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Dear Mr Woodward, Ian

REL0032: Template for Generator Compliance Programs – Issues Paper

Thank you for the opportunity to respond to the Australian Energy Market Commission Reliability Panel's *Template for Generator Compliance Programs – Issues Paper*.

The Australian Energy Regulator (AER) is responsible for monitoring and enforcing compliance with the National Electricity Rules (NER), including registered participants' compliance with performance standards as required by clause 4.15 of the NER.

The purpose of this submission is to contribute to the development of a template for generator compliance programs, by:

- clarifying how the AER intends to monitor and enforce compliance with this area of the NER, and
- providing feedback on the experience gained when the AER audited four generators' compliance programs last year.

<u>AER's compliance monitoring and enforcement strategy</u>

Informing participants about the AER's compliance and enforcement strategy helps to foster a cooperative approach and encourage voluntary compliance. There are two main strands to the AER's compliance strategy with respect to generators' compliance programs:

- responding to a notification of a breach or possible breach of a performance standard; and
- spot audits of selected generators' compliance programs.

Responding to notifications of breaches

Under clause 4.15(f) of the NER, the AER is informed when a registered participant notifies the National Electricity Market Management Company (NEMMCO) of a breach or possible breach of a performance standard. In these circumstances, the AER will follow up with that registered participant by seeking further information and clarifications about its compliance program, which must be instituted and maintained in accordance with clause 4.15(b) of the Rules.

In particular, the AER will seek information on how the registered participant's compliance program meets the requirements of clause 4.15(c) of the NER, which requires their compliance program to:

- provide reasonable assurance of ongoing compliance with the relevant performance standards;
- include procedures to monitor the performance of the plant that is consistent with good electricity industry practice;
- be consistent with the template for generator compliance programs[1].

In addition, the compliance program should address any issues specific to the registered participant's plant.[2]

The AER notes that in some circumstances, a notification of a breach or possible breach may demonstrate that a registered participant's compliance program is working effectively. That is, the program is adequately identifying problems, and, where a technical problem is identified and NEMMCO is notified, the system security impacts of the issue can be managed.

Having received the registered participant's response to its enquiries, the AER will decide whether or not to escalate the matter in accordance with its *Compliance and Enforcement Statement of Approach*.[3] The AER aims for a proportionate enforcement response taking into account the impact of the breach and the circumstances surrounding the breach, including the processes established by the participant to avoid the breach in the first place. Appendix A provides further information on the AER's approach to enforcement, as set out in its Statement of Approach.

Audits

The AER also conducts spot audits of selected registered participants' compliance programs. This creates incentives for registered participants to have robust compliance programs in place. The AER completed its first round of technical audits in June 2008, with the assistance of technical consultants Sinclair Knight Merz (SKM). The AER plans to undertake additional

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1 Noting that there are transitional rules, which requires that compliance programs be in accordance with good electricity industry practice until they are refined to be in accordance with the template.

2 Clause 4.15(ca)(2) of the Rules.

3 See http://www.aer.gov.au/content/index.phtml/itemId/685897.

audits during 2009. The lessons learnt by the AER during its first round of technical audits are discussed below.

Lessons learnt during technical audits of generators' compliance programs

The background to the AER's technical audits is described in the Quarterly Compliance Report for July to September 2008.[4] While the process had some limitations, the AER was nevertheless able to largely meet its audit objectives. The audit reports provide some useful findings regarding the adequacy of the audited participants' compliance programs which is relevant to the Reliability Panel's review. It should be noted that the NER at the time of the audits predated the current process where the Reliability Panel determines a template[5]. The compliance program was required to be in accordance with good electricity industry practice. The audit was therefore attempting to come to a view on how good electricity industry practice should be interpreted. Clause 4.15(c)(4) also requires that a compliance program must provide reasonable assurance of ongoing compliance with each applicable performance standard.

One outcome from the audit was an assessment of what constitutes a good compliance program. The auditors found that each performance standard required a different compliance mechanism and in most cases, a combination of compliance mechanisms. The auditor's report outlines different mechanisms for each performance standard. These mechanisms included:

- benchmarking;
- testing;
- calculation;
- modelling; and
- continuous monitoring.

The auditor concluded that a good compliance program is one that uses:

> *a multifaceted approach that combines an acceptable process (below) with additional or alternative testing, calculation, monitoring, modelling, analysis or industry review. The additional facets are provided in order to confirm result stability, minimise systematic errors and identify ongoing continuous compliance with the registered technical requirements under all phases and configurations of operation.*
>
> *In addition, compliance is proven and there is a high probability of ongoing compliance with the applicable performance requirement.*

The auditors considered a compliance process to be acceptable if:

> *there is a written procedure that identifies and schedules all of the activities that are required to ascertain the status of the plant performance relative to the registered technical requirement in*

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4 See http://www.aer.gov.au/content/index.phtml/itemId/692887.

5 Version 17 of the NER dated 25 October 2007

accordance with the compliance program guidelines, OR a written procedure has been provided that is assessed as an acceptable alternative to the compliance program guidelines.

In addition, there are records of testing, instrumentation and calibration as prescribed by the participant's instituted and maintained compliance program that can be provided for assessment AND there is a high probability that compliance is proven and there is reasonable assurance of ongoing compliance with the applicable performance requirement.

To further assist the Reliability Panel in its deliberations, the AER encloses an extract from its audit report, prepared by SKM into the compliance programs of four generating stations of varying technology conducted during 2008. The extract, which represents the views of the consultant (SKM) at the time, provides an overview of the types of compliance mechanisms it considered appropriate for each of the 13 technical requirements that were audited, suggests the timeframe between tests and highlights any compliance issues identified during the audit process associated with each requirement.

In summary, the AER considers that clause 4.15(c)(4) requires a multifaceted approach, where different compliance mechanisms are applied to different aspects of the technical requirements (in most cases, multiple mechanisms are appropriate). The template should reflect this multifaceted approach. The goal of the compliance program should be to demonstrate that there is ongoing compliance with the relevant performance and technical standards.

We trust that you find this information useful. Should you or your officers like to discuss these issues further, please don't hesitate to contact Mark Wilson, who is available on (08) 8213 3419.

