Clements Gap BESS

Dynamic Model Acceptance Report (PSSE) - Discharging

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Revision History

Table 1: Revision history

Rev.	Date	Prepared By	Reviewed By	Description
1-0-0	16/05/2024	Daniel Bruce and Jared Geere	Ben Kearney	First release

This document uses *Semantic Versioning for Documents* for revision numbering.

Given a version number *MAJOR-MINOR-FIX*, the

- *MAJOR* is incremented when the document has undergone significant changes
- *MINOR* is incremented when new information has been added to the document or information has been removed from the document, and
- *FIX* is incremented when minor changes are made (e.g. fixing typos)

Where appropriate, several revisions may be represented in one table entry with all notable changes described in the *Description* column.

1. Purpose

This report has been prepared to assess the accuracy, consistency and robustness of the Root Mean Square (RMS) model prepared in PSSE to represent Clements Gap BESS (CGBESS) between upper and lower boundaries of system strength. The results obtained as part of this assessment also provide a basis for comparison between the proposed PSSE (being an RMS platform) and PSCAD (being and Electromagnetic Transients (EMT) platform) models. This assessment was conducted in accordance with the requirements of the Dynamic Model Acceptance Test (DMAT) Guidelines published by the Australian Energy Market Operator (AEMO) in June 2024 [1].

The results of this assessment provide confidence that the PSSE model prepared to represent CGBESS is usable and numerically robust under all operating conditions that can be reasonably expected.

2. Project Overview

The Clements Gap Battery Energy Storage System (CGBESS) is a $\pm 60MW/120MWh$ Battery Energy Storage Project, located 170km North of Adelaide in South Australia as shown in Figure 2.1. As part of this project, the existing 132kV line between Red Hill substation and Clements Gap Wind Farm will be converted to a Designated Network Asset (DNA), after which both the existing wind farm and CGBESS will connect to the wind farm end of the line.

CGBESS will include 25 SMA Sunny Central 3.6 MW (SCS 3600 UP) inverters which will be connected to a 132/33kV, 70MVA transformer through the 33kV reticulation system. Each inverter will have a dedicated 33/0.63kV, 3.78 MVA step up transformer.

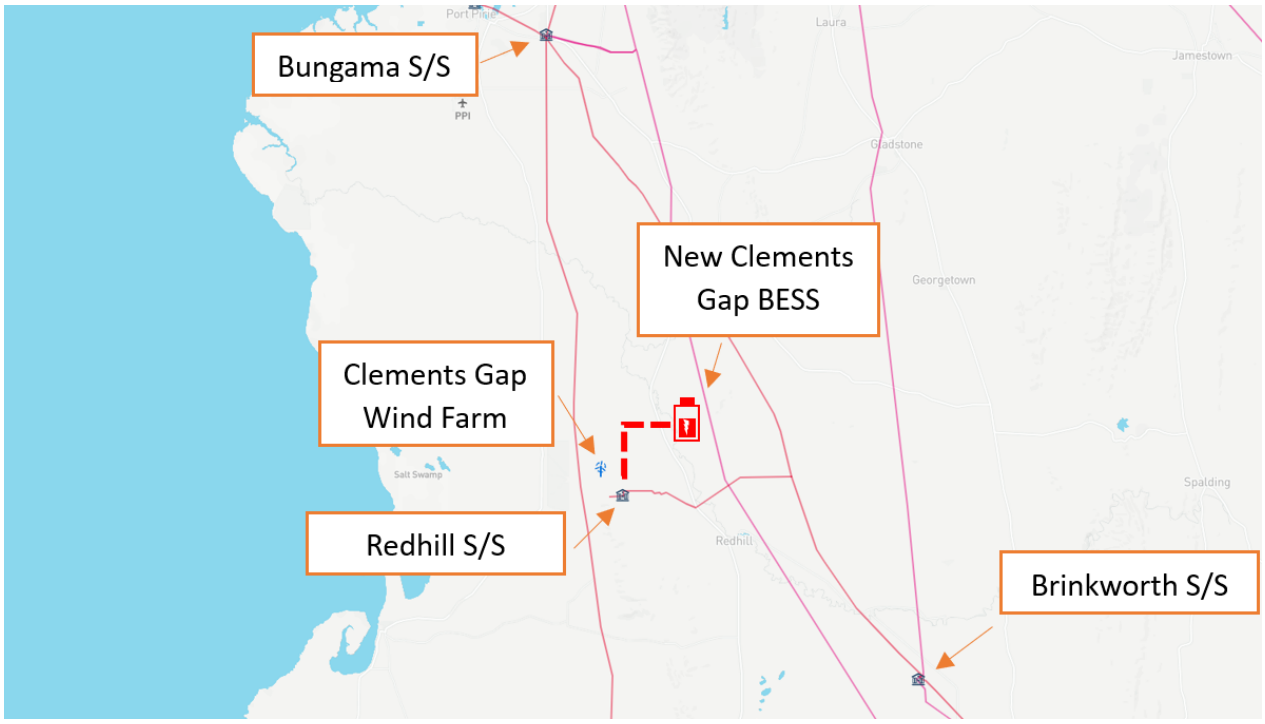

Figure 2.1: Project location

The project received 5.3.4A/B letter in September 2023. The project developer, Pacific Blue (formerly Pacific Hydro), has engaged Enzen for R1 package preparation and delivery works.

3. Results

All simulations have been performed on version v1-0-0 of the CGBESS PSSE model.

The following site-specific values have been used in performing the DMAT tests:

- Maximum fault level and associated Short Circuit Ratio (SCR): 1068 MVA and 17.8.
- Minimum fault level and associated SCR: 510 MVA and 8.5.

Figure 3.1. shows the PSS/E model single line diagram including layout of the generating system and the infinite bus grid model.

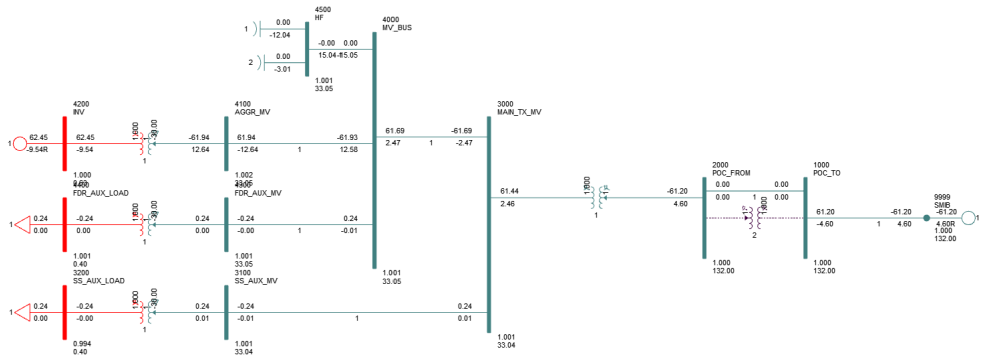

Figure 3.1: PSSE model single line diagram

Further detail regarding the detailed parameters of plant equipment has been outlined in the Clements Gap BESS Releasable User Guide (RUG).

3.0.1 Note On PLL Instability

For a select number of TOV and grid voltage disturbance tests the response seen in PSS/E is understood to be a result of potential PLL instability seen on fault clearance. Furthermore, we believe the reason this appears in PSS/E is related to differences in RMS and EMT modelling platforms - as Spike Mitigation algorithms implemented in PSS/E meant to filter out discontinuities appear to influence this response. Please refer to the supporting technical note "Clements Gap BESS - Spike mitigation and PLL issue at low SCR" [2].

3.1 Balanced faults - DMAT 3.2.4

Balanced faults are applied to the Connection Point as shown in Figure 3.2. The fault impedance, Z_{fault}, is selected using one of two strategies, as required by the given test:

- As a ratio of the fault impedance to the grid impedance. This could be used to specify an intended depth of fault (before generator response).

- Using exact values for R_{fault} and X_{fault}.

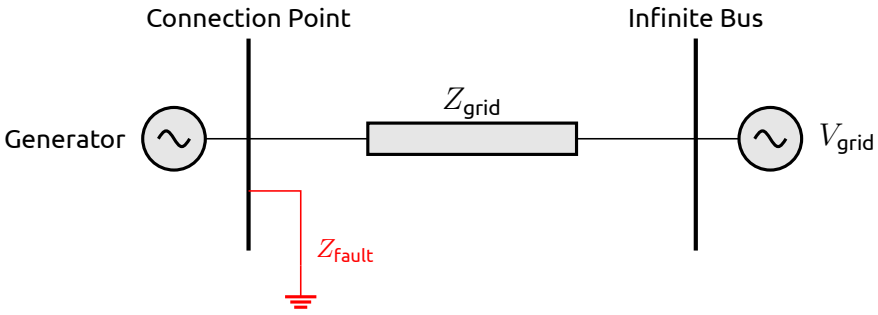

Figure 3.2: Fault application methodology

The full list of balanced faults assessed can be found in Table 3.1.

