Arnold Schwarzenegger
Governor

CERTS MICROGRID LABORATORY TEST BED

Summary of CERTS Microgrid Static Switch Power Quality Tests at AEP Dolan, CERTS Microgrid Static Switch Testing

APPENDIX G

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CERTS
CONSORTIUM FOR ELECTRIC RELIABILITY TECHNOLOGY SOLUTIONS

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AEP DTC Proposed Test Plan – CERTS Micro-grid Static Switch

Project Engineer: David A. Klapp

Date: March 3, 2006

Background

The Static Switch (SS) will be the power gateway between the protected and unprotected portions of the Microgrid Test Bed. This gateway is required to incorporate many different functions in order that the Microgrid will seamlessly transition from grid connection to grid disconnection for certain reasons. These reasons include, but aren't limited to, Power Quality Events and Power Export to the utility grid. This gateway must also handle the seamless reconnection of the Microgrid following any of these events. Originally, it was discussed that the SS would meet IEEE Standard 1547 for interconnecting DR with electric power systems. Since these tests are not trying to qualify the SS at this time, some portions of testing will be left for a later date (i.e. Thermal, EMI, Harmonics, etc). Therefore, DTC testing will focus on how the SS disconnects and reconnects to the utility grid. Although the SS function may not completely fit into IEEE Standard 1547, it does not cause any problems for the intended testing of the Microgrid, however testing of the SS needs to incorporate this knowledge. A brief example of the differences and a suggested test plan at AEP's DTC follows.

From a protection point of view the SS can be setup to meet the IEEE 1547 criteria or more stringent criteria, such as ITIC, CBEMA, etc. The deviation from standard deals primarily with reconnection to the utility grid. Briefly, IEEE 1547 has windows for frequency difference, voltage difference, and phase angle difference between the two electrical buses. It is understood that there are possible operating points under which the Microgrid would not reconnect to the utility grid, if the SS strictly followed IEEE Standard 1547. Therefore, the SS will have somewhat looser criteria under which it is acceptable to reconnect to the utility grid and will be tested in the Microgrid Test Bed to see what the results show.

1.0 Proposed DTC Test Plan

The proposed DTC tests are designed to test the functionality of the protection portion of the SS. For example, does the switch open when out of voltage, current, and frequency criteria, etc. From discussions with Ed, Northern Power Systems (NPS) has put together a good basic test sequence for SS functionality. This is appropriate, as any system debugging will be easiest to perform at the NPS site. Thus, more advanced testing of the SS will be performed at the DTC, primarily dealing with power quality events. Examples would be sags, swells, switching transient events, etc. It is our intention to treat this SS as a protection relay and test it similarly. To achieve this, we will inject various stimuli and capture the SS's response. This stimulus is best kept low power in nature as larger power may cause damage to the SS. It is also appropriate for the team to agree on what the stimulus should be prior to testing. Currently, AEP budgeted/scheduled 10 days to setup and test the SS at the DTC site and we must make the most of it without delaying the project schedule.

Originally, we discussed testing the SS with high power stimuli, such as fault currents. Because the SS is likely to be the most critical path device during Microgrid installation, it would cause large delays in the project schedule if damage to the SS occurred during DTC tests. Also, there is adequate secondary protection within the Walnut Test Site, so that this high power testing may take place on site. We believe power fault tests would be more appropriately tested once in the Microgrid. However, we would like to simulate faults at the DTC site both in the utility system and faults within the Microgrid to determine if the SS reacts properly. This testing would inject voltage and current signals into the sensing portion of the SS and capture its response.

Based on the above information, we recommend the following tests take place at the DTC site.

- Ramp testing of Over/Under Voltage, and Over/Under Frequency protection. This protection is part of IEEE Standard 1547, which may be somewhat difficult for NPS to complete. Currently, NPS is performing the step technique portion of this test. The ramp test technique will complete the test requirements.
- Synchronization to the utility grid. As mentioned, above, the criterion for synchronization is likely to be different to IEEE Standard 1547; however, it should be tested to the CERTS Microgrid criteria set-points, i.e., Frequency, Voltage, and Phase Angle. Currently, NPS is testing the SS with an inverter source, mimicking the Tecogen generator devices. This testing needs further verification to demonstrate that the SS alone meets its design criteria.
- Power Quality Events.
  - Sags/Swells in Voltage, reflecting ITIC, CBEMA, and/or SEMI
  - Sags/Swells in Frequency
  - Switching/Line Transients
  - Simulated Utility/Microgrid Faults

We also recommend the following tests take place at NPS.

- Open phase combinations

  We recommend this test be done as this can be a common occurrence in the utility system. This testing can be satisfied, if the minimum import relay is tested successfully.

- SCR failure to "Open"

  We recommend this test be done to satisfy concerns that the SS may be unable to "Open" under asymmetrical faults. This testing can take place at either NPS or DTC; however, AEP will need more detail of this functionality if done here.