Yours sincerely

Michelle Groves
CEO
Australian Energy Regulator

Appendix 1: Extract from AER's *Compliance and Enforcement Statement of Approach*

Chapter 3, Enforcement

The NEL allows the AER to take enforcement action against participants who are in breach of the NEL, NER or associated regulations. The AER has discretion in deciding whether to take enforcement action and the nature of enforcement action. This chapter discusses the enforcement options available to the AER and the criteria it uses in determining its response to identified breaches.

Assessment criteria for enforcement action

The AER considers a number of factors when deciding whether to take enforcement action and which enforcement option to adopt. In general, the AER aims for a proportionate enforcement response taking into account the impact of the breach, the circumstances surrounding the breach and the participant's compliance programs and compliance culture. More specifically, the AER's considerations include:

- the nature and extent of the contravening conduct
- the amount of loss or damage caused
- the circumstances in which the conduct took place
- the deliberateness of the contravention and the period over which it extended
- whether the contravention arose out of the conduct of senior management or at a lower level
- whether the participant has a corporate culture conducive to compliance with the NEL, NER and the regulations, as evidenced by educational programs and disciplinary or other corrective measures in response to an acknowledged contravention
- whether the participant has shown a disposition to cooperate with the AER in relation to the contravention.

In addition, the AER will take into account the existence and effectiveness of the participant's compliance programs in deciding whether to take enforcement action and which enforcement option to adopt.[6]

[6] This approach will apply to all obligations in the NER, including those relating to technical performance standards in chapters 4 and 5 of the NER.

Appendix 2: Extract from SKM final audit report

Audit of compliance with technical requirements, 16 June 2008.

[See attached document.]

Appendix 2

Australian Energy Regulator
National Electricity Rules

AUDIT OF COMPLIANCE TO TECHNICAL REQUIREMENTS

- Final Report
- 16 June 2008

EXTRACT OF COMPLIANCE AUDIT REPORT PREPARED FOR THE AER BY SKM – EDITED TO REMOVED CONFIDENTIAL PARTICIPANT INFORMATION

Based on version 17 of the National Electricity Rules published on 25 October 2007

1 Analysis

This section provides a general commentary on each of the technical requirements that characterise the registered technical requirements of each of the audit participants. The section also summarises what Sinclair Knight Merz considers are accepted strategies that can be used in participant compliance programs to demonstrate compliance and to provide reasonable assurance of future compliance to the registered technical requirements.

1.1 Sub classes of registered technical requirements

The registered technical requirements may be divided into five sub-classes as follows:

- Those that are considered as plant benchmarks. It is considered that these requirements do not need to be regularly tested once compliance is established as plant benchmarks are not likely to alter during the course of normal operation.
- Those that may be considered as likely to alter during the course of normal operation and need to be routinely tested using a schedule of tests.
- Those Technical Standards that may be calculated and proven from plant data.
- Those that require extended analysis or modelling of the plant in order to establish likely performance beyond observed events.
- Those that cannot be readily benchmarked, tested, calculated or modelled in order to establish compliance status shall then rely on continuous monitoring. Where other activities cannot confirm or deny compliance with the registered technical requirements then some application of continuous monitoring must be incorporated into the participant's compliance program to provide day to day evidence of compliance status or evidence of compliance status during significant events even if such events do not align with the registered technical requirements .

Sinclair Knight Merz has categorised each of the reviewed technical standards according to the classification criteria set out above. The categorisation is based on our understanding of how the plant condition relating to each requirement may change in time and the methodologies that have been undertaken to gain evidence of compliance. The fact that a requirement may be benchmarked is independent to the way by which compliance is ascertained. It should be noted that only the likelihood of compliance with the relevant technical performance requirements may be provided by benchmarking, calculation, modelling, monitoring or testing or any combination of these techniques. Regardless of the comprehensiveness of the compliance program it is entirely possible that during some system events a facility may fail to perform even though the compliance program results suggest otherwise.

A summary of the results of the categorisation of appropriate analysis of technical requirements is set out in Table 1 below.

▪ **Table 1 Sub classes of Technical Performance Requirements**

Audit Clause	Requirement	Benchmark	Testing	Calculation	Modelling	Monitoring
1	Reactive Power Capability		√			
2	Quality of Electricity Generated	√	√			
3	Response to Disturbances		√		√	√
4	Partial Load Rejection				√	√
5	Protection from Power System Disturbances		√			
6	Protection that impacts on System Security		√			
7	Asynchronous Operation		√			
8	Frequency Control				√	√
9	Stability	√	√	√	√	√
10	Excitation Control System		√			
11	Remote Monitoring					√
12	Auxiliary Transformers	√	√	√		
13	Fault Level	√		√		

This section explains the basis upon which the relevant technical requirements were categorised. It identifies compliance program elements including any systematic difficulties encountered by the participants whilst endeavouring to reach a level of confidence in their technical compliance as well as any shortcomings in the methodologies applied.

1.1.1 Benchmarking

Sinclair Knight Merz considers that a number of the registered requirements do not need to be regularly tested. Once these have been established or benchmarked, the relevant plant conditions will not change the established compliance status. New benchmarks must be established whenever there is, or has likely been, a change in the material components that established the initial benchmark. Major unit rebuild or system augmentation may, as an example, trigger a revised benchmark.

This category of technical requirements may be benchmarked by reviewing design and commissioning information, monitoring performance for a significant period in order to gain enough confidence that the performance is defined or performing a once off test to establish the level of compliance.

1.1.2 Recognised test procedures

Testing appears to be the most widely used sub class category of a compliance program. Tests that can confirm the status of the plant performance relative to the registered technical requirements support a proactive compliance program. In many cases tests are performed on system parts to confirm settings and operation. Testing is often undertaken during plant shutdown to minimise the risk of production interruption

It is appropriate that testing routines vary based on the technical requirements and the type of plant. The audit has identified that some testing routines vary between 3 to 5 years, although some low capacity factor plant does have significantly longer routines partially justified because of the nature of their operation. Where programmable protection and excitation systems have been installed there has to a large extent been a reduction in the requirement for short period secondary injection.