Table 3.1: Balanced faults test suite

Test Num	SCR	X/R	Vpoc [pu]	Qpoc [pu]	Vref [pu]	Ppoc [pu]	Type	Duration [s]	Impedance	Appendix Reference	Results
Test 1	17.8	14	1.0227	0	1.0227	1	3PHG	0.43	0.03 pu	PSSE DMAT Appendix A Balanced fault tests	Acceptable
Test 2	17.8	14	1.0227	-0.3	1.0167	1	3PHG	0.43	0.03 pu	PSSE DMAT Appendix A Balanced fault tests	Acceptable
Test 3	17.8	14	1.0227	0.3	1.0287	1	3PHG	0.43	0.03 pu	PSSE DMAT Appendix A Balanced fault tests	Acceptable
Test 4	3	14	1.0227	0	1.0227	1	3PHG	0.43	0.03 pu	PSSE DMAT Appendix A Balanced fault tests	Acceptable
Test 5	3	3	1.0227	-0.3	1.0167	1	3PHG	0.43	0.03 pu	PSSE DMAT Appendix A Balanced fault tests	Acceptable
Test 6	3	3	1.0227	0.3	1.0287	1	3PHG	0.43	0.03 pu	PSSE DMAT Appendix A Balanced fault tests	Acceptable
Test 7	17.8	14	1.0227	0	1.0227	0.05	3PHG	0.43	0.03 pu	PSSE DMAT Appendix A Balanced fault tests	Acceptable
Test 8	17.8	14	1.0227	-0.3	1.0167	0.05	3PHG	0.43	0.03 pu	PSSE DMAT Appendix A Balanced fault tests	Acceptable
Test 9	17.8	14	1.0227	0.3	1.0287	0.05	3PHG	0.43	0.03 pu	PSSE DMAT Appendix A Balanced fault tests	Acceptable
Test 10	3	14	1.0227	0	1.0227	0.05	3PHG	0.43	0.03 pu	PSSE DMAT Appendix A Balanced fault tests	Acceptable
Test 11	3	3	1.0227	-0.3	1.0167	0.05	3PHG	0.43	0.03 pu	PSSE DMAT Appendix A Balanced fault tests	Acceptable
Test 12	3	3	1.0227	0.3	1.0287	0.05	3PHG	0.43	0.03 pu	PSSE DMAT Appendix A Balanced fault tests	Acceptable
Test 13	17.8	14	1.0227	0	1.0227	1	3PHG	0.43	Zf = 1 Zs	PSSE DMAT Appendix A Balanced fault tests	Acceptable
Test 14	17.8	14	1.0227	-0.3	1.0167	1	3PHG	0.43	Zf = 1 Zs	PSSE DMAT Appendix A Balanced fault tests	Acceptable
Test 15	17.8	14	1.0227	0.3	1.0287	1	3PHG	0.43	Zf = 1 Zs	PSSE DMAT Appendix A Balanced fault tests	Acceptable
Test 16	3	14	1.0227	0	1.0227	1	3PHG	0.43	Zf = 1 Zs	PSSE DMAT Appendix A Balanced fault tests	Acceptable
Test 17	3	3	1.0227	-0.3	1.0167	1	3PHG	0.43	Zf = 1 Zs	PSSE DMAT Appendix A Balanced fault tests	Acceptable
Test 18	3	3	1.0227	0.3	1.0287	1	3PHG	0.43	Zf = 1 Zs	PSSE DMAT Appendix A Balanced fault tests	Acceptable
Test 19	17.8	14	1.0227	0	1.0227	0.05	3PHG	0.43	Zf = 1 Zs	PSSE DMAT Appendix A Balanced fault tests	Acceptable
Test 20	17.8	14	1.0227	-0.3	1.0167	0.05	3PHG	0.43	Zf = 1 Zs	PSSE DMAT Appendix A Balanced fault tests	Acceptable
Test 21	17.8	14	1.0227	0.3	1.0287	0.05	3PHG	0.43	Zf = 1 Zs	PSSE DMAT Appendix A Balanced fault tests	Acceptable
Test 22	3	14	1.0227	0	1.0227	0.05	3PHG	0.43	Zf = 1 Zs	PSSE DMAT Appendix A Balanced fault tests	Acceptable
Test 23	3	3	1.0227	-0.3	1.0167	0.05	3PHG	0.43	Zf = 1 Zs	PSSE DMAT Appendix A Balanced fault tests	Acceptable
Test 24	3	3	1.0227	0.3	1.0287	0.05	3PHG	0.43	Zf = 1 Zs	PSSE DMAT Appendix A Balanced fault tests	Acceptable
Test 25	17.8	14	1.0227	0	1.0227	1	3PHG	0.5	Zf = 2 Zs	PSSE DMAT Appendix A Balanced fault tests	Acceptable
Test 26	17.8	14	1.0227	-0.3	1.0167	1	3PHG	0.5	Zf = 2 Zs	PSSE DMAT Appendix A Balanced fault tests	Acceptable
Test 27	17.8	14	1.0227	0.3	1.0287	1	3PHG	0.5	Zf = 2 Zs	PSSE DMAT Appendix A Balanced fault tests	Acceptable
Test 28	3	14	1.0227	0	1.0227	1	3PHG	0.5	Zf = 2 Zs	PSSE DMAT Appendix A Balanced fault tests	Acceptable
Test 29	3	3	1.0227	-0.3	1.0167	1	3PHG	0.5	Zf = 2 Zs	PSSE DMAT Appendix A Balanced fault tests	Acceptable
Test 30	3	3	1.0227	0.3	1.0287	1	3PHG	0.5	Zf = 2 Zs	PSSE DMAT Appendix A Balanced fault tests	Acceptable
Test 31	17.8	14	1.0227	0	1.0227	0.05	3PHG	0.5	Zf = 2 Zs	PSSE DMAT Appendix A Balanced fault tests	Acceptable
Test 32	17.8	14	1.0227	-0.3	1.0167	0.05	3PHG	0.5	Zf = 2 Zs	PSSE DMAT Appendix A Balanced fault tests	Acceptable
Test 33	17.8	14	1.0227	0.3	1.0287	0.05	3PHG	0.5	Zf = 2 Zs	PSSE DMAT Appendix A Balanced fault tests	Acceptable
Test 34	3	14	1.0227	0	1.0227	0.05	3PHG	0.5	Zf = 2 Zs	PSSE DMAT Appendix A Balanced fault tests	Acceptable
Test 35	3	3	1.0227	-0.3	1.0167	0.05	3PHG	0.5	Zf = 2 Zs	PSSE DMAT Appendix A Balanced fault tests	Acceptable
Test 36	3	3	1.0227	0.3	1.0287	0.05	3PHG	0.5	Zf = 2 Zs	PSSE DMAT Appendix A Balanced fault tests	Acceptable

Results for DMAT 3.2.4 can be found in Appendix A: Balanced faults.

All tests conducted produced results that were acceptable.

3.2 Multiple fault ride-through (PSSE) - DMAT 3.2.7

Multiple Fault Ride Through (MFRT) tests are performed in the same manner as balanced and unbalanced faults. However, instead of a single fault being applied, a selection of faults with different characteristics (balanced/unbalanced, different fault impedances, different durations) are selected to demonstrate the ability to withstand many disturbances.

As with balanced and unbalanced faults, the faults are all applied to the Connection Point as shown in Figure 3.3.

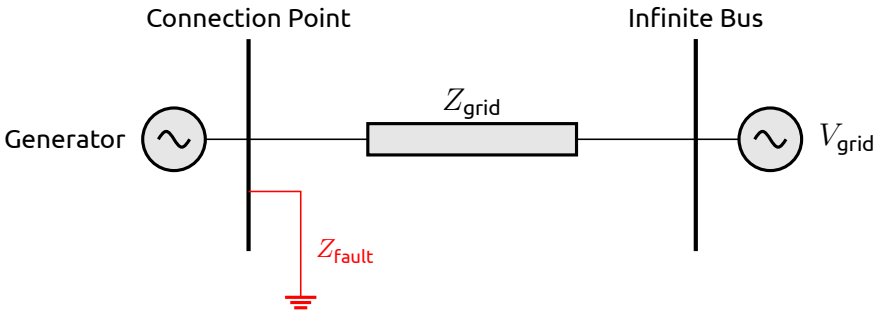

Figure 3.3: MFRT application methodology

The full list of multiple fault ride through PSSE tests assessed can be found in Table 3.2.

Table 3.2: MFRT test suite

Test	Fault Types	Fault Durations	Time Between Faults	Fault Impedance Z_f/Z_s
S1	3PHG, 3PHG, 3PHG, 3PHG, 3PHG, 3PHG, 3PHG, 3PHG, 3PHG, 3PHG, 3PHG, 3PHG, 3PHG, 3PHG, 3PHG	0.43, 0.12, 0.12, 0.12, 0.12, 0.22, 0.12, 0.22, 0.12, 0.22, 0.22, 0.22, 0.22, 0.12, 0.12	5, 0.5, 0.01, 1.5, 0.2, 7, 1, 0.2, 0.75, 2, 0.5, 0.01, 10, 2	2, 1, 2, 0, 3.5, 1, 3.5, 0.2, 1, 1, 0.2, 2, 0, 0.2, 1
S2	3PHG, 3PHG, 3PHG, 3PHG, 3PHG, 3PHG, 3PHG, 3PHG, 3PHG, 3PHG, 3PHG, 3PHG, 3PHG, 3PHG, 3PHG	0.22, 0.22, 0.12, 0.12, 0.22, 0.12, 0.43, 0.22, 0.12, 0.22, 0.12, 0.22, 0.12, 0.12, 0.12	0.2, 10, 2, 0.2, 0.75, 0.5, 1, 0.5, 2, 0.01, 7, 5, 1.5, 3	1, 2, 2, 0.2, 1, 1, 2, 0, 0.2, 1, 1, 0.2, 3.5, 0, 3.5
S3	3PHG, 3PHG, 3PHG, 3PHG, 3PHG, 3PHG, 3PHG, 3PHG, 3PHG, 3PHG, 3PHG, 3PHG, 3PHG, 3PHG, 3PHG	0.12, 0.22, 0.22, 0.12, 0.43, 0.22, 0.12, 0.22, 0.12, 0.12, 0.12, 0.12, 0.12, 0.22, 0.22	0.2, 5, 1.5, 2, 3, 1, 0.5, 0.5, 0.75, 10, 7, 0.2, 0.01, 0.01	1, 0.2, 2, 0, 3.5, 1, 0, 1, 1, 0.2, 0.2, 3.5, 1, 2, 2
S4	3PHG, 3PHG, 3PHG, 3PHG, 3PHG, 3PHG, 3PHG, 3PHG, 3PHG, 3PHG, 3PHG, 3PHG, 3PHG, 3PHG, 3PHG	0.12, 0.22, 0.12, 0.22, 0.12, 0.43, 0.12, 0.12, 0.22, 0.22, 0.22, 0.12, 0.12, 0.22, 0.12	3, 5, 0.2, 2, 10, 1.5, 0.75, 0.01, 0.5, 0.01, 1, 2, 0.2, 0.5	1, 2, 0.2, 2, 2, 1, 1, 3.5, 1, 0.2, 1, 3.5, 0, 0, 0.2
S5	3PHG, 3PHG, 3PHG, 3PHG, 3PHG, 3PHG, 3PHG, 3PHG, 3PHG, 3PHG, 3PHG, 3PHG, 3PHG, 3PHG, 3PHG	0.12, 0.12, 0.43, 0.22, 0.22, 0.12, 0.12, 0.12, 0.22, 0.12, 0.22, 0.12, 0.22, 0.22, 0.12	0.2, 7, 1, 0.5, 3, 0.5, 2, 0.75, 0.01, 1.5, 0.01, 5, 0.2, 2	1, 0, 3.5, 0.2, 2, 0.2, 1, 3.5, 1, 2, 2, 1, 0, 0.2, 1

Results for DMAT 3.2.6 can be found in Appendix B: Multiple fault ride-through tests.

It was observed for test for MFRT test S5 that the generating system trips as a result of frequency protection. This was found to be a numerical issue with PSS/E whereby an extreme frequency disturbance is observed on fault inception (at approximately t=35s) for an extended period of time and the inverter protection then responds as expected. All other tests conducted produced acceptable results.

3.3 Temporary over-voltage - DMAT 3.2.9

Temporary Over-Voltage tests assess the ability of the generator to ride through high voltage disturbances and supply the correct amount of inductive reactive current. To perform these tests, the appropriate $V_{\text{grid}_{\text{initial}}}$ is first identified to achieve $V_{\text{POC}_{\text{initial}}}$ given the required initial P_{POC}, Q_{POC}, SCR and X/R conditions.

A shunt capacitor is then inserted at the Connection Point, sized such that $V_{\text{POC}_{\text{TOV}}} = k_{\text{OV}} * V_{\text{POC}_{\text{initial}}}$, where k_{OV} is the desired percentage increase in V_{POC}.

