ElectraNet
electricity transmission

Appendix X

Future Generator Testing and Modelling Requirements

ElectraNet Pty Ltd

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30 May 2007

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1. Executive Summary

This report discusses and identifies the need for generator testing, derivation of parameters and how the results from these tests are used by NEMMCO and NSPs to support the ongoing management of system security and provide a reliable basis for network development.

The report identifies and discusses ElectraNet's new obligations under the National Electricity Rules ("Rules") for generator testing, derivation of parameters and development of generator models for simulation purposes.

In order to comply with these obligations, it is recommended that ElectraNet develop a systematic and ongoing generator testing and model development program.

This program will require the development and engagement of additional technical resources to support compliance with these new requirements.

It is recommended that ElectraNet initiate a program to confirm the validity of generator models for each generator and generating system every 15 years and that generator control system tests be performed on each generator and generating system every 5 years.

The total cost of the proposed testing regime and development of associated generator models is estimated at $1.2M per annum.

2. Introduction

Accurate power system models are required by NEMMCO and NSPs to ensure that the power system is operated and developed in a secure manner.

This is recognised in the National Electricity Rules ("Rules"), which places obligations on *Generators* and *Network Service Provider* to carry out generator tests to confirm the validity and accuracy of models used to support the management of system security.

Generally, a dynamic model will typically consists of:

- A model structure;
- Model parameters; and
- Supplementary information regarding the use and range of conditions for which the model is valid.

Broadly, generator tests are required to prove that the dynamic model and associated parameters are sufficiently accurate for:

- Planning of *power system* performance, including the determination of future *network* limits, determination of dynamic *plant* settings throughout the *power system*, and network augmentation requirements; and
- Operational requirements, which may include determination of current *network* limits, or for operational planning purposes to determine future operations (e.g. *network* outages).

The above functions are critical to the ongoing management of system security.

On the 15 March 2007, the Rules were changed with respect to generator testing and development of analytic parameters for modelling purposes.

The Rules now make it clear that it is the responsibility of NSPs to support and manage the testing of generators, develop analytic parameters of generators and prepare associated models.

Prior to these recent rules changes, ElectraNet and many other NSPs were of the understanding that field testing of generators, preparation of analytic parameters and development of "valid" generator models was a matter for the generator owners and not the connecting NSP.

Before the 15 March 2007, ElectraNet held the view that the owners and operators of generators are best placed to manage the accuracy of generator data, control systems integrity and validity of associated models. For these reasons, ElectraNet has not engaged in the testing and development of existing generator models during the 2003 – 2008 regulatory period.

In summary, the Rules now places clear obligations on NSPs to evaluate generator test results, calculate analytic parameters, and develop generator models of sufficient accuracy and functionality that comply with NEMMCO technical requirements.

3. ElectraNet Obligations

Under the Rules, a Network Service Provider (NSP) may be required to initiate the testing of generators. These provisions are addressed in clause 5.7.6 *Tests of generating units requiring changes to normal operation*. The clause 5.7.6 (a) provides that:

> A *Network Service Provider* may, at intervals of not less than 12 months per *generating system*, require the testing by a *Generator* of any *generating unit connected* to the *network* of that provider in order to determine analytic parameters for modeling purposes or to assess the performance of the relevant *generating unit* or *generating system* for the purposes of a *connection agreement*, and that provider is entitled to witness such tests.

On the 15 March 2007, substantial changes were made to the Rules in relation to the testing of generators. Clause 5.7.6(b) provides for:

> If *NEMMCO* reasonably considers that:
>
> (1) the analytic parameters for modeling of a *generating unit* or *generating system* are inadequate; or
>
> (2) available information, including results from a previous test of a *generating unit* or *generating system*, are inadequate to determine parameters for an applicable model developed in accordance with the *Generating System Model Guidelines*, or otherwise agreed with *NEMMCO* under clause S5.2.4(c)(2),
>
> *NEMMCO* may direct a *Network Service Provider* to require a *Generator* to conduct a test under paragraph (a), and *NEMMCO* may witness such a test.

In effect, the above provisions now enable NEMMCO to direct NSPs to undertake the testing of generator units based on their evaluation of existing generator model adequacy and integrity.

NEMMCO has expressed the view that provision of accurate generator models is essential to effectively manage system security and that these rule changes have been developed and implemented for this reason.

The Rules were also changed with respect to the development of analytic parameters, clause 5.7.6 (g) states:

> A *Generator* must provide the test records obtained from a test under paragraph (a) to the *Network Service Provider*, who must derive the analytical parameters for the applicable model developed in accordance with the *Generating System Model Guidelines*, or otherwise agreed with *NEMMCO* under clause S5.2.4(c)(2) and provide them to *NEMMCO* and the relevant *Generator*.