1.1.3 Calculation based assessments

Desk top studies may be used by the participant to analyse compliance to any of the registered requirements as well as a preliminary study into any modelling as described in Section 1.1.4 below. Participants have also appropriately used estimated load calculations to provide evidence of compliance for some of the aspects of the requirements for auxiliary transformers.

1.1.4 Modelling

Plant performance relevant to some of the technical requirements can be established by performing model assessments of electrical and/or mechanical parameters depending on the technical requirement.

Plant modelling can be an expensive process that may be employed when there is no practical alternative to provide the time response of plant during undesirable conditions. It is necessary to provide a preliminary desk top study in order to minimise as much as possible the plant components to be represented in the model. The preparation of an appropriate model must include ratification of accuracy with the existing monitoring data provided from the actual plant. The extrapolation of the historical plant performance out to the limits of the technical requirements must be accepted as a further significant risk to this methodology.

Fortunately both modelling and desktop studies can be further enhanced by the addition of plant information from any of the following sources:

- Gathered data from normal plant operation and random Power System disturbances.
- Further availability of design information.
- The results of small scale testing of plant components.
- Maintenance evidence of plant performance and degradation following Power System events.

The plant and Power System conditions and assumptions made in undertaking desk top studies or dynamic modelling must be documented in detail. The output of such studies may give the participant greater confidence to apply appropriate protection or constraints to safeguard plant thereby facilitating efficient reconnection during future Power System disturbances.

1.1.5 Performance monitoring

When a requirement cannot be readily tested, modelled or calculated or where proactive elements of the compliance program can benefit from validation, a performance monitoring strategy may be employed. Sinclair Knight Merz considers that plant response monitoring may provide evidence of compliance however there are several shortcomings if this approach is solely used to assess compliance status:

- System disturbances occur seldom and with varying severity so plant performance specified by the technical requirement may be observed infrequently.
- The impacts of system disturbances vary significantly across the system. Some plant may never see a disturbance to the extent required under the registered technical requirements.
- Monitoring alone is largely responsive, the participant only being aware of problems after the event. This shortcoming may be overcome to some extent by monitoring coupled with plant modelling. Plant data gathered during minor disturbance may be used to validate models that are then extrapolated to provide scenario analysis of disturbances that comply with the technical requirements.
- Monitoring plant performance during on line operation may mean the contribution to performance by the generating plant is difficult to separate from that of the Power System.

Notwithstanding these shortcomings, while active monitoring may not provide the appropriate plant configuration or conditions to confirm compliance status over all operational possibilities, the monitoring data may be used to ratify simulation models. Under the appropriate conditions this may provide confidence that the plant can comply with the registered technical requirements.

1.2 Technical Requirements and Compliance Program

The participant's compliance program instituted and maintained in accordance with rule 4.15 must[1]:

- Monitor the performance of the plant (in accordance with the provisions of the program)
- Ensure the plant complies with the relevant performance standards
- Be in accordance with GEIP
- Provide reasonable assurance of ongoing compliance with each applicable performance standard.

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[1] Based on version 17 of the National Electricity Rules published on 25 October 2007

Dot point 4 above has been interpreted by Sinclair Knight Merz that once benchmarked, tested, calculated or monitored and analysed there will be reasonable assurance up to the time of further testing of ongoing compliance with each applicable performance standard.

Each of the registered technical requirements has been reviewed below in relation to Table 2 in order to formulate a compliance program that Sinclair Knight Merz would consider appropriate. It should be stressed that the recommendations of a compliance monitoring program is essentially the opinion of Sinclair Knight Merz and these recommendations may not align with a more informed view of GEIP after significantly greater review of this industry has been completed.

The process of assessing compliance monitoring programs in a standardised manner is not a simple process, particularly if appropriate independent methodologies have been developed by the participant being assessed. Such assessments should be based on the opinions of a competent engineer experienced in the review of power plant testing and operation.

It is clear from dot point two and four above that to be an acceptable program it is mandatory that the outcome of the compliance program ensures the plant complies with the registered technical requirements and there is a reasonable assurance of ongoing compliance. It is therefore essential that an assessment of compliance to the registered technical requirements and the likelihood of ongoing compliance form a critical part of the assessment of the compliance program.

What would then provide a good, acceptable, warning and alert status assessment of a compliance program? Sinclair Knight Merz has taken the view that the compliance program for each technical requirement should be tested separately. If the compliance program for each requirement is supported with procedures and records evidence that timely activities have been undertaken that provide a high probability of compliance and with reasonable assurance of ongoing compliance, then the compliance program for that requirement is "acceptable". The participant may use some of the suggested procedures detailed below or they may develop their own methodology that may be assessed as an acceptable alternative.

A "good" assessment for a specific technical requirement compliance program can be attained by, in addition to an acceptable assessment, providing a multifaceted approach to more firmly establish compliance with the registered technical requirement therefore providing a greater confidence of compliance and a reasonable assurance of ongoing compliance.

A "warning" assessment would be provided to a compliance program for a requirement that provides the basic framework of procedures and schedules without comprehensive evidence of compliance or complete data gathering or analysis.

An "alert" assessment would be provided to compliance program for a requirement that is less complete that any of the above assessments.

A guide for the assessment of the compliance program for each technical requirement is provided in Table 2 below.

- **Table 2 Compliance Program Assessment for each Registered Technical Requirement**

B	**Good: Blue**	A multifaceted approach that combines an acceptable process (below) with additional or alternative testing, calculation, monitoring, modelling, analysis or industry review. The additional facets are provided in order to confirm result stability, minimise systematic errors and identify ongoing continuous compliance with the registered technical requirements under all phases and configurations of operation. AND Compliance is proven and there is a high probability of ongoing compliance with the applicable performance requirement
G	**Acceptable: Green**	There is a written procedure that identifies and schedules all of the activities that are required to ascertain the status of the plant performance relative to the registered technical requirment in accordance with the compliance program guidelines described in Section 3.2.1 *et al* below. OR A written procedure has been provided that is assessed as an acceptable alternative to the compliance guidelines described below. AND in associatiation with the options above: Records of testing, instrumentation and calibration as prescribed by the participant's instituted and maintained compliance program can be provided for assessment AND High probability that compliance is proven and there is reasonable assurance of ongoing compliance with the applicable performance requirement
Y	**Warning: Yellow**	The framework of a procedure and a schedule have been developed but there is evidence of non compliance or incomplete or inappropriate data gathering or analysis.
R	**Alert: Red**	The assessment requirements (above) have not been met
	Not Observed: White	Responses to this technical requirement were not provided.
*	**Not Applicable: White & ***	The category does not apply to the reviewed plant / technical requirements.