The test is then performed by initialising the system with the shunt capacitor out of service, then switching it in for the intended disturbance duration, as shown in Figure 3.4.

It should be noted that due to the dynamics of capacitor switching, the initial instantaneous voltage spike may appear filtered and not reach $k_{\text{OV}} * V_{\text{POC}_{\text{initial}}}$. The settled P_{POC} will typically also be lower than this value due to the inductive reactive current support of the generator.

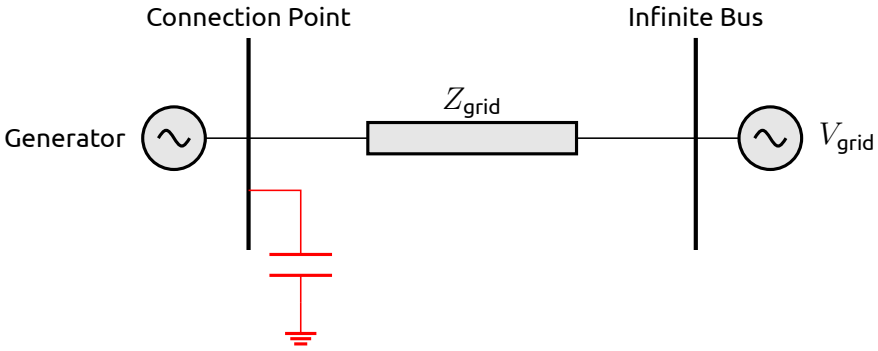

Figure 3.4: TOV test application methodology

The full list of Temporary Over-Voltage (TOV) tests assessed can be found in Table 3.3.

Table 3.3: TOV test suite

Test Num	SCR	X/R	Vpoc [pu]	Qpoc [pu]	Vref [pu]	Ppoc [pu]	Duration [s]	Uov [pu]	Appendix Reference	Results
Test 131	10	14	1.0227	0	1.0227	1	0.9	1.15	PSSE DMAT Appendix C Temporary over-voltage tests	Acceptable
Test 132	10	14	1.0227	-0.3	1.0167	1	0.9	1.15	PSSE DMAT Appendix C Temporary over-voltage tests	Acceptable
Test 133	10	14	1.0227	0.3	1.0287	1	0.9	1.15	PSSE DMAT Appendix C Temporary over-voltage tests	Acceptable
Test 134	3	14	1.0227	0	1.0227	1	0.9	1.15	PSSE DMAT Appendix C Temporary over-voltage tests	Acceptable
Test 135	3	3	1.0227	-0.3	1.0167	1	0.9	1.15	PSSE DMAT Appendix C Temporary over-voltage tests	See Discussion
Test 136	3	3	1.0227	0.3	1.0287	1	0.9	1.15	PSSE DMAT Appendix C Temporary over-voltage tests	Acceptable
Test 137	8.5	4.208	1.0227	0	1.0227	1	0.9	1.15	PSSE DMAT Appendix C Temporary over-voltage tests	Acceptable
Test 138	8.5	4.208	1.0227	-0.3	1.0167	1	0.9	1.15	PSSE DMAT Appendix C Temporary over-voltage tests	Acceptable
Test 139	8.5	4.208	1.0227	0.3	1.0287	1	0.9	1.15	PSSE DMAT Appendix C Temporary over-voltage tests	Acceptable
Test 140	10	14	1.0227	0	1.0227	1	0.1	1.2	PSSE DMAT Appendix C Temporary over-voltage tests	See Discussion
Test 141	10	14	1.0227	-0.3	1.0167	1	0.1	1.2	PSSE DMAT Appendix C Temporary over-voltage tests	See Discussion
Test 142	10	14	1.0227	0.3	1.0287	1	0.1	1.2	PSSE DMAT Appendix C Temporary over-voltage tests	Acceptable
Test 143	3	14	1.0227	0	1.0227	1	0.1	1.2	PSSE DMAT Appendix C Temporary over-voltage tests	See Discussion
Test 144	3	3	1.0227	-0.3	1.0167	1	0.1	1.2	PSSE DMAT Appendix C Temporary over-voltage tests	See Discussion
Test 145	3	3	1.0227	0.3	1.0287	1	0.1	1.2	PSSE DMAT Appendix C Temporary over-voltage tests	See Discussion
Test 146	8.5	4.208	1.0227	0	1.0227	1	0.1	1.2	PSSE DMAT Appendix C Temporary over-voltage tests	See Discussion
Test 147	8.5	4.208	1.0227	-0.3	1.0167	1	0.1	1.2	PSSE DMAT Appendix C Temporary over-voltage tests	See Discussion
Test 148	8.5	4.208	1.0227	0.3	1.0287	1	0.1	1.2	PSSE DMAT Appendix C Temporary over-voltage tests	See Discussion

Results for DMAT 3.2.9 can be found in Appendix C: Temporary over-voltage tests.

When reviewing the plots, it should be noted that the size of the initial voltage step, as well as the size of the settled voltage disturbance, are influenced by the reactive current absorbed by the generating system in response to the disturbance, so these values will not always match the exactly intended over-voltage. The results provide an indication of generating system behaviour for a variety of different disturbances.

Please refer to section 3.0.1 for discussion on the response of tests 135, 140, 141, 143, 144-148.

All other tests conducted produced results that were acceptable.

3.4 Voltage reference step changes - DMAT 3.2.10

Grid voltage step and ramp tests assess the ability of the generator to provide stable reactive response to a changing Connection Point voltage. In VAr and power factor control modes, this is just about P_{POC} and Q_{POC} settling to their pre-disturbance values. However, in voltage droop control modes, a V_{POC} will result in a new calculated Q_{ref}, so the generator will need to track to a new reactive power target at the same time as rejecting the disturbance.

To implement these tests, the appropriate V_{grid_1} is first identified to achieve V_{POC_1} given the required initial P_{POC}, Q_{POC}, SCR and X/R conditions. Subsequent V_{grid} values $V_{\text{grid}_2}, V_{\text{grid}_3}, \ldots, V_{\text{POC}_n}$ can then be calculated to achieve the desired V_{POC} values $V_{\text{POC}_2}, V_{\text{POC}_3}, \ldots, V_{\text{POC}_n}$.

With all $V_{\text{grid,i}}$ calculated, a simulation is performed with V_{grid} stepped or ramped as required to implement the desired disturbance, as shown in Figure 3.5.

It should be noted that this test could also be performed by manipulating the turns ratio of a zero impedance ('dummy') transformer at the Connection Point, however this methodology is not preferred as a ramped disturbance cannot be applied to a transformer turns ratio in PSS/E, which negatively affects the benchmarking between PSCAD and PSS/E.

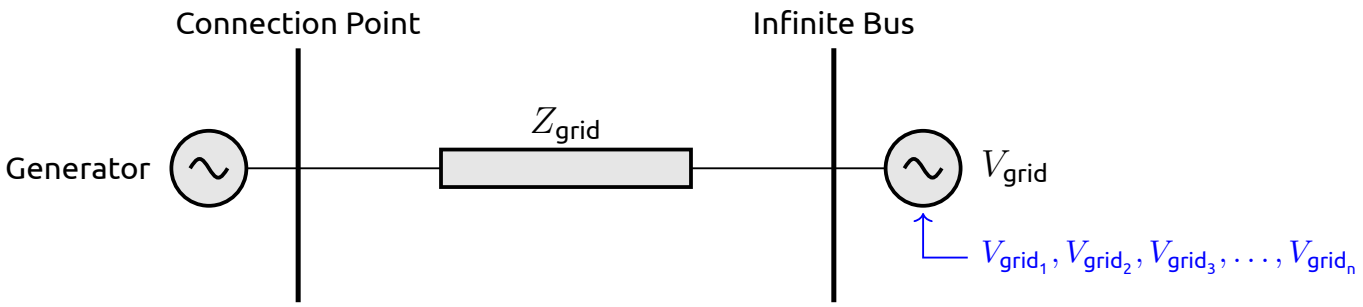

Figure 3.5: Grid voltage disturbance methodology

Voltage reference step tests assess the ability of the generator to provide a damped reactive response to a change in voltage reference (in voltage droop control mode).

To perform this test, the generator is first initialised to the initial V_{POC}, P_{POC}, Q_{POC}, SCR and X/R conditions, where Q_{POC} is the target reactive output of the generator for the associated $V_{\text{err}} = V_{\text{ref}_1} - V_{\text{POC}}$ per the droop characteristic.

Once the generator has been initialised, the series of voltage references $V_{ref_2}, V_{ref_3}, \ldots, V_{ref_n}$ are applied to the PPC, as shown in Figure 3.6.

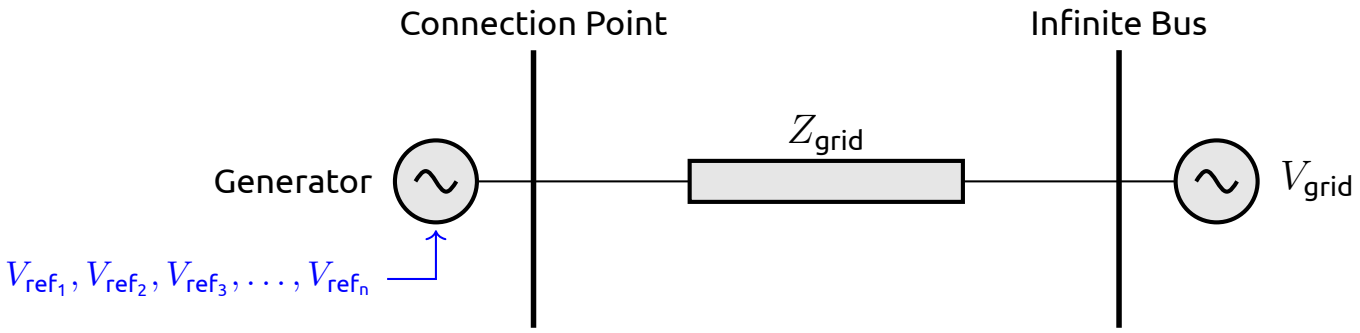

Figure 3.6: Voltage reference change methodology

Direct reactive power control tests and power factor control tests are performed in the same manner as voltage reference step tests, using the appropriate reference required to meet the target change in reactive output at the connection point specified by the DMAT.

The full list of tests assessed for this section can be found in Tables 3.4 to 3.20. As both DMAT sections 3.2.10 (Voltage reference step changes) and 3.2.14 (Grid voltage change), both sections will be discussed here.

