance the efficiency of converting wind energy to electrical power. However only the power from the rotor (or around $^{1}/_{3}$ of the total power output) requires frequency conversion through power electronics. Whilst it remains an induction generator, the more complex design and control systems can be configured to provide some reactive power capability. Alternatively an SVC or STATCOM can be used to supplement any native ability of the turbines to provide reactive support if needed.

For generators which are not synchronous machines, the National Electricity Rules provide only a minimum access standard which is “no requirement to supply or absorb reactive power at the connection point.” It does, however, provide that the “generator and the Network Service Provider may, in accordance with clause 5.3.4A of the Code, negotiate a reactive power capability sufficient to ensure all relevant system standards are met under system normal and contingency operating conditions.” The application of this clause to nonsynchronous machines is unclear, the cross-reference to clause 5.3.4A is limiting and the application to an individual generator connection is fraught. As a result, any wind farms connected to the power system in both South Australia and interstate have no reactive capability at all.

The analysis of the Planning Council and the work undertaken by international expert consultants DIgSILENT raise concerns with this outcome under the current rules. As more wind farms with no reactive capability are connected to the power system the total reactive support available to the power system falls. At times of high wind speed, the wind farms can be expected to displace other conventional generators from the market reducing the capability at certain times to unsustainable levels. The reduction in dynamic reactive support shows in the 800 and 1200 MW of wind generation cases studied by DIgSILENT.