* 3.2.1 in the table refers to 1.2.1 below

With consideration to the above assessment classification each of the thirteen registered technical requirements are now reviewed

1.2.1 Audit Clause No. 1 Reactive Power Capability

Requirement: This registered requirement indicates that each synchronous generating unit, while operating at any level of active power output, is capable of:

(1) Supplying at the machine terminals a defined maximum of reactive power

(2) Absorbing at the machine terminals a defined maximum of reactive power

subject to an apparent power rating in MVA.

In some instances the requirement may be defined at the connection point and not at the machine terminals. In this case the reactive loading due to generator transformer and unit load must be provided in addition to the requirement.

Compliance Issues: Sinclair Knight Merz has noted the rectangular region bounded by this registered requirement on each of the participant's capability diagrams. This registered requirement has been tested by participants operating the generator to the limits required under the technical requirements. The following difficulties were encountered:

- The excitation limiter range determined by the appropriate TNSP may conflict with range of reactive loads required by the technical requirements.
- Testing reactive capacity at the limits of the plant capability diagram may, at remote Power System nodes, require other plant to be operated at corrective reactive loads in order to maintain local voltages. This requirement increases significantly the cost of performing such tests.

Compliance Monitoring Program: In the case of large generators where local voltage is not substantially affected by this test this activity may be undertaken at appropriate periods during normal operation. In the case of plant at remote network nodes where the impact of performing tests at extreme limits of reactive power may compromise local voltage control, some form of additional, counteracting, voltage control may be required

The test is essentially a static test at each test point, must be undertaken on line and may be implemented using appropriately calibrated AVR testing equipment employing existing instrumentation transformers. The test should be undertaken at an appropriate level of active power to maintain the apparent power (MVA) below plant rating. The tap setting of the generator step up transformer may be adjusted to facilitate the achievement of the required conditions. An appropriate test schedule interval would be of the order of three years.

Assessment of Compliance Program: Assessment may be undertaken using the guidelines of Table 2 based on a testing regime. Continuous on-line monitoring and analysis of plant performance in addition to routine testing would contribute to the participant achieving the highest assessment status.

1.2.2 Audit Clause No.2 Quality of Electricity Generated

Requirement: This registered requirement is similar for each of the participants audited and requires that when operating unsynchronised, each generator produces a constant voltage level with balanced phase voltages. The harmonic distortion to comply must be equal to or less than permitted in accordance with AS 1359 "General Requirements for Rotating Electrical Machines".

This requirement can only measure the generator contribution when tested off line. The harmonic distortion of the load may be difficult to isolate from that of the generator.

Once tested, unless significant plant decay of the rotor or stator circuits is evident, the plant performance will be unlikely to change significantly over the life of the plant.

Compliance Issues: It is the understanding of Sinclair Knight Merz that the harmonic voltage standards for distortion are onerous and difficult to test without expensive analysers and substantial analysis of instrumentation transformers. More analysis of this requirement and the proposed testing methodology is recommended. Notwithstanding these difficulties, Sinclair Knight Merz considers that compliance with the registered requirement could be achieved by generators manufactured under AS 1359, however at the time of the audit, no participant has established they conclusively comply with this registered technical requirement.

Compliance Monitoring Program: As this is a benchmark activity once defined from manufacturing or commissioning information there should be little requirement for testing the generator during its life unless there is a major disturbance to the field circuits or generator stator.

If tested, the test must be undertaken off line and may be implemented using appropriately calibrated AVR testing equipment employing instrumentation transformers of the required accuracy. As this is considered a benchmark there is no required test schedule interval.

Assessment of Compliance Program: Assessment may be undertaken using the guidelines of Table 2 based on manufacturers and/or commissioning data. If this is not available then a test should be undertaken as an alternative. Confirmation of the stability over time of the result would contribute to the highest assessment.

1.2.3 Audit Clause No. 3 Response to Disturbances

Requirement: This registered requirement in the case of three of the participants audited required that each generating unit is capable of continuous uninterrupted operation during the occurrence of power system frequency variations between 47 to 52 Hz. Depending on the departure from normal operation, between 49.5 to 50.5 Hz, a time of endurance is required from each generator. In the case of one participant, the departure endurance is dependent on both operating load as well as boiler fouling and differs further depending on the unit. This approach is in recognition that the performance of thermal plant during disturbances is dependent on plant configuration and other short term variables such as active load and boiler fouling.

In addition, each participant is typically required to operate continuously within 10% of nominal voltage with a "defined time" endurance depending on departure from the normal range.

Finally it is a registered requirement that a generating unit "ride through" a zero voltage condition at its connection point for a period of up to 175 ms in any one or combination of phases and then endure a defined recovery over more than 3 min. All of the power stations audited except one have analysed control circuitry voltage dip vulnerability on their plant. One participant, with gas turbine technology, has many shaft driven auxiliaries that would be unaffected by such a test and most other power stations audited have extensive DC battery systems that would be unaffected by voltage suppression.

An application of zero voltage for 170 ms ride through has been applied by those who have tested. This is a conservative approach as the objective of the test is to emulate a fault at the EHV switchyard. Under fault conditions some residual control voltage would be found at the unit transformer terminals.

Compliance Issues: All of the participants indicated that they could not conclusively prove that they complied with all of the requirements. Sinclair Knight Merz perceives there are several significant issues limiting the degree of confidence a generator may achieve to the other aspects of this requirement.

None of the voltage ride through tests has been applied to primary drives. The participants expressed concern about applying short period supply interruptions to large drives. Such a test would result in significant risk of damage to the motor winding. Consequently the testing has only been performed on the control circuits.