Table 3.4: Voltage reference step test suite

Test Num	SCR	X/R	Qpoc [pu]	Ppoc [pu]	Appendix Reference	Results
Test 149 p1	10	14	0	1	PSSE DMAT Appendix D Voltage reference step change tests	Acceptable
Test 149 p2	10	3	0	1	PSSE DMAT Appendix D Voltage reference step change tests	Acceptable
Test 150 p1	10	14	0	0.05	PSSE DMAT Appendix D Voltage reference step change tests	Acceptable
Test 150 p2	10	3	0	0.05	PSSE DMAT Appendix D Voltage reference step change tests	Acceptable
Test 151 p1	3	14	0	1	PSSE DMAT Appendix D Voltage reference step change tests	Acceptable
Test 151 p2	3	3	0	1	PSSE DMAT Appendix D Voltage reference step change tests	Acceptable
Test 152 p1	3	14	0	0.05	PSSE DMAT Appendix D Voltage reference step change tests	Acceptable
Test 152 p2	3	3	0	0.05	PSSE DMAT Appendix D Voltage reference step change tests	Acceptable
Test 153 p1	8.5	4.208	0	1	PSSE DMAT Appendix D Voltage reference step change tests	Acceptable
Test 154 p1	8.5	4.208	0	0.05	PSSE DMAT Appendix D Voltage reference step change tests	Acceptable

All voltage reference tests conducted produced results that were acceptable.

Table 3.5: Connection point voltage step test suite (includes 3.2.14 tests)

Test Num	SCR	X/R	Qpoc [pu]	Ppoc [pu]	Appendix Reference	Results
Test 155 p1	10	14	0	1	PSSE DMAT Appendix I Grid voltage change response tests	Acceptable
Test 155 p2	10	3	0	1	PSSE DMAT Appendix I Grid voltage change response tests	Acceptable
Test 156 p1	10	14	0	0.05	PSSE DMAT Appendix I Grid voltage change response tests	Acceptable
Test 156 p2	10	3	0	0.05	PSSE DMAT Appendix I Grid voltage change response tests	Acceptable
Test 157 p1	3	14	0	1	PSSE DMAT Appendix I Grid voltage change response tests	Acceptable
Test 157 p2	3	3	0	1	PSSE DMAT Appendix I Grid voltage change response tests	Acceptable
Test 158 p1	3	14	0	0.05	PSSE DMAT Appendix I Grid voltage change response tests	Acceptable
Test 158 p2	3	3	0	0.05	PSSE DMAT Appendix I Grid voltage change response tests	Acceptable
Test 159 p1	8.5	4.208	0	1	PSSE DMAT Appendix I Grid voltage change response tests	Acceptable
Test 160 p1	8.5	4.208	0	0.05	PSSE DMAT Appendix I Grid voltage change response tests	Acceptable
Test 178 p1	10	14	0	1	PSSE DMAT Appendix I Grid voltage change response tests	Acceptable
Test 178 p2	10	3	0	1	PSSE DMAT Appendix I Grid voltage change response tests	Acceptable
Test 179 p1	3	14	0	1	PSSE DMAT Appendix I Grid voltage change response tests	Acceptable
Test 179 p2	3	3	0	1	PSSE DMAT Appendix I Grid voltage change response tests	Acceptable
Test 180	8.5	4.208	0	1	PSSE DMAT Appendix I Grid voltage change response tests	Acceptable
Test 181	8.5	4.208	0	0.5	PSSE DMAT Appendix I Grid voltage change response tests	Acceptable
Test 182 p1	10	14	0	1	PSSE DMAT Appendix I Grid voltage change response tests	Acceptable
Test 182 p2	10	3	0	1	PSSE DMAT Appendix I Grid voltage change response tests	Acceptable
Test 183 p1	3	14	0	1	PSSE DMAT Appendix I Grid voltage change response tests	See Discussion
Test 183 p2	3	3	0	1	PSSE DMAT Appendix I Grid voltage change response tests	See Discussion

Test Num	SCR	X/R	Qpoc [pu]	Ppoc [pu]	Appendix Reference	Results
Test 184	8.5	4.208	0	1	PSSE DMAT Appendix I Grid voltage change response tests	See Discussion
Test 185	8.5	4.208	0	0.5	PSSE DMAT Appendix I Grid voltage change response tests	See Discussion
Test 186 p1	10	14	0	1	PSSE DMAT Appendix I Grid voltage change response tests	Acceptable
Test 186 p2	10	3	0	1	PSSE DMAT Appendix I Grid voltage change response tests	Acceptable
Test 186 p3	10	14	0	1	PSSE DMAT Appendix I Grid voltage change response tests	Acceptable
Test 186 p4	10	3	0	1	PSSE DMAT Appendix I Grid voltage change response tests	Acceptable
Test 186 p5	10	14	0	1	PSSE DMAT Appendix I Grid voltage change response tests	Acceptable
Test 186 p6	10	3	0	1	PSSE DMAT Appendix I Grid voltage change response tests	Acceptable
Test 187 p1	3	14	0	1	PSSE DMAT Appendix I Grid voltage change response tests	Acceptable
Test 187 p2	3	3	0	1	PSSE DMAT Appendix I Grid voltage change response tests	Acceptable
Test 187 p3	3	14	0	1	PSSE DMAT Appendix I Grid voltage change response tests	Acceptable
Test 187 p4	3	3	0	1	PSSE DMAT Appendix I Grid voltage change response tests	Acceptable
Test 187 p5	3	14	0	1	PSSE DMAT Appendix I Grid voltage change response tests	See Discussion
Test 187 p6	3	3	0	1	PSSE DMAT Appendix I Grid voltage change response tests	See Discussion
Test 188 p1	8.5	4.208	0	1	PSSE DMAT Appendix I Grid voltage change response tests	Acceptable
Test 188 p2	8.5	4.208	0	1	PSSE DMAT Appendix I Grid voltage change response tests	Acceptable
Test 188 p3	8.5	4.208	0	1	PSSE DMAT Appendix I Grid voltage change response tests	Acceptable
Test 189 p1	8.5	4.208	0	0.5	PSSE DMAT Appendix I Grid voltage change response tests	Acceptable
Test 189 p2	8.5	4.208	0	0.5	PSSE DMAT Appendix I Grid voltage change response tests	Acceptable
Test 189 p3	8.5	4.208	0	0.5	PSSE DMAT Appendix I Grid voltage change response tests	Acceptable

Tests 183p1, 183p2, 184, 185 and 187p5 were found to exhibit the behaviour discussed in section 3.0.1.

For a single test 187p6 the generating system is observed to trip off on frequency protection. This was found to be to be a numerical issue with PSS/E whereby an extreme frequency disturbance (greater than 80 Hz) is observed on at approximately. As a result the inverters frequency protection operates accordingly.

Table 3.6: Reactive power reference step test suite

Test Num	SCR	X/R	Qpoc [pu]	Ppoc [pu]	Appendix Reference	Results
Test 161 p1	10	14	0	1	PSSE DMAT Appendix E Reactive power reference step change tests	Acceptable
Test 161 p2	10	3	0	1	PSSE DMAT Appendix E Reactive power reference step change tests	Acceptable
Test 162 p1	10	14	0	0.05	PSSE DMAT Appendix E Reactive power reference step change tests	Acceptable
Test 162 p2	10	3	0	0.05	PSSE DMAT Appendix E Reactive power reference step change tests	Acceptable
Test 163 p1	3	14	0	1	PSSE DMAT Appendix E Reactive power reference step change tests	Acceptable
Test 163 p2	3	3	0	1	PSSE DMAT Appendix E Reactive power reference step change tests	Acceptable
Test 164 p1	3	14	0	0.05	PSSE DMAT Appendix E Reactive power reference step change tests	Acceptable
Test 164 p2	3	3	0	0.05	PSSE DMAT Appendix E Reactive power reference step change tests	Acceptable
Test 165 p1	8.5	4.20848	0	1	PSSE DMAT Appendix E Reactive power reference step change tests	Acceptable
Test 166 p1	8.5	4.20848	0	0.05	PSSE DMAT Appendix E Reactive power reference step change tests	Acceptable

All reactive power reference tests conducted produced results that were acceptable.

Table 3.7: Power factor reference step test suite

Test Num	SCR	X/R	Qpoc [pu]	Ppoc [pu]	Appendix Reference	Results
Test 161 p1	10	14	0	1	PSSE DMAT Appendix F Power factor reference step change tests	Acceptable
Test 161 p2	10	3	0	1	PSSE DMAT Appendix F Power factor reference step change tests	Acceptable
Test 162 p1	10	14	0	0.05	PSSE DMAT Appendix F Power factor reference step change tests	Acceptable
Test 162 p2	10	3	0	0.05	PSSE DMAT Appendix F Power factor reference step change tests	Acceptable
Test 163 p1	3	14	0	1	PSSE DMAT Appendix F Power factor reference step change tests	Acceptable
Test 163 p2	3	3	0	1	PSSE DMAT Appendix F Power factor reference step change tests	Acceptable
Test 164 p1	3	14	0	0.05	PSSE DMAT Appendix F Power factor reference step change tests	Acceptable
Test 164 p2	3	3	0	0.05	PSSE DMAT Appendix F Power factor reference step change tests	Acceptable
Test 165 p1	8.5	4.20848	0	1	PSSE DMAT Appendix F Power factor reference step change tests	Acceptable
Test 166 p2	8.5	4.20848	0	0.05	PSSE DMAT Appendix F Power factor reference step change tests	Acceptable

All power factor reference tests conducted produced results that were acceptable.

Results for DMAT 3.2.10 can be found in Appendix D: Voltage reference step change tests, Appendix I: Grid voltage change response tests, Appendix F: Power factor reference step change tests, and Appendix E: Reactive power reference step change tests. It should be noted that, for

power factor reference step tests, the equivalent reactive power reference to the power factor reference applied to the Power Plant Manager (PPM) is shown in plots to clearly show the tracking behaviour. This does not mean that the controller was in VAr control mode for these tests.

3.5 Active power reference changes - DMAT 3.2.11

Active power reference step tests assess the ability of the generator to provide a damped active (and reactive) power response to a change in the active power target applied to the PPC.

To perform this test, the generator is first initialised to the initial V_{POC}, P_{POC}, Q_{POC}, SCR and X/R conditions, where $P_{\text{POC}} = P_{\text{ref}_1}$. Once the generator has been initialised, the series of active power references $P_{\text{ref}_2}, P_{\text{ref}_3} \ldots, P_{\text{ref}_n}$ are applied to the PPC, as shown in Figure 3.7.

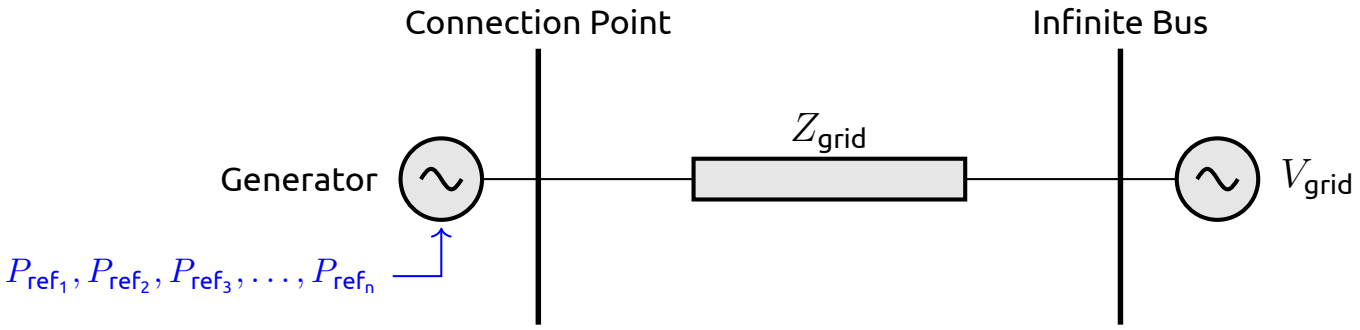

Figure 3.7: Active power reference change methodology

The full list of tests assessed for this section can be found in Table 3.8.