These provisions place a clear obligation on NSPs to evaluate generator test results and develop generator models of sufficient accuracy and functionality that comply with NEMMCO technical requirements.

Prior to the introduction of these rule changes there was no clear obligation on NPSs to prepare and develop generator models. ElectraNet has not applied the provisions of Rules clause 5.7.6 as it was of the view that the development and validity of generator models is the responsibility of the generator asset owners and not the connecting NSP.

In addition, clause 4.3.4(a) provides:

> 'Each *Network Service Provider* must use reasonable endeavors to exercise its rights and obligations in relation to its *networks* so as to co-operate with and assist NEMMCO in the proper discharge of the *NEMMCO power system security responsibilities*.'

In summary, following changes to the Rules on the 15 March 2007, NSPs have an obligation to undertake generator testing and develop analytic parameters to support generator modelling if NEMMCO or the NSP are of the view that existing generating or generating system models are inadequate and to maintain the accuracy of system models.

The obligation for NSPs to derive analytic parameters from test and develop generator models that comply with NEMMCO *Generating System Model Guidelines* did not exist prior to the 15 March 2007.

4. Future Requirements

The new Rules provisions that require NSPs to develop generator models from the results of field testing and comply with NEMMCO *Generating System Model Guidelines* represent a significant new regulatory obligation on ElectraNet.

In order to comply with these obligations, it is recommended that ElectraNet develop a systematic and ongoing generator testing and model development program. The program will ensure that generator models are valid, have sufficient accuracy to support the management of system security and form a reliable basis for network development.

This program will require the development and engagement of appropriate technical resources.

Presently there are 44 traditional generating units connected to the transmission system (see Attachment A). In addition there are over 300 individual wind turbines connected to the transmission system via 7 large scale wind farms.

By the end of the next regulatory period in 2013 it is expected that the number of traditional generating units will have increased to approximately 50 units and the number of large scale wind farm increased to approximately 10 generating systems.

It is recommended that ElectraNet establish a range of tests to confirm the validity of generator models. It is proposed that generator tests be performed on each generator and generating system every 15 years and that control system tests of each generator and generating system be made every 5 years.

4.1. Generator Tests

It is recommended that generator tests would be performed on each generator and generating system once every 15 years. A term of 15 years has been selected as this would:

- Capture major plant refits;
- Take advantage of improved on-line monitoring and control system test instrumentation that may be installed during this period; and
- Enable the application of improved modelling and test techniques that may contribute to improved modelling accuracy.

The installation of modern on-line monitoring and control system test instrumentation will significantly improve recording capability and therefore model accuracy.

It is proposed that the tests would cover:

- Machine parameter measurement
- Excitation systems
- Excitation control systems
- Power system stabilisers
- Turbine controls (selected systems only)

Following completion of these tests, it is proposed that detailed models would be developed that complied with NEMMCO *Generating System Model Guidelines.* It is recommended that the results of all tests and model derivation are fully documented to support comparison of future results and provide support for investigation of future unplanned system events.

4.2. Generator Control System Tests

It is proposed that ElectraNet undertake generator control system tests on each generator and generating system once every 5 years.

Typically, the tests would cover:

- Excitation systems
- Excitation control systems
- Power system stabilisers
- Turbine controls (selected components only)

Tests results would be used to confirm the validity of the generator control system models. The proposed testing regime would be effective in capturing and identifying generator control system that are malfunctioning and could present an operational risk.

It is recommended that the above test results be complemented, with results and information gathered from field measurement devices, such as the PSPM recording devices used by ElectraNet. While these results are good at capturing actual disturbances and support comparison between actual and simulated performance, they are not able to adequately check all aspects of control system or generator performance.

5. Forecast of Costs

5.1. Generator Testing

Connell Wagner are consultants that provide specialist advice in the field testing of large machines.

Connell Wagner has advised that the costs associated with undertaking field testing of generators is dependent on the accuracy of results required. Indicative pricing can range from $100,000 to 250,000 for generator parameter testing depending on accuracy requirements. The cost of testing excitation systems and analysis of results can range from $50,000 to $100,000 depending on the complexity of system under consideration and modelling accuracy required. This estimate represents Network Service Provider cost only and does not reflect costs that may be borne by the generator owner. It should also be noted that the costs reflect the substantial complexity of testing and associated liabilities.

In order to provide for increased confidence in these costs estimates, Hydro Tasmania was approached and requested to provide cost estimates for testing and modelling both conventional generation and wind generation systems (refer to Attachment B). Again these estimates reflect costs that would be incurred by

the Network Service Provider and do not address the generator owners testing costs (i.e. fuel, unit unavailability, labour etc).