In relation to the frequency case it is not possible for any test to conclusively prove compliance with this technical requirement. In this case each of the participants have identified they can provide evidence of their compliance ability only by monitoring historical data and the performance of their plant at the time of past disturbances. This historical data has, by some, been enhanced with plant and disturbance modelling to postulate the effects of more significant disturbances. This process can with some confidence provide an indication where in the operational configuration the compliance status may be compromised, providing an operating envelope at varying loads and at different disturbances.

An example of typical constraints on thermal plant is presented in the graph of Figure 1 which is a plot of percentage load at the time of the disturbance against the extent of the frequency disturbance (Hz). The green area of the chart identifies the operational region where the modelled plant 'rode through' a standardised disturbance profile and is limited at both the low and high end by furnace pressure and separator vessel (drum level) trips respectively. The limitations on plant operation do vary depending on both the configuration, loading and condition of the plant. The representation of Figure 1 identifies possible constraints and the region of operation and disturbance intensity over which plant ride through may be compromised and the likely cause of the plant trip. The predominant reason for control loss of plant during low frequency disturbances has been identified as separator vessel and furnace pressure trips and safety valve operation and steam pressure unloader operation were predominant during over frequency events although these may not result in a complete plant trip. Thermal plants with fouled boilers or below design boiler feed-pumps were more vulnerable to loss of control as a result of the disturbance.

If this registered technical requirement is to remain, Sinclair Knight Merz sees no alternative than a monitoring and modelling approach to identify the constraints of the plant operation envelope.

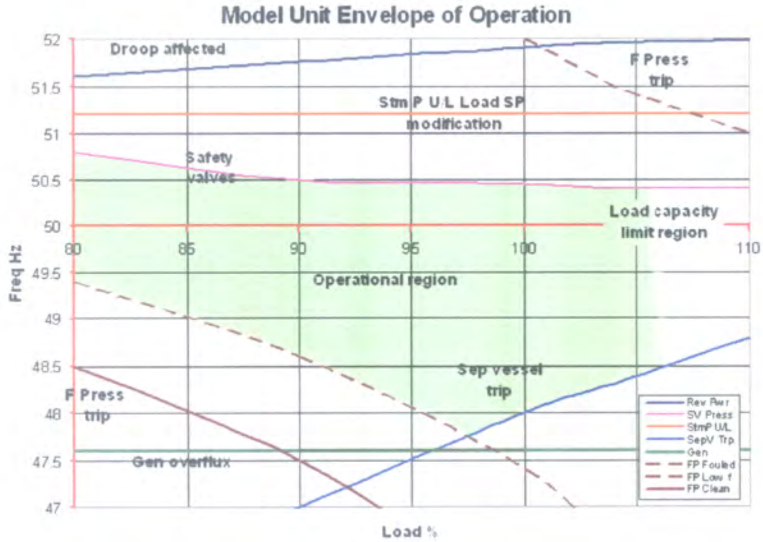

Figure 1 Thermal plant envelope of operation during frequency disturbance

Although the technical requirements treat the voltage and frequency events with independent requirements during 'close in' disturbances the plant may be subjected to coincident voltage and frequency disturbance events. How performance under these conditions may be assessed is also unclear.

Compliance Monitoring Program

Testing: The testing of motor control systems for voltage dip has been performed on all plants except one. Where there are many auxiliaries that are shaft driven, this is not considered to be a high risk.

This ride through testing is exclusively undertaken with the primary drive out of service using a timed interruption that corresponds to that required by each registered technical requirement. This is typically 0 V at the connection point for 175 ms with a subsequent 10 seconds with the control voltage anywhere between 80% and 110% of connection point voltage. This form of testing is well established using 0 V at the control supply for the required period. The methodology of the test being more onerous to the control circuit ride through than that required by the registered standard. An appropriate test schedule interval would be of the order of three years.

Monitor and Model: Notwithstanding the success of the control circuit voltage dip tests, the monitor and model approach is the only practical way of participants gaining confidence of the ability of plant to respond correctly to disturbances.

Integrated models have been prepared of many thermal plant systems in order to understand the possible performance of plant during modelled disturbances that are to the technical requirements. These activities have provided evidence of limitations of the plant to comply with the requirements particularly under specific plant configuration or condition prior to the disturbance. The significant cost of the modelling activity of a major thermal plant as well as the limited ability to ratify the model tend to reduce large models to applications of specific importance to the plant or system. The practice of participants supporting compliance programs by undertaking significant plant modelling using monitored data for ratification could become more widespread in the future.

Assessment of Compliance Program: Assessment may be undertaken using the guidelines of Table 2 based on testing for control circuit voltage collapse and continuous on line monitoring and analysis of plant performance during disturbances. In addition to monitoring, mechanical plant modelling and analysis during voltage and frequency disturbances would contribute to the participant achieving the highest status of assessment.

1.2.4 Audit Clause No.4 Partial Load Rejection

Requirement: This registered requirement requires each generating unit being capable of remaining synchronised during and following a loading level reduction directly imposed from the power system in less than 10 seconds from a fully or partially loaded condition provided that the loading level reduction is less than 30[2] percent of the generating unit's nameplate rating and the loading level remains above a minimum active load. This requirement is intended to maintain system integrity by the application or rejection of load as a result of transmission line power angle disturbance.

Compliance Issues: In the case of power stations located near strong nodes, this registered requirement cannot easily be tested. The load rejection by a thermal power station is influenced by the transmission line, local node, step up transformer and generator parameters as well as the prior conditions and line configuration. A similar regime to that used with Clause 1.2.3 is recommended using historical monitoring of disturbances and plant dynamics.

This clause appears to be poorly understood as reflected in the registered technical requirements. Sinclair Knight Merz believes that this rule requires some clarification to the participants of the impact of transmission power angle and its affect on the transient power transfer.

Compliance Monitoring Program

In the case of generator offload action as a result of transmission power angle dynamics the compliance program is recommended to include the following activities.

Calculation: System studies of related parameters including transmission load angle dynamics should be undertaken.