Table 3.8: Active power reference step test suite

Test Num	SCR	X/R	Qpoc [pu]	Ppoc [pu]	PwrAtRateMax [MW/min]	Appendix Reference	Results
Test 167 p1	10	14	0	1	60000	PSSE DMAT Appendix G Active power reference change tests	Acceptable
Test 168 p1	3	14	0	1	60000	PSSE DMAT Appendix G Active power reference change tests	Acceptable
Test 169 p1	8.5	4.208	0	1	60000	PSSE DMAT Appendix G Active power reference change tests	Acceptable
Test 167 p2	10	14	0	1	999999	PSSE DMAT Appendix G Active power reference change tests	Acceptable
Test 168 p2	3	14	0	1	999999	PSSE DMAT Appendix G Active power reference change tests	Acceptable
Test 169 p2	8.5	4.208	0	1	999999	PSSE DMAT Appendix G Active power reference change tests	Acceptable

Results for DMAT 3.2.11 can be found in Appendix G: Active power reference change tests.

All tests conducted produced results that were acceptable.

3.6 Grid frequency controller test - DMAT 3.2.12

Grid frequency ramp tests assess the ability of the generator to ride-through and provide stable response to a changing Connection Point frequency. Where an active power droop is implemented, these tests will also show the response of this controller.

To implement these tests, F_{grid} is driven with a time-series signal $F_{\text{grid}_1}, F_{\text{grid}_2}, F_{\text{grid}_3}, \ldots, F_{\text{grid}_n}$, as shown in Figure 3.8.

The full list of tests assessed for this section can be found in Table 3.9.

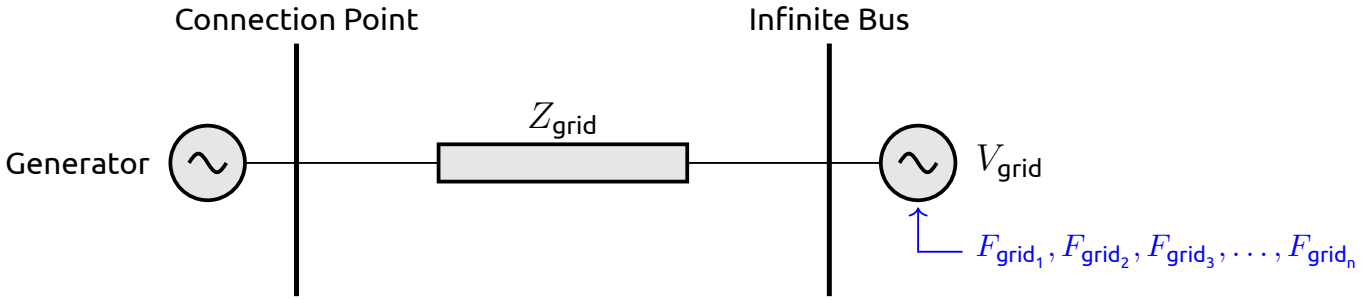

Figure 3.8: Grid frequency disturbance methodology

Table 3.9: Grid frequency controller test suite

Test Num	SCR	X/R	Qpoc [pu]	Ppoc [pu]	Appendix Reference	Results
Test 170 p1	8.5	4.208	0	1	PSSE DMAT Appendix H Grid frequency controller tests	Acceptable
Test 170 p2	8.5	4.208	0	1	PSSE DMAT Appendix H Grid frequency controller tests	Acceptable
Test 170 p3	8.5	4.208	0	1	PSSE DMAT Appendix H Grid frequency controller tests	Acceptable
Test 170 p4	8.5	4.208	0	1	PSSE DMAT Appendix H Grid frequency controller tests	Acceptable
Test 171 p1	8.5	4.208	0	0.5	PSSE DMAT Appendix H Grid frequency controller tests	Acceptable
Test 171 p3	8.5	4.208	0	0.5	PSSE DMAT Appendix H Grid frequency controller tests	Acceptable
Test 171 p4	8.5	4.208	0	0.5	PSSE DMAT Appendix H Grid frequency controller tests	Acceptable
Test 172 p2	8.5	4.208	0	0.5	PSSE DMAT Appendix H Grid frequency controller tests	Acceptable
Test 173 p1	8.5	4.208	0	0.05	PSSE DMAT Appendix H Grid frequency controller tests	Acceptable
Test 173 p2	8.5	4.208	0	0.05	PSSE DMAT Appendix H Grid frequency controller tests	Acceptable
Test 173 p3	8.5	4.208	0	0.05	PSSE DMAT Appendix H Grid frequency controller tests	Acceptable
Test 173 p4	8.5	4.208	0	0.05	PSSE DMAT Appendix H Grid frequency controller tests	Acceptable
Test 174 p1	8.5	4.208	0	1	PSSE DMAT Appendix H Grid frequency controller tests	Acceptable
Test 174 p2	8.5	4.208	0	1	PSSE DMAT Appendix H Grid frequency controller tests	Acceptable
Test 175 p1	8.5	4.208	0	0.5	PSSE DMAT Appendix H Grid frequency controller tests	Acceptable
Test 176 p2	8.5	4.208	0	0.5	PSSE DMAT Appendix H Grid frequency controller tests	Acceptable
Test 177 p1	8.5	4.208	0	0.05	PSSE DMAT Appendix H Grid frequency controller tests	Acceptable
Test 177 p2	8.5	4.208	0	0.05	PSSE DMAT Appendix H Grid frequency controller tests	Acceptable

Results for DMAT 3.2.12 can be found in Appendix H: Grid frequency controller tests.

All tests conducted produced results that were acceptable.

3.7 Grid voltage change response tests - DMAT 3.2.14

This test suite is addressed in Section 3.4 (Voltage reference step tests - DMAT 3.2.10) which also contains tests where the connection point voltage is manipulated.

3.8 Grid voltage angle change response tests - DMAT 3.2.16

Angle changes are applied by manipulating a dummy (no impedance) transformer at the connection point to cause an angle change of the desired magnitude, as shown in Figure 3.9.

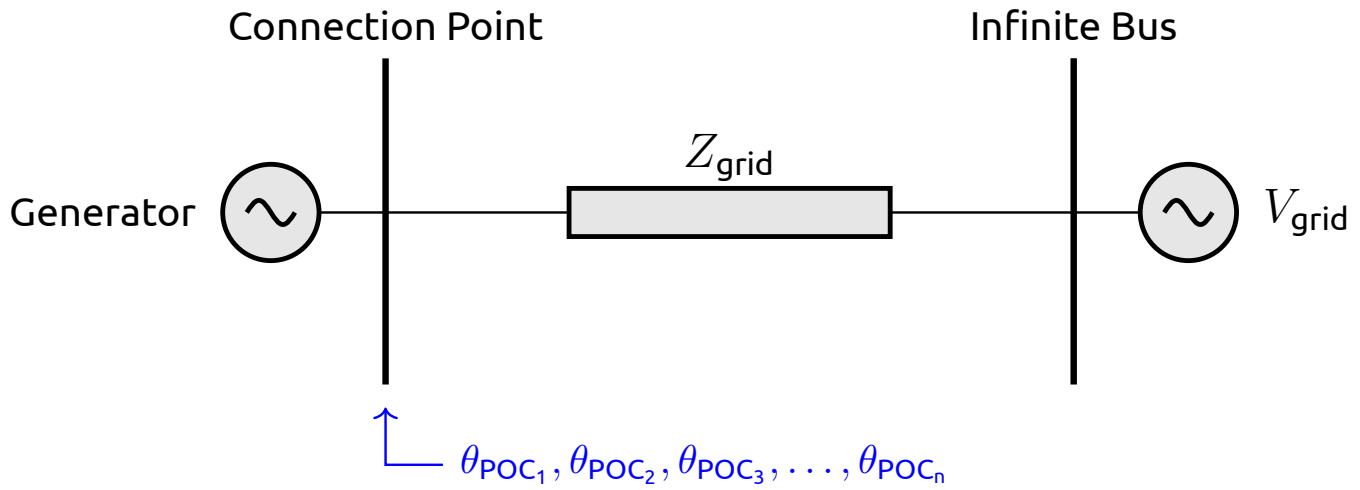

Figure 3.9: Angle change application methodology

The full list of tests assessed for this section can be found in Table 3.10.

Table 3.10: Phase angle change test suite

Test Num	SCR	X/R	Qpoc [pu]	Ppoc [pu]	Appendix Reference	Results
Test 193 p1	10	14	0	1	PSSE DMAT Appendix J Grid voltage angle change response tests	Acceptable
Test 193 p2	10	3	0	1	PSSE DMAT Appendix J Grid voltage angle change response tests	Acceptable
Test 194 p1	10	14	0	0.05	PSSE DMAT Appendix J Grid voltage angle change response tests	Acceptable
Test 194 p2	10	3	0	0.05	PSSE DMAT Appendix J Grid voltage angle change response tests	Acceptable
Test 195 p1	3	14	0	1	PSSE DMAT Appendix J Grid voltage angle change response tests	Acceptable
Test 195 p2	3	3	0	1	PSSE DMAT Appendix J Grid voltage angle change response tests	Acceptable
Test 196 p1	3	4.208	0	0.05	PSSE DMAT Appendix J Grid voltage angle change response tests	Acceptable
Test 196 p2	3	4.208	0	0.05	PSSE DMAT Appendix J Grid voltage angle change response tests	Acceptable
Test 197	8.5	4.208	0	1	PSSE DMAT Appendix J Grid voltage angle change response tests	Acceptable
Test 198	8.5	4.208	0	0.05	PSSE DMAT Appendix J Grid voltage angle change response tests	Acceptable

Results for DMAT 3.2.16 can be found in Appendix J: Grid voltage angle change response tests.

All tests conducted produced results that were acceptable.

3.9 Active power reference change tests (POC SCR=1) - DMAT 3.2.17

SCR=1 active power reference step tests are performed using the same methodology as described in Section 3.5, except with a SCR of 1.0. For this reason, simulation results for these tests are presented for information only and are not expected to initialise correctly or remain stable.

The full list of tests assessed for this section can be found in Table 3.11.