For conventional generator units, testing is based on assessment using load rejection techniques and does not provide for the same level of accuracy when compared to standstill frequency injection testing. Hydro Tasmania has indicated cost of approximately $200,000 covering test preparation, testing and analysis of results. These costs are based on having some "pre knowledge" of the control system structure and assume that no major obstacles are encountered in the testing process.

Presently, ElectraNet does not have in house technical capability to undertake the field testing of generator units and support the development of generator unit analytic parameters. As an alternative to the above, two additional staff could be employed by ElectraNet and skills be developed to support generator testing and development of analytic parameters. The estimated cost for two appropriately skilled Full Time Equivalent (FTE) employees would be in the order of $350,000 per annum.

5.2. Generator Control System Testing

Based on prices provided by Connell Wagner, the cost of testing and developing models that reflect accurate control system operation are estimated at $100,000 per generating unit. Information provided by Hydro Tasmania also reflects costs in the range of $100,000 - $150,000 assuming testing and model development proceed smoothly.

As an alternative to the above, ElectraNet could employ additional staff to support testing and development of generator models. The estimated cost of employing one additional employee would be approximately $175,000 per annum.

5.3. Forecast of Expenditure

Assuming that full generator tests are undertaken once for each unit every 15 years, then the average annual cost of this service based on the connection of 33 generator unit types and generating system types is estimated at $550,000 per annum. Details regarding the number of generator units types are shown in Attachment A.

The cost of generator control system testing is estimated at $650,000 per annum and is based on testing of each generator unit type or generating system type every 5 years.

The total cost of the recommended testing regime and development of associated generator models is estimated at $1.2M per annum.

6. Efficient Expenditure

The following actions are proposed to ensure that generator testing and modeling requirements are managed effectively.

6.1. Collaboration with other NSPs

It is proposed costs could be negated by establishing a collaborative approach with other NSPs.

Activity would extend to the development of new tools and systems to more efficiently develop generator testing techniques and prepare models of the required accuracy.

The collaborative approach could be extended to the provision of common training schemes and course development.

6.2. Engage testing specialists

NSPs could engage specialists in the field of generator testing (Connell Wagner, PTI etc) that may provide for more efficient delivery of services. These national and international specialists may provide increased experience and improved scales of economy compared to developing equivalent in house services.

6.3. Screening based PSPM results

As mentioned, ElectraNet Power System Performance Monitors (PSPMs) could also be used to support the efficient selection of generators for testing by supporting comparison of actual and simulated results.

6.4. Prioritisation of generator testing

Generators requiring testing could undergo a prioritisation process to ensure that units most need in of testing are scheduled first.

Adopting one or more of the above initiatives may allow cost savings in implementing the recommended generator testing and model validation program compared to the above $1.2M per annum cost estimate.

7. Conclusion

This report discusses and identifies the need for generator testing and how the results from these tests are used by NEMMCO and NSPs to support the ongoing management of system security and ensure reliable network development.

The report identifies and discusses ElectraNet's new obligations under the Rules for testing, derivation of parameters and development of generator models.

In order to comply with these obligations, it is recommended that ElectraNet develop a systematic and ongoing generator testing and model development program.

This program will require the development and engagement of appropriate technical resources to support compliance with these new requirements.

It is recommended that ElectraNet undertake a range of field tests to confirm the validity of generator models. It is recommended that generator and generator system tests be performed every 15 years and that generator and generator system control system tests be conducted every 5 years.

The total cost of the proposed testing regime and development of associated generator models is estimated at $1.2M per annum.

A number of initiatives, including greater reliance on PSPM data to validate models, may allow cost savings compared to this cost estimate.

Attachment A

Existing conventional generation

Participant	Power Station	Name Plate rating	Units	Capacity (MW)	Plant Type	Fuel	Commissioning Date	Orginal Test Date (R2)	15 Year Test Date	Total unique unit types	Unique units needing testing (greater than 15 years at 2013)	Unique units needing testing to comply with NER R2 obligations
International Power	Dry Creek	52	3	156	Gas Turbine	Natural Gas	1942	1994	2009	1	1	0
AGL	Hallett		11	192	Gas Turbine	Distillate	2002	Not undertaken	2008	9	0	9
Origin Energy Ladbroke	Ladbroke Grove	43	2	86	Gas Turbine	Natural Gas	1996	2000	2015	1	1	0
International Power	Mintaro	90	1	90	Gas Turbine	Natural Gas	1948	1996	2011	1	1	0
Flinders Power	Northern	260	2	520	Steam Turbine	Coal	1985	1994	2009	1	1	0
Flinders Power	Osborne	190	1	190	Cogeneration	Natural Gas	1997	1999	2014	2	2	0
International Power	Pelican Point	487	3	487	Combined	Natural Gas	2000	2001	2016	2	0	0
Flinders Power	Playford	60	4	470	Steam Turbine	Coal	1960	Not undertaken	2008	2	0	1
International Power	Pt Lincoln	24	2	48	Gas Turbine	Distillate	1995	Not undertaken	2008	1	0	1
Origin Energy Quarantine	Quarantine	24.6	4	98.4	Gas Turbine	Natural Gas	2002	2001	2016	1	0	0
International Power	Snuggery	26	3	78	Gas Turbine	Distillate	1980	Not undertaken	2008	1	0	1
TRU Energy	TIPS A	120	4	480	Steam Turbine	Natural Gas	1967	1994	2009	1	1	0
TRU Energy	TIPS B	200	4	800	Steam Turbine	Natural Gas	1980	1994	2009	2	2	0
Murraylink	Murraylink	200	1	200	Interconnector	HVDC	2002	2003	2018	1	0	0
									total	26	9	12