Monitor and Model: It is reasonable in these cases to rely on plant monitoring with system studies and model analysis to quantify the extent of operation over which partial load rejection operates. These models once ratified have been used to confirm generator offloading over a range of associated conditions including partial system separation. When these are considered, load rejection studies of large thermal plant can be used to confirm the performance of generating plant under offload imposed from the power system.

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[2] or a lower level in some cases

Assessment of Compliance Program: Assessment may be undertaken using the guidelines of Table 2 based on continuous on line monitoring and analysis of plant performance and system dynamics.

1.2.5 Audit Clause No. 5 Protection from Power System Disturbances

Requirement: This registered technical requirement varies significantly across those audited. All participant requirements indicate the agreement for automatic disconnection from the system only in response to abnormal conditions. One participant's registered requirements specify that generating units may be disconnected from the power system only when conditions do not require the unit to remain connected, however, no generator protection parameters are defined within this requirement. Another participant is only required to trip on sustained negative phase sequence voltages or single phasing. A third participant was required to trip at over and under frequency, over voltage and over current, while a fourth participant is required to trip on over flux, under and over voltage, over current negative phase sequence currents, load imbalance and provide load dump at high frequency.

Compliance Issues: Sinclair Knight Merz during earlier work has observed that overcurrent protection for large generators is not used in significant areas. Older plant may be fitted with electromechanical protection relays whose characteristics may alter during system disturbances.

Large thermal plant is particularly vulnerable to frequency disturbances. This type of plant in many cases is also protected against process control swings that have the propensity to cause secondary damage to plant. Boiler and turbine tripping may result from operation of this protection. Also thermal plant may be more vulnerable either due to the plant operating configuration or the phase of the maintenance or boiler cleaning cycle.

Thermal process protection systems are generally tested by secondary injection as well as physical plant tests to confirm performance from the following effects:

- Generator temperature rises
- Generator operation at extreme over excitation
- Generator and generator transformer overflux
- Furnace pressure disturbances
- Boiler drum/separator vessel level swings
- Load limiter action
- Generator exciter protection operation at extreme limits of excitation
- Governor offloading and the reverse power protection
- Operation of safety valves
- Load set point modification

Many older plants do not have protection systems for all of these undesirable conditions.

Compliance Monitoring Program: Testing of electrical protection systems is almost universally undertaken using secondary injection. This form of testing is well established as a routine practice by the participants and across the electricity industry. Under and over frequency protection and negative phase sequence protection is typical of the protection systems employed despite the registered requirements listed in the audit sample.

Most participants undertake secondary injection at three year intervals with low service factor participants being up to five years. Sinclair Knight Merz considers these test rates are reasonable. It is the opinion of Sinclair Knight Merz that the test rate may be decreased if digital multifunction relays are widely employed as long as there has been adequate consideration of the following protection system parameters:

- Relay stability as evidenced by the comparison between the as found and last test result.
- The operational demand on the protection system
- The required reliability
- Probability of protection failures on demand.

The testing of mechanical plant protection will vary much more significantly across different plants and different technologies. These systems too may be tested by secondary injection, however significant routine maintenance activities are required to maintain the mechanical protection system response within power plants.

Assessment of Compliance Program: Assessment may be undertaken using the guidelines of Table 2 based on a secondary injection testing regime with an associated maintenance program for mechanical protection. Continuous on line monitoring, modelling and analysis of mechanical plant protection performance in addition to 'two out of three' trip systems in association with routine testing would contribute to the participant achieving the highest assessment.

1.2.6 Audit Clause No. 6 Protection that impacts on Power System Security

Requirement: This requirement identifies that the participant shall have protection systems to remove faulted plant items from the system. This registered technical requirement is consistent across those audited and identifies the requirement for automatic disconnection from the system of faulted plant specifying the time for fault clearance and that the protection system must have redundancy and provided with a breaker failure system.

Compliance Issues: There have been no issues noted. Sinclair Knight Merz found that all of the participants could demonstrate compliance with the registered requirements.

Compliance Monitoring Program: This requirement is tested by secondary injection. Most participants undertake secondary injection at three year intervals with low service factor participants being up to five years. Sinclair Knight Merz considers these test rates are reasonable and the test rate may be decreased if there has been adequate consideration of the protection system parameters as discussed in Section 1.2.5.

Assessment of Compliance Program: Assessment may be undertaken using the guidelines of Table 2 based on a secondary injection testing. Continuous on line monitoring in addition to routine testing would contribute to the participant achieving the highest assessment.

1.2.7 Audit Clause No. 7 Asynchronous Operation

Requirement: This registered requirement is listed for most participants although there is a variation of the protection description between incoming reactive, under excitation and reverse power. Each synchronous generating unit is required to have installed a protection system to promptly disconnect the generating unit in order to prevent pole slipping. Modern practice may implement pole slip and loss of field protection by identifying the passage of the impedance loci through a zones defined by the system and machine impedances at the generator terminals.

Sinclair Knight Merz considers that both field loss and pole slip protection is a safeguard for both the generator and the system. Turbo-generator damage following a loss of excitation and pole slip incident may include heavy rotor and stator currents with corresponding arc damage to retaining rings and damping windings as well as damage to stator overhang bracing.

Compliance Monitoring Program: This requirement is tested by secondary injection. Most participants undertake secondary injection at three year intervals with low service factor participants being up to five years. Sinclair Knight Merz considers these test rates are reasonable and the test rate may be decreased if there has been adequate consideration of the protection system parameters as discussed in Section 1.2.5.

Assessment of Compliance Program: Assessment may be undertaken using the guidelines of Table 2 based on a secondary injection testing. Continuous on line monitoring in addition to routine testing would contribute to the participant achieving the highest assessment.