Table 3.11: Active power reference step test (with SCR of 1.0) suite

Test Num	SCR	X/R	Vpoc [pu]	Qpoc [pu]	Vref [pu]	Appendix Reference	Results
Test 199 p1	1	14	1.0227	0	1.0227	PSSE DMAT Appendix K Active power reference change tests (POC SCR=1)	Acceptable
Test 199 p2	1	14	1.0227	0	1.0227	PSSE DMAT Appendix K Active power reference change tests (POC SCR=1)	Acceptable

As a result of the low SCR conditions for these tests, the model was not able to be initialised to the operating conditions defined in Table 3.11. For this reason appendices have been excluded for this section.

3.10 FRT tests at SCR=1 - DMAT 3.2.18

SCR=1 faults are studied using the same methodology as described in Sections 3.1, except that the SCR is changed mid-disturbance from the maximum fault level expected for the project (and associated X/R) to a SCR of 1.0 (and a specified X/R ratio). For this reason, simulation results for these tests are presented for information only and are not expected to initialise correctly or remain stable.

The full list of tests assessed for this section can be found in Table 3.12.

Table 3.12: SCR=1 fault suite

Test Num	SCR	X/R	Vpoc [pu]	Qpoc [pu]	Vref [pu]	Ppoc [pu]	Type	Duration [s]	Impedance	Appendix Reference	Results
Test 200 p1	3	14	1.0227	0	1.0227	1	3PHG	0.43	Zf = 4 Zs	PSSE DMAT Appendix M FRT tests at SCR 1	Acceptable
Test 200 p2	3	3	1.0227	0	1.0227	1	3PHG	0.43	Zf = 4 Zs	PSSE DMAT Appendix M FRT tests at SCR 1	Acceptable
Test 201 p1	3	14	1.0227	0	1.0227	0.5	3PHG	0.43	Zf = 4 Zs	PSSE DMAT Appendix M FRT tests at SCR 1	Acceptable
Test 201 p2	3	3	1.0227	0	1.0227	0.5	3PHG	0.43	Zf = 4 Zs	PSSE DMAT Appendix M FRT tests at SCR 1	Acceptable
Test 202 p1	3	14	1.0227	0	1.0227	0.05	3PHG	0.43	Zf = 4 Zs	PSSE DMAT Appendix M FRT tests at SCR 1	Acceptable
Test 202 p2	3	3	1.0227	0	1.0227	0.05	3PHG	0.43	Zf = 4 Zs	PSSE DMAT Appendix M FRT tests at SCR 1	Acceptable
Test 203 p1	3	14	1.0227	0	1.0227	1	3PHG	0.43	Zf = 0 Zs	PSSE DMAT Appendix M FRT tests at SCR 1	Acceptable
Test 203 p2	3	3	1.0227	0	1.0227	1	3PHG	0.43	Zf = 0 Zs	PSSE DMAT Appendix M FRT tests at SCR 1	Acceptable
Test 204 p1	3	14	1.0227	0	1.0227	0.5	3PHG	0.43	Zf = 0 Zs	PSSE DMAT Appendix M FRT tests at SCR 1	Acceptable
Test 204 p2	3	3	1.0227	0	1.0227	0.5	3PHG	0.43	Zf = 0 Zs	PSSE DMAT Appendix M FRT tests at SCR 1	Acceptable
Test 205 p1	3	14	1.0227	0	1.0227	0.05	3PHG	0.43	Zf = 0 Zs	PSSE DMAT Appendix M FRT tests at SCR 1	Acceptable
Test 205 p2	3	3	1.0227	0	1.0227	0.05	3PHG	0.43	Zf = 0 Zs	PSSE DMAT Appendix M FRT tests at SCR 1	Acceptable

For all tests conducted at an SCR of 1 the model was found to be unstable as expected. These results have been included for convenience. Results for DMAT 3.2.18 can be found in Appendix M: FRT tests at SCR=1.

3.11 FRT tests at site specific SCR - DMAT 3.2.19

Site-specific SCR faults are studied using the same methodology as described in Sections 3.1, except that the minimum SCR (and associated X/R) is used for all faults.

The full list of tests assessed for this section can be found in Table 3.13.

Table 3.13: Site-specific SCR fault tests suite

Test Num	SCR (initial)	SCR (final)	X/R (initial)	X/R (final)	Vpoc [pu]	Qpoc [pu]	Vref [pu]	Ppoc [pu]	Type	Duration [s]	Impedance	Appendix Reference	Results
Test 206	17.8	8.5	4.01518	4.01518	1.0227	0	1.0227	1	3PHG	0.43	Zf = 0.0 Zs	PSSE DMAT Appendix L FRT tests at site-specific SCR	Acceptable
Test 207	17.8	8.5	4.01518	4.01518	1.0227	0	1.0227	1	3PHG	0.43	Zf = 0.11 Zs	PSSE DMAT Appendix L FRT tests at site-specific SCR	Acceptable
Test 208	17.8	8.5	4.01518	4.01518	1.0227	0	1.0227	1	3PHG	0.43	Zf = 0.25 Zs	PSSE DMAT Appendix L FRT tests at site-specific SCR	Acceptable
Test 209	17.8	8.5	4.01518	4.01518	1.0227	0	1.0227	1	3PHG	0.43	Zf = 0.42 Zs	PSSE DMAT Appendix L FRT tests at site-specific SCR	Acceptable
Test 210	17.8	8.5	4.01518	4.01518	1.0227	0	1.0227	1	3PHG	0.43	Zf = 0.66 Zs	PSSE DMAT Appendix L FRT tests at site-specific SCR	Acceptable
Test 211	17.8	8.5	4.01518	4.01518	1.0227	0	1.0227	1	3PHG	0.43	Zf = 1.0 Zs	PSSE DMAT Appendix L FRT tests at site-specific SCR	Acceptable
Test 212	17.8	8.5	4.01518	4.01518	1.0227	0	1.0227	1	3PHG	0.43	Zf = 1.5 Zs	PSSE DMAT Appendix L FRT tests at site-specific SCR	Acceptable
Test 213	17.8	8.5	4.01518	4.01518	1.0227	0	1.0227	1	3PHG	0.43	Zf = 2.3 Zs	PSSE DMAT Appendix L FRT tests at site-specific SCR	Acceptable
Test 214	17.8	8.5	4.01518	4.01518	1.0227	0	1.0227	1	3PHG	0.43	Zf = 4.0 Zs	PSSE DMAT Appendix L FRT tests at site-specific SCR	Acceptable
Test 215	17.8	8.5	4.01518	4.01518	1.0227	0	1.0227	1	3PHG	0.43	Zf = 9.0 Zs	PSSE DMAT Appendix L FRT tests at site-specific SCR	Acceptable
Test 216	17.8	8.5	4.01518	4.01518	1.0227	0	1.0227	0.5	3PHG	0.43	Zf = 0.0 Zs	PSSE DMAT Appendix L FRT tests at site-specific SCR	Acceptable
Test 217	17.8	8.5	4.01518	4.01518	1.0227	0	1.0227	0.5	3PHG	0.43	Zf = 0.11 Zs	PSSE DMAT Appendix L FRT tests at site-specific SCR	Acceptable
Test 218	17.8	8.5	4.01518	4.01518	1.0227	0	1.0227	0.5	3PHG	0.43	Zf = 0.25 Zs	PSSE DMAT Appendix L FRT tests at site-specific SCR	Acceptable
Test 219	17.8	8.5	4.01518	4.01518	1.0227	0	1.0227	0.5	3PHG	0.43	Zf = 0.42 Zs	PSSE DMAT Appendix L FRT tests at site-specific SCR	Acceptable
Test 220	17.8	8.5	4.01518	4.01518	1.0227	0	1.0227	0.5	3PHG	0.43	Zf = 0.66 Zs	PSSE DMAT Appendix L FRT tests at site-specific SCR	Acceptable
Test 221	17.8	8.5	4.01518	4.01518	1.0227	0	1.0227	0.5	3PHG	0.43	Zf = 1.0 Zs	PSSE DMAT Appendix L FRT tests at site-specific SCR	Acceptable
Test 222	17.8	8.5	4.01518	4.01518	1.0227	0	1.0227	0.5	3PHG	0.43	Zf = 1.5 Zs	PSSE DMAT Appendix L FRT tests at site-specific SCR	Acceptable
Test 223	17.8	8.5	4.01518	4.01518	1.0227	0	1.0227	0.5	3PHG	0.43	Zf = 2.3 Zs	PSSE DMAT Appendix L FRT tests at site-specific SCR	Acceptable
Test 224	17.8	8.5	4.01518	4.01518	1.0227	0	1.0227	0.5	3PHG	0.43	Zf = 4.0 Zs	PSSE DMAT Appendix L FRT tests at site-specific SCR	Acceptable
Test 225	17.8	8.5	4.01518	4.01518	1.0227	0	1.0227	0.5	3PHG	0.43	Zf = 9.0 Zs	PSSE DMAT Appendix L FRT tests at site-specific SCR	Acceptable

Results for DMAT 3.2.19 can be found in Appendix L: FRT tests at site-specific SCR.

3.12 Additional tests for South Australian Connections

Given that CGBESS is in South Australia, an additional suite of tests are conducted. These tests are studied using the same methodologies included in the above sections of this report. These tests

are the same as those outlined above, except for the SCR and X/R values which are set to 1.5 and 2 respectively at the equipment terminal. This corresponds to SCR = 1.88 and X/R = 1.6 at the POC.

The full list of tests assessed for this section can be found in the below tables.