Wind Generators

Participant	Power Station	Name plate rating	Units	Capacity (MW)	Status	Commissioning Date	Orginal Test Date (R2)	15 Year Test Date	Total unique unit types	Unique units needing testing (greater than 15 years at 2013)	Unique units needing testing to comply with NER R2 obligations
Babcock and Brown	Lake Bonney Stage 1	1.75	46	80.5	Operational	2004	Not undertaken	2008	1	0	1
Babcock and Brown	Lake Bonney Stage 2	6	53	159	Operational	2007	Not undertaken	2008	1	0	1
Hydro Tasmania/EHN	Cathedral Rocks	5	33	66	Operational	2005	2006	2021	1	0	0
AGL Hydro	Wattle Point	1.65	55	90.75	Operational	2005	Not undertaken	2008	1	0	1
Tarong Energy	Mt Millar	2	35	70	Operational	2006	Not undertaken	2008	1	0	1
Trust Power	Snowtown	2.1	42	88.2	Committed	2008	Not undertaken	2008	1	0	1
AGL	Hallett	2.1	45	94.5	Committed	2007	Not undertaken	2008	1	0	1
								total	7	0	6
								total	33	9	18

Attachment B

Email from Donald Vaughan to John Thompson 23/05/07

Subject: Cost of generator unit R2 data testing and analysis

John,
Further to our telephone conversation of Thursday 17th May I am happy to provide indicative pricing for testing and analysis activities sufficient to provide R2 data as defined by Schedule 5.5 of the NER.

In our experience we would treat wind generating systems differently to more conventional forms such as thermal or hydro generating systems. A further distinction can be made if standard or pre-existing models are available. The costings below are indicative for each of these variations.

Generating System	Test Preparation	Testing	Analysis
Wind	$25k	$50k	$45k
Hydro/Thermal/Gas*	$35k	$75k	$85k

Table 1: Testing and Analysis Costs assuming pre-existing models
*For conventional, synchronous machines testing would include alternator, excitation and governor testing.

Test Preparation would generally comprise:
i) liaison with site
ii) preparation of detailed test procedure
iii) pre-simulation of on-line tests likely to cause network disturbances

Testing comprises:
i) equipment hire;
ii) testing; and
iii) accommodation and travel expenses.

Analysis:
i) evaluation of performance against Schedule 5 requirements;
ii) calculation of model parameters; and
iii) comparison of model performance with measurements.

Where pre-existing models do not exist this impacts the testing in two ways:
i) test preparation phase must be increased to either devise tests to "discover" the nature of the dynamic model or investigate the nature of the model to allow testing of individual control loops. we would expect this to be in the order of 50% increase on the costs noted in Table 1;

ii) the testing phase must be augmented (by perhaps 30-50% for wind systems and 20-30% for conventional systems) and then, as a result, the analysis phase is also augmented. The increase in cost for analysis is a little more difficult to estimate since if the behaviour under test lends itself to a pre-defined model then the analysis can proceed with perhaps only 5% increase over that shown in Table 1. Where there is some uncertainty over the model topology then the analysis can require between 50% and 100% additional effort.

Although this seems uncertain we would expect that this uncertainty would be limited to new generating technologies such as wind turbines with power electronic controls. We would expect conventional forms of generation, using modern micro-processor based control systems to be relatively straightforward to model using manufacturers block diagrams.

If model writing (i.e. there is no suitable standard or pre-existing model) is required then this is a further cost. We do not address the cost of creation of new models here as there is a wide variation in the cost of this sort of work.

We have endeavoured to give you an indication of the costs associated with testing of generating systems as required to provide R2 data. We also indicate that there is a degree of variation to these costs depending on the equipment under test and the quality of information available on that equipment. The basis of these estimates is at our standard rates, ex-GST.

If you have any queries or comments on the above please do not hesitate to contact us.
Regards,

Donald Vaughan| Principal Consultant: Electrical Primary Systems

B.E.(Elec) hons

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