1.2.8 Audit Clause No.8 Frequency Control

Requirement: This registered requirement begins by defining for each generator its key terms[3] relative to the size and function of the turbo generator. The generator is required not to increase active power output in response to a system rise in frequency. The generator is required not to decrease its active power output in response to a system fall in frequency. Oscillatory active power behaviour is damped with a damping ratio of more than 0.4[4]. Each generator shall be capable of automatically changing its output by at least the smallest of:

(i.) an amount proportional to the difference between the system frequency and the limit

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[3] These terms are:

- Maximum operating level means, in relation to a generating unit, the greater of its nameplate rating and its value for Maximum Continuous Power rating (PMAX)
- Minimum operating level means, in relation to a generating unit, the greater of zero and its value for Minimum Continuous Power rating (PMIN)
- System frequency means the electrical frequency of the transmission system
- Pre-disturbance level means the generating unit's level of output just before the system frequency first exceeds the upper or lower limit of the normal operating frequency band during the frequency disturbance

[4] The damping ratio ξ is the ratio of actual damping to the critical damping. $\xi = 0$ the oscillation does not decay, $\xi = 1$ the system is critically damped and there is minimal overshoot. At $\xi = 0.4$ the system will overshoot by 0.25PU and settle within 0.02 PU by the second peak. Ref [60] Page 229

(ii.) ten percent of the limit level

(iii.) subject to the frequency recovering gradually only the positive difference between the pre-disturbance level and the minimum action level.[5]

Compliance Issues: This requirement cannot easily be tested directly at power stations fitted with mechanical governors. The frequency recovery rejection by a thermal power station is also influenced by the turbine and boiler parameters as well as the initial conditions and plant configuration.

A similar regime of historical monitoring of disturbances and plant performance and analysis of the data has been followed by all of those audited.

Compliance Monitoring Program

Testing: In the case of electronic governors, frequency control action can be tested by speed offset injection into the speed governor control. This test may be performed on line with sufficient standby plant available. An appropriate test schedule interval would be of the order of three years.

Monitor and Model: Speed offset injection is impractical in the case of mechanical governor systems. It is reasonable in these cases to rely on plant monitoring with model analysis to quantify the extent of operation over which partial load rejection operates.

Assessment of Compliance Program: Assessment may be undertaken using the guidelines of Table 2 based on testing of electronic governor offloading by speed offset injection or in the case of mechanical governors continuous on line monitoring and analysis of plant performance during disturbances. In addition to monitoring or testing, mechanical plant modelling and analysis during frequency disturbances would contribute to the participant achieving the highest status of assessment.

1.2.9 Audit Clause No.9 Stability

Requirement: This registered requirement differs depending on the participant. In general the participant is required to provide each generating unit with the plant capabilities and control systems including but not limited to inertia and short circuit ratio (in some cases satisfying the requirements of IEC 60034-3:1988), sufficient to achieve the following two requirements:

1. Not reduce an inter-regional or intra-regional power transfer capability (in some cases only to import into the generating units' region by more than its loading level whenever it is synchronised.) With some participants this is specified as relating to either:

    i. transient stability;

    ii. oscillatory stability; or

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[5] These three values are significantly simplified and only presented as a general case.

iii. voltage stability,

2. The generator shall not cause instability that would adversely impact on other Participants.

Compliance Issues: Generator stability in many cases is an interaction between the performance of the generator voltage and load/frequency control and the system to which it is connected. Changes to the Power System its configuration or its development can affect machine stability at a power station.

Maintenance and on line testing can provide quality assurance of governors, voltage controllers while benchmark calculations can provide confidence that the generator operation remains consistent. The only feasible way to confirm the extent of generator interaction with the network is with on line testing followed by modelling analysis under various network configurations. Sinclair Knight Merz agrees with some of the participants that some of the variables of compliance under this requirement lay in the transmission network. The power station participant can only be held responsible for maintaining the benchmark condition of its plant.

The technical requirement for turbo generator stability at each plant being written in terms of the regional transfer capacity of the system and the impact of the participant on other participants makes it difficult for a participant to ascertain their performance against their registered requirements.

It is the opinion of Sinclair Knight Merz that the recorded benchmark and base parameters and a disturbance monitoring regime should form the compliance monitoring program for the participant's registered requirements in this case.

If the benchmark and base parameters remain unchanged then the cause of changes in stability at a regional level are more likely to be due to changes from external influences rather than the participant's plant. System monitoring as well as stability modelling required by participants would undoubtedly require support from the TNSP and cannot be readily achieved by the participant. Modelling of system stability is a well established practice by the TNSPs and their subcontractors. In order to provide evidence of compliance following network power transfer instability, participants would have to contract studies of their plant behaviour using such models.

Should a system stability issue arise then participants whose plant is performing to benchmark and base parameters should not be deemed responsible.

Most power stations were able to provide evidence of monitoring key stability parameters in the required time domain.

Compliance Monitoring Program

Benchmarking: Sinclair Knight Merz recommends that as the plant inertia and short circuit ratio are usually unchanged over the life of a plant these may be considered as benchmark parameters. **Testing:** Voltage regulators and Power System Stabilisers are set to required output within the parameters required by the Transmission Network Service Provider (TNSP). These and governor parameters may be checked for consistency after major plant overhauls using off line and on line testing and monitoring. All of this information including governor, AVR and PSS settings may also form the base information that can be used as reference data following subsequent overhauls or testing.

Monitoring, Calculation and Model: Local stability analysis by the participant using monitoring and analysis is practical. It is reasonable to rely on plant benchmark and base parameters supported by monitoring. This information is then available to investigate system wide instability using calculations and model analysis to quantify the extent of contribution by each system component.

Assessment of Compliance Program: Assessment may be undertaken using the guidelines of Table 2 based on testing and bench marking of electronic governor and AVR. In the case of mechanical governors, step tests and continuous on line monitoring and analysis of plant performance during disturbances should be undertaken. In addition to monitoring or testing, system modelling and analysis during frequency disturbances would contribute to the participant achieving the highest assessment status.

1.2.10 Audit Clause No. 10 Excitation Control System

Requirement: This registered requirement is listed for all participants. Each generating unit is required to have installed an excitation control system that is adequately damped and can maintain a continuous voltage. Particular requirements are listed for each participant for the following parameters:

(i) Time for field voltage rise to excitation ceiling voltage

(ii) Settling time following a disturbance off line

(iii) Settling time following a disturbance on line

(iv) Settling time following a disturbance which causes an excitation limiter to operate

Excitation control is tested by both on line and off line step response testing. Testing has been performed across the industry typically three to four yearly.