Table 3.14: SA Balanced faults test suite

Test Num	SCR	X/R	Vpoc [pu]	Qpoc [pu]	Vref [pu]	Ppoc [pu]	Type	Duration [s]	Impedance	Appendix Reference	Results
Test 4	1.88	1.6	1.0227	0	1.0227	1	3PHG	0.43	0.03 pu	SA PSSE DMAT Appendix A Balanced fault tests	Acceptable
Test 5	1.88	1.6	1.0227	-0.3	1.0167	1	3PHG	0.43	0.03 pu	SA PSSE DMAT Appendix A Balanced fault tests	See Discussion
Test 6	1.88	1.6	1.0227	0.3	1.0287	1	3PHG	0.43	0.03 pu	SA PSSE DMAT Appendix A Balanced fault tests	Acceptable
Test 10	1.88	1.6	1.0227	0	1.0227	0.05	3PHG	0.43	0.03 pu	SA PSSE DMAT Appendix A Balanced fault tests	Acceptable
Test 11	1.88	1.6	1.0227	-0.3	1.0167	0.05	3PHG	0.43	0.03 pu	SA PSSE DMAT Appendix A Balanced fault tests	Acceptable
Test 12	1.88	1.6	1.0227	0.3	1.0287	0.05	3PHG	0.43	0.03 pu	SA PSSE DMAT Appendix A Balanced fault tests	Acceptable
Test 16	1.88	1.6	1.0227	0	1.0227	1	3PHG	0.43	Zf = 1 Zs	SA PSSE DMAT Appendix A Balanced fault tests	Acceptable
Test 17	1.88	1.6	1.0227	-0.3	1.0167	1	3PHG	0.43	Zf = 1 Zs	SA PSSE DMAT Appendix A Balanced fault tests	See Discussion
Test 18	1.88	1.6	1.0227	0.3	1.0287	1	3PHG	0.43	Zf = 1 Zs	SA PSSE DMAT Appendix A Balanced fault tests	Acceptable
Test 22	1.88	1.6	1.0227	0	1.0227	0.05	3PHG	0.43	Zf = 1 Zs	SA PSSE DMAT Appendix A Balanced fault tests	Acceptable
Test 23	1.88	1.6	1.0227	-0.3	1.0167	0.05	3PHG	0.43	Zf = 1 Zs	SA PSSE DMAT Appendix A Balanced fault tests	Acceptable
Test 24	1.88	1.6	1.0227	0.3	1.0287	0.05	3PHG	0.43	Zf = 1 Zs	SA PSSE DMAT Appendix A Balanced fault tests	Acceptable
Test 28	1.88	1.6	1.0227	0	1.0227	1	3PHG	0.5	Zf = 2 Zs	SA PSSE DMAT Appendix A Balanced fault tests	Acceptable
Test 29	1.88	1.6	1.0227	-0.3	1.0167	1	3PHG	0.5	Zf = 2 Zs	SA PSSE DMAT Appendix A Balanced fault tests	See Discussion
Test 30	1.88	1.6	1.0227	0.3	1.0287	1	3PHG	0.5	Zf = 2 Zs	SA PSSE DMAT Appendix A Balanced fault tests	Acceptable
Test 34	1.88	1.6	1.0227	0	1.0227	0.05	3PHG	0.5	Zf = 2 Zs	SA PSSE DMAT Appendix A Balanced fault tests	Acceptable
Test 35	1.88	1.6	1.0227	-0.3	1.0167	0.05	3PHG	0.5	Zf = 2 Zs	SA PSSE DMAT Appendix A Balanced fault tests	Acceptable
Test 36	1.88	1.6	1.0227	0.3	1.0287	0.05	3PHG	0.5	Zf = 2 Zs	SA PSSE DMAT Appendix A Balanced fault tests	Acceptable

Balanced faults p11,p23, and p35 were found to exhibit the behaviour discussed in section 3.0.1.

Table 3.15: SA MFRT test suite

Test	Fault Types	Fault Durations	Time Between Faults	Fault Impedance Z_f/Z_s
S1	3PHG, 3PHG, 3PHG, 3PHG, 3PHG, 3PHG, 3PHG, 3PHG, 3PHG, 3PHG, 3PHG, 3PHG, 3PHG, 3PHG, 3PHG, 3PHG, 3PHG, 3PHG	0.43, 0.12, 0.12, 0.12, 0.12, 0.22, 0.12, 0.22, 0.12, 0.22, 0.22, 0.22, 0.22, 0.12, 0.12	5, 0.5, 0.01, 1.5, 0.2, 7, 1, 0.2, 0.75, 2, 0.5, 0.01, 10, 2	2, 1, 2, 0, 3.5, 1, 3.5, 0.2, 1, 1, 0.2, 2, 0, 0.2, 1
S2	3PHG, 3PHG, 3PHG, 3PHG, 3PHG, 3PHG, 3PHG, 3PHG, 3PHG, 3PHG, 3PHG, 3PHG, 3PHG, 3PHG, 3PHG, 3PHG, 3PHG, 3PHG	0.22, 0.22, 0.12, 0.12, 0.22, 0.12, 0.43, 0.22, 0.12, 0.22, 0.12, 0.22, 0.12, 0.12, 0.12	0.2, 10, 2, 0.2, 0.75, 0.5, 1, 0.5, 2, 0.01, 7, 5, 1.5, 3	1, 2, 2, 0.2, 1, 1, 2, 0, 0.2, 1, 1, 0.2, 3.5, 0, 3.5
S3	3PHG, 3PHG, 3PHG, 3PHG, 3PHG, 3PHG, 3PHG, 3PHG, 3PHG, 3PHG, 3PHG, 3PHG, 3PHG, 3PHG, 3PHG, 3PHG, 3PHG, 3PHG	0.12, 0.22, 0.22, 0.12, 0.43, 0.22, 0.12, 0.22, 0.12, 0.12, 0.12, 0.12, 0.12, 0.22, 0.22	0.2, 5, 1.5, 2, 3, 1, 0.5, 0.5, 0.75, 10, 7, 0.2, 0.01, 0.01	1, 0.2, 2, 0, 3.5, 1, 0, 1, 1, 0.2, 0.2, 3.5, 1, 2, 2
S4	3PHG, 3PHG, 3PHG, 3PHG, 3PHG, 3PHG, 3PHG, 3PHG, 3PHG, 3PHG, 3PHG, 3PHG, 3PHG, 3PHG, 3PHG, 3PHG, 3PHG, 3PHG	0.12, 0.22, 0.12, 0.22, 0.12, 0.43, 0.12, 0.12, 0.22, 0.22, 0.22, 0.12, 0.12, 0.22, 0.12	3, 5, 0.2, 2, 10, 1.5, 0.75, 0.01, 0.5, 0.01, 1, 2, 0.2, 0.5	1, 2, 0.2, 2, 2, 1, 1, 3.5, 1, 0.2, 1, 3.5, 0, 0, 0.2

S5	3PHG, 3PHG, 3PHG, 3PHG, 3PHG, 3PHG, 3PHG, 3PHG, 3PHG, 3PHG, 3PHG, 3PHG, 3PHG, 3PHG, 3PHG	0.12, 0.12, 0.43, 0.22, 0.22, 0.12, 0.12, 0.12, 0.22, 0.12, 0.22, 0.12, 0.22, 0.22, 0.12	0.2, 7, 1, 0.5, 3, 0.5, 2, 0.75, 0.01, 1.5, 0.01, 5, 0.2, 2	1, 0, 3.5, 0.2, 2, 0.2, 1, 3.5, 1, 2, 2, 1, 0, 0.2, 1

It was observed for test for MFRT test S5 that the generating system trips as a result of frequency protection. This was found to be a numerical issue with PSS/E whereby an extreme frequency disturbance is observed on fault inception (at approximately t=35s) for an extended period of time and the inverter protection then responds as expected. All other tests conducted produced acceptable results.

Table 3.16: SA TOV test suite

Test Num	SCR	X/R	Vpoc [pu]	Qpoc [pu]	Vref [pu]	Ppoc [pu]	Duration [s]	Uov [pu]	Appendix Reference	Results
Test 134	1.88	1.6	1.0227	0	1.0227	1	0.9	1.15	SA PSSE DMAT Appendix C Temporary over-voltage tests	See Discussion
Test 135	1.88	1.6	1.0227	-0.3	1.0167	1	0.9	1.15	SA PSSE DMAT Appendix C Temporary over-voltage tests	See Discussion
Test 136	1.88	1.6	1.0227	0.3	1.0287	1	0.9	1.15	SA PSSE DMAT Appendix C Temporary over-voltage tests	See Discussion
Test 143	1.88	1.6	1.0227	0	1.0227	1	0.1	1.2	SA PSSE DMAT Appendix C Temporary over-voltage tests	See Discussion
Test 144	1.88	1.6	1.0227	-0.3	1.0167	1	0.1	1.2	SA PSSE DMAT Appendix C Temporary over-voltage tests	See Discussion
Test 145	1.88	1.6	1.0227	0.3	1.0287	1	0.1	1.2	SA PSSE DMAT Appendix C Temporary over-voltage tests	See Discussion

All TOV tests were found to exhibit oscillations in active and reactive power at a low system SCR. This is expected as the generating system has not been tuned to operate at this low of an SCR. Appendices have been included for completeness.

Table 3.17: SA Voltage reference step test suite

Test Num	SCR	X/R	Qpoc [pu]	Ppoc [pu]	Appendix Reference	Results
Test 151 p1	1.88	1.6	0	1	SA PSSE DMAT Appendix D Voltage reference step change tests	Acceptable
Test 151 p2	1.88	1.6	0	1	SA PSSE DMAT Appendix D Voltage reference step change tests	Acceptable
Test 152 p1	1.88	1.6	0	0.05	SA PSSE DMAT Appendix D Voltage reference step change tests	Acceptable
Test 152 p2	1.88	1.6	0	0.05	SA PSSE DMAT Appendix D Voltage reference step change tests	Acceptable

All voltage reference step tests were found to produce acceptable results.

Table 3.18: SA Connection point voltage step test suite (includes 3.2.14 tests)

Test Num	SCR	X/R	Qpoc [pu]	Ppoc [pu]	Appendix Reference	Results
Test 157 p1	1.88	1.6	0	1	SA PSSE DMAT Appendix I Grid voltage change response tests	Acceptable
Test 157 p2	1.88	1.6	0	1	SA PSSE DMAT Appendix I Grid voltage change response tests	Acceptable
Test 158 p1	1.88	1.6	0	0.05	SA PSSE DMAT Appendix I Grid voltage change response tests	Acceptable
Test 158 p2	1.88	1.6	0	0.05	SA PSSE DMAT Appendix I Grid voltage change response tests	Acceptable
Test 179 p1	1.88	1.6	0	1	SA PSSE DMAT Appendix I Grid voltage change response tests	Acceptable
Test 179 p2	1.88	1.6	0	1	SA PSSE DMAT Appendix I Grid voltage change response tests	Acceptable
Test 183 p1	1.88	1.6	0	1	SA PSSE DMAT Appendix I Grid voltage change response tests	See Discussion
Test 183 p2	1.88	1.6	0	1	SA PSSE DMAT Appendix I Grid voltage change response tests	See Discussion
Test 187 p1	1.88	1.6	0	1	SA PSSE DMAT Appendix I Grid voltage change response tests	See Discussion
Test 187 p2	1.88	1.6	0	1	SA PSSE DMAT Appendix I Grid voltage change response tests	See Discussion
Test 187 p3	1.88	1.6	0	1	SA PSSE DMAT Appendix I Grid voltage change response tests	See Discussion
Test 187 p4	1.88	1.6	0	1	SA PSSE DMAT Appendix I Grid voltage change response tests	See Discussion
Test 187 p5	1.88	1.6	0	1	SA PSSE DMAT Appendix I Grid voltage change response tests	See Discussion
Test 187 p6	1.88	1.6	0	1	SA PSSE DMAT Appendix I Grid voltage change response tests	See Discussion

Tests 183p1, 183p2, 187p1-187p6 were found to exhibit oscillations in active and reactive power at a low system SCR. This is expected as the generating system has not been tuned to operate at this low of an SCR. Appendices have been included for completeness.