Compliance Issues: Sinclair Knight Merz is of the opinion that a program of appropriate testing is required to maintain performance of excitation control systems. The characteristics of this program may depend on several factors that could include:

(i) Variability of the control equipment. If the equipment has had a history of drift then the period of testing and calibration should be associated with the anticipated time for the control to drift out of specification. Modern digital controls are inherently much more stable and provide diagnostic reports on line.

(ii) Plant that operates with very low service factors may find that longer periods between testing is appropriate.

(iii) Settings both before and after test are recorded and the rate of drift of each setting may be calculated and recorded.

Compliance Monitoring Program: In the case of large generators where local voltage is not substantially affected by testing, this requirement may be tested at appropriate periods during normal operation. In the case of plant at remote network nodes where the impact of performing tests at extreme limits of excitation may compromise local voltage control, some form of additional, counteracting, voltage control may be required

The test is essentially a step or dynamic test at each test point and must be undertaken both off and on line and may be implemented using appropriately calibrated AVR testing equipment employing existing instrumentation transformers. The test should be undertaken at an appropriate level of active power. The tap setting of the generator step up transformer may be adjusted to facilitate the achievement of the required load. An appropriate test schedule interval would be of the order of three years.

Assessment of Compliance Program: Assessment may be undertaken using the guidelines of Table 2 based on a testing regime. Continuous on line monitoring and analysis of plant performance in addition to routine testing would contribute to the participant achieving the highest assessment status.

1.2.11 Audit Clause No. 11 Remote Monitoring

Requirement: This technical requirement calls for each generating unit to have remote monitoring equipment to transmit to NEMMCO's control centres in real time. The following quantities are required by NEMMCO to discharge its market and power system security functions:

(i) Status Indications:

- (1) Generating unit on-line indication

(ii) Analogue Values:

- (1) Generating unit gross active power
- (2) Generating unit gross reactive power
- (3) Unit transformer active power and reactive power
- (4) Generating unit stator voltage
- (5) Generating unit transformer tap position

Compliance Issues: This requirement is tested online by NEMMCO and the factors addressed as they might arise. There is little proactive work required by the participants.

Sinclair Knight Merz considers the requirements were met by all of the participants audited.

Compliance Monitoring Program: As the remote monitoring system testing is provided on line by NEMMCO the participant must ensure all signals required by the system are at no time put at risk of failure and are presented correctly to the input modules of the system. Procedures and personnel must be available to rectify local faults should they be identified by the on line testing.

Assessment of Compliance Program: Assessment may be undertaken using the guidelines of Table 2 based on a monitoring regime. Continuous back up of plant data capable of maintaining interrupted files in addition to the on line fault monitoring would contribute to the participant achieving the highest assessment status.

1.2.12 Audit Clause No.12 Auxiliary Transformers

Requirement: This registered requirement differs depending on the nature of the operation of the participant's plant. The technical requirements may be summarised as follows:

Some low capacity factor power stations, whilst offline consume very low active power loads that are significantly reactive. These reactive power loads are connected to the high voltage network and are negligible when related to the capacity of the connection. The registered requirement for these plants is:

1. Each generating unit, while not generating, draws electricity with a power factor that meets the requirements of Electricity Distribution Code, or, that the power station takes its auxiliary supplies through a distribution transformer via a separate connection point subject to the Distribution Code. This may be an issue for some participants under light load conditions.
2. At large thermal power plants the connection of the auxiliary supplies is to a very strong electrical node. At these node there are defined protection requirements including:
    - Clearance time (different at each location)
    - Protection system redundancy and breaker fail protection

   The phase currents must be balanced with required levels of harmonic distortion and voltage fluctuations

Unless significant auxiliary plant or operational practice changes are undertaken the participants' compliance with the registered requirements for auxiliary transformers may be considered a benchmarked activity.

Compliance Issues: Sinclair Knight Merz considers the significant range of technical requirements for auxiliary transformers make the application of a standard compliance requirement difficult. The application of distribution system requirements may be inappropriate to the operation of the auxiliary supplies at a power station, particularly when connected to the transmission network. In the case of large thermal power stations situated at strong electrical nodes of the network, the small voltage fluctuations experienced would require additional monitoring to ascertain compliance with the registered requirements. If undertaken, the analysis of such monitoring may also be affected by external switching and/or network configuration.

Compliance Monitoring Program: A desk top study supported by benchmark tests would establish the typical range of auxiliary loading under various configurations.

Assessment of Compliance Program: Assessment may be undertaken using the guidelines of Table 2 based on a calculated benchmark and testing regime. Continuous load monitoring and analysis of plant configuration in addition to calculated benchmarking would contribute to the participant achieving the highest assessment status.

1.2.13 Audit Clause No.13 Fault Level

Requirement: This registered requirement is usually expressed as each generator's contribution to either a single phase or three phase fault on the local connected network. Some participants requirements are expressed as a fault at the extra high voltage bus and another participant was required to express the calculation in terms of the MVA base at a particular voltage level and the PU sub-transient reactance.[6]

Compliance Issues: All of the participants audited were unclear that only the generator contribution to a terminal fault is required by this registered requirement. Once calculated, unless significant changes are made to the generator, step-up transformer or the configuration to the point of supply then the fault contribution can be considered to be unchanged.

Sinclair Knight Merz considers use of design calculations or if not possible a desk-top study the most appropriate approach to develop this benchmark requirement.

Compliance Monitoring Program: Design calculations of fault levels should be reviewed, or if not possible, a study undertaken to confirm the fault contribution by each generator expressed as required by the registered technical requirement. Procedures must be in place to initiate recalculation should significant changes to significant plant or configuration be undertaken.

Assessment of Compliance Program: Assessment may be undertaken using the guidelines of Table 2 based on a calculated benchmark regime.

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[6] PU Sub- transient reactance: is the impedance of a generator during the short period immediately, within one or two cycles, following a short circuit expressed as a PU ratio. The fast decay of the sub-transient currents is due to the damper windings and eddy current low resistances. In this instance the leakage reactance of the step up transformer must also be considered.