Table 3.19: SA Reactive power reference step test suite

Test Num	SCR	X/R	Qpoc [pu]	Ppoc [pu]	Appendix Reference	Results
Test 163 p1	1.88	1.6	0	1	SA PSSE DMAT Appendix E Reactive power reference step change tests	Acceptable
Test 163 p2	1.88	1.6	0	1	SA PSSE DMAT Appendix E Reactive power reference step change tests	Acceptable
Test 164 p1	1.88	1.6	0	0.05	SA PSSE DMAT Appendix E Reactive power reference step change tests	Acceptable
Test 164 p2	1.88	1.6	0	0.05	SA PSSE DMAT Appendix E Reactive power reference step change tests	Acceptable

All reactive power reference step tests were found to produce acceptable results.

Table 3.20: SA Power factor reference step test suite

Test Num	SCR	X/R	Qpoc [pu]	Ppoc [pu]	Appendix Reference	Results
Test 163 p1	1.88	1.6	0	1	SA PSSE DMAT Appendix F Power factor reference step change tests	Acceptable
Test 163 p2	1.88	1.6	0	1	SA PSSE DMAT Appendix F Power factor reference step change tests	Acceptable
Test 164 p1	1.88	1.6	0	0.05	SA PSSE DMAT Appendix F Power factor reference step change tests	Acceptable
Test 164 p2	1.88	1.6	0	0.05	SA PSSE DMAT Appendix F Power factor reference step change tests	Acceptable

All power factor reference step tests were found to produce acceptable results.

Table 3.21: SA Active power reference step test (with SCR of 1.0) suite

Test Num	SCR	X/R	Qpoc [pu]	Ppoc [pu]	Appendix Reference	Results
Test 168 p1	1.88	1.6	0	1	SA PSSE DMAT Appendix G Active power reference change tests	Acceptable
Test 168 p2	1.88	1.6	0	1	SA PSSE DMAT Appendix G Active power reference change tests	Acceptable

All active power reference step tests were found to produce acceptable results.

Table 3.22: SA Grid frequency controller test suite

Test Num	SCR	X/R	Qpoc [pu]	Ppoc [pu]	Appendix Reference	Results
Test 170 p1	1.88	1.6	0	1	SA PSSE DMAT Appendix H Grid frequency controller tests	Acceptable
Test 170 p2	1.88	1.6	0	1	SA PSSE DMAT Appendix H Grid frequency controller tests	Acceptable
Test 170 p3	1.88	1.6	0	1	SA PSSE DMAT Appendix H Grid frequency controller tests	Acceptable
Test 170 p4	1.88	1.6	0	1	SA PSSE DMAT Appendix H Grid frequency controller tests	Acceptable
Test 171 p1	1.88	1.6	0	0.5	SA PSSE DMAT Appendix H Grid frequency controller tests	Acceptable
Test 171 p3	1.88	1.6	0	0.5	SA PSSE DMAT Appendix H Grid frequency controller tests	Acceptable
Test 171 p4	1.88	1.6	0	0.5	SA PSSE DMAT Appendix H Grid frequency controller tests	Acceptable
Test 172 p2	1.88	1.6	0	0.5	SA PSSE DMAT Appendix H Grid frequency controller tests	Acceptable
Test 173 p1	1.88	1.6	0	0.05	SA PSSE DMAT Appendix H Grid frequency controller tests	Acceptable
Test 173 p2	1.88	1.6	0	0.05	SA PSSE DMAT Appendix H Grid frequency controller tests	Acceptable
Test 173 p3	1.88	1.6	0	0.05	SA PSSE DMAT Appendix H Grid frequency controller tests	Acceptable
Test 173 p4	1.88	1.6	0	0.05	SA PSSE DMAT Appendix H Grid frequency controller tests	Acceptable
Test 174 p1	1.88	1.6	0	1	SA PSSE DMAT Appendix H Grid frequency controller tests	Acceptable
Test 174 p2	1.88	1.6	0	1	SA PSSE DMAT Appendix H Grid frequency controller tests	Acceptable
Test 175 p1	1.88	1.6	0	0.5	SA PSSE DMAT Appendix H Grid frequency controller tests	Acceptable
Test 176 p2	1.88	1.6	0	0.5	SA PSSE DMAT Appendix H Grid frequency controller tests	Acceptable
Test 177 p1	1.88	1.6	0	0.05	SA PSSE DMAT Appendix H Grid frequency controller tests	Acceptable
Test 177 p2	1.88	1.6	0	0.05	SA PSSE DMAT Appendix H Grid frequency controller tests	Acceptable

All grid frequency disturbance step tests were found to produce acceptable results.

Table 3.23: SA Phase angle change test suite

Test Num	SCR	X/R	Qpoc [pu]	Ppoc [pu]	Appendix Reference	Results
Test 195 p1	1.88	1.6	0	1	SA PSSE DMAT Appendix J Grid voltage angle change response tests	Acceptable
Test 195 p2	1.88	1.6	0	1	SA PSSE DMAT Appendix J Grid voltage angle change response tests	Acceptable
Test 196 p1	1.88	1.6	0	0.05	SA PSSE DMAT Appendix J Grid voltage angle change response tests	Acceptable
Test 196 p2	1.88	1.6	0	0.05	SA PSSE DMAT Appendix J Grid voltage angle change response tests	Acceptable

All phase step disturbance tests were found to produce acceptable results.

Table 3.24: SA Active power reference step test (with SCR of 1.0) suite

Test Num	SCR	X/R	Vpoc [pu]	Qpoc [pu]	Vref [pu]	Appendix Reference	Results
Test 199 p1	1.88	1.6	1.0227	0	1.0227	SA PSSE DMAT Appendix K Active power reference change tests (POC SCR=1)	Acceptable
Test 199 p2	1.88	1.6	1.0227	0	1.0227	SA PSSE DMAT Appendix K Active power reference change tests (POC SCR=1)	Acceptable

Please note that although the DMAT test suite requires a POC SCR of 1 is used for these tests, the N POC SCR is 8.5 for this project. All active power reference steps were found to produce acceptable results.

Table 3.25: SA Site-specific SCR fault tests suite

Test Num	SCR	X/R	Vpoc [pu]	Qpoc [pu]	Vref [pu]	Ppoc [pu]	Type	Duration [s]	Impedance	Appendix Reference	Results
Test 206 p2	1.88	1.6	1.0227	0	1.0227	1	3PHG	0.43	0.03 pu	SA PSSE DMAT Appendix N FRT Tests At Site-Specific SCR	Acceptable
Test 207 p2	1.88	1.6	1.0227	0	1.0227	1	3PHG	0.43	Zf = 0.11 Zs	SA PSSE DMAT Appendix N FRT Tests At Site-Specific SCR	Acceptable
Test 208 p2	1.88	1.6	1.0227	0	1.0227	1	3PHG	0.43	Zf = 0.25 Zs	SA PSSE DMAT Appendix N FRT Tests At Site-Specific SCR	Acceptable
Test 209 p2	1.88	1.6	1.0227	0	1.0227	1	3PHG	0.43	Zf = 0.42 Zs	SA PSSE DMAT Appendix N FRT Tests At Site-Specific SCR	Acceptable
Test 210 p2	1.88	1.6	1.0227	0	1.0227	1	3PHG	0.43	Zf = 0.66 Zs	SA PSSE DMAT Appendix N FRT Tests At Site-Specific SCR	Acceptable
Test 211 p2	1.88	1.6	1.0227	0	1.0227	1	3PHG	0.43	Zf = 1.0 Zs	SA PSSE DMAT Appendix N FRT Tests At Site-Specific SCR	Acceptable
Test 212 p2	1.88	1.6	1.0227	0	1.0227	1	3PHG	0.43	Zf = 1.5 Zs	SA PSSE DMAT Appendix N FRT Tests At Site-Specific SCR	Acceptable
Test 213 p2	1.88	1.6	1.0227	0	1.0227	1	3PHG	0.43	Zf = 2.3 Zs	SA PSSE DMAT Appendix N FRT Tests At Site-Specific SCR	Acceptable
Test 214 p2	1.88	1.6	1.0227	0	1.0227	1	3PHG	0.43	Zf = 4.0 Zs	SA PSSE DMAT Appendix N FRT Tests At Site-Specific SCR	Acceptable
Test 215 p2	1.88	1.6	1.0227	0	1.0227	1	3PHG	0.43	Zf = 9.0 Zs	SA PSSE DMAT Appendix N FRT Tests At Site-Specific SCR	Acceptable
Test 216 p2	1.88	1.6	1.0227	0	1.0227	0.5	3PHG	0.43	0.03 pu	SA PSSE DMAT Appendix N FRT Tests At Site-Specific SCR	Acceptable
Test 217 p2	1.88	1.6	1.0227	0	1.0227	0.5	3PHG	0.43	Zf = 0.11 Zs	SA PSSE DMAT Appendix N FRT Tests At Site-Specific SCR	Acceptable
Test 218 p2	1.88	1.6	1.0227	0	1.0227	0.5	3PHG	0.43	Zf = 0.25 Zs	SA PSSE DMAT Appendix N FRT Tests At Site-Specific SCR	Acceptable
Test 219 p2	1.88	1.6	1.0227	0	1.0227	0.5	3PHG	0.43	Zf = 0.42 Zs	SA PSSE DMAT Appendix N FRT Tests At Site-Specific SCR	Acceptable
Test 220 p2	1.88	1.6	1.0227	0	1.0227	0.5	3PHG	0.43	Zf = 0.66 Zs	SA PSSE DMAT Appendix N FRT Tests At Site-Specific SCR	Acceptable
Test 221 p2	1.88	1.6	1.0227	0	1.0227	0.5	3PHG	0.43	Zf = 1.0 Zs	SA PSSE DMAT Appendix N FRT Tests At Site-Specific SCR	Acceptable
Test 222 p2	1.88	1.6	1.0227	0	1.0227	0.5	3PHG	0.43	Zf = 1.5 Zs	SA PSSE DMAT Appendix N FRT Tests At Site-Specific SCR	Acceptable
Test 223 p2	1.88	1.6	1.0227	0	1.0227	0.5	3PHG	0.43	Zf = 2.3 Zs	SA PSSE DMAT Appendix N FRT Tests At Site-Specific SCR	Acceptable
Test 224 p2	1.88	1.6	1.0227	0	1.0227	0.5	3PHG	0.43	Zf = 4.0 Zs	SA PSSE DMAT Appendix N FRT Tests At Site-Specific SCR	Acceptable
Test 225 p2	1.88	1.6	1.0227	0	1.0227	0.5	3PHG	0.43	Zf = 9.0 Zs	SA PSSE DMAT Appendix N FRT Tests At Site-Specific SCR	Acceptable

All tests were found to produce acceptable results.

Acronyms

CGBESS Clements Gap BESS 1

DMAT Dynamic Model Acceptance Test 1

EMT Electromagnetic Transients 1

PPM Power Plant Manager 10

RMS Root Mean Square 1

SCR Short Circuit Ratio 3

TOV Temporary Over-Voltage 6

References

[1] Dynamic Model Acceptance Test Guideline - Version 3: June 2024

[2] Clements Gap BESS - Spike mitigation and PLL issue at low SCR (CGBESS-GR-TN-001.pdf)

4. Appendices