Most, if not all, of this testing can be accomplished with the capabilities of a single set of test equipment. This includes a 480volts 3-phase variac, an Elgar SW 5250A Smart Wave, an Elgar SS-66 3-phase power supply, a Manta MTS 1710 relay test set, and a Wavetek Datron Model 195 Universal Waveform Generator.

2.0 DTC Test Details

For all of the following tests the SCR switches will be disconnected from the circuit. This is to prevent any stress on the SCR switches and damage to any test equipment. The stimuli will be injected into the sensing PTs and CTs with the resultant response measured on the signal that "opens" and "closes" the SCR switches.

1) **Ramp testing of Over/Under Voltage and Over/Under Frequency protection.** This testing is used to determine if the SS meets the design criteria for voltage and frequency protection. Specifically, ramping the voltage and frequency will allow accurate measurement of where the trip points are set. This test setup will require only the Manta 1710 Relay Test Set (Manta) and shown in Figure 1. The measurement PTs of the SS will be disconnected and the Manta connected in their place. The Manta will be configured to deliver the same stimuli to both sides of the switch. These stimuli will be the ramping functions as laid out in IEEE Standard 1547.1. Individual tests for voltage and frequency will be performed. The SS will be energized to nominal conditions and then ramped from them. The magnitude of the ramp at the command to "open" the SS will be recorded for 5 test runs. For voltage each phase will be tested, individually, as well as all three phases together. For frequency all three phases will be tested together.

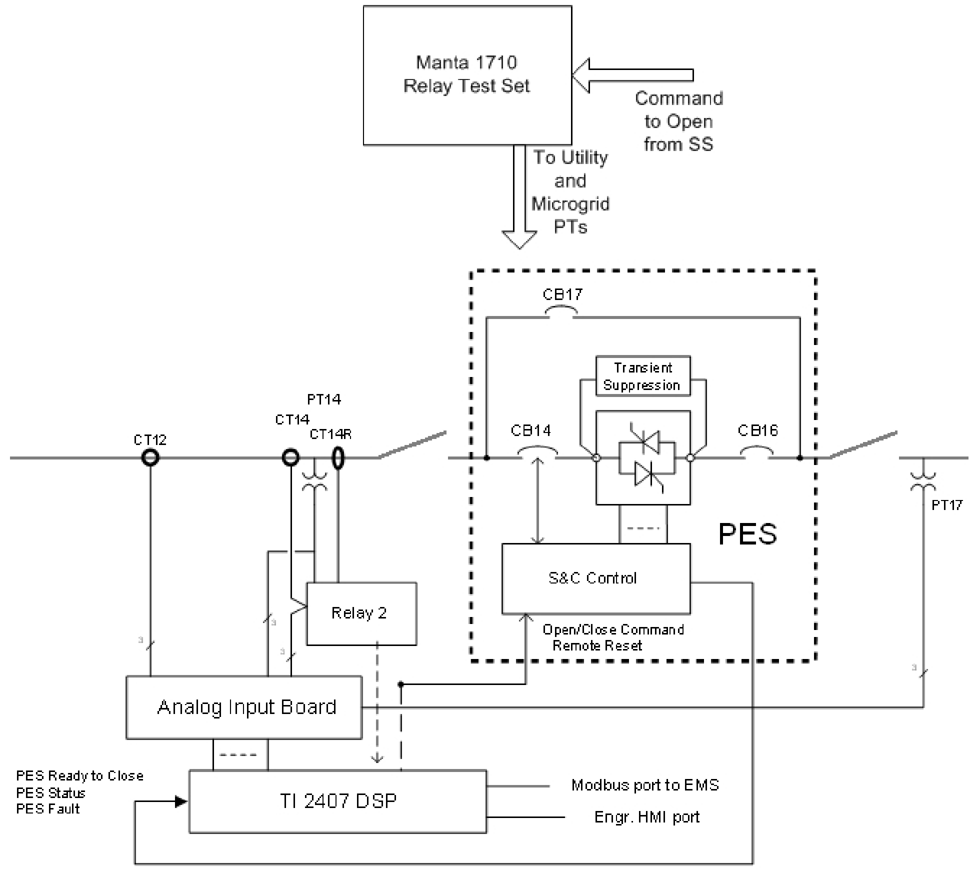

Figure 1: Ramp Test Setup for Over/Under Voltage & Over/Under Frequency.

2) **Synchronization to the utility grid.** This testing is used to determine if the SS meets the CERTS Microgrid criteria for synchronizing to the utility grid. Specifically, this test will allow us to test the each condition for acceptable synchronization, individually, instead of as a combined process. This test setup will require both the Manta 1710 Relay Test Set and a 3-phase variac, as shown in Figure 2. The Manta will provide stimulus to the Microgrid side of the SS. The 3-phase variac will connect to the Utility side of the SS and will primarily correct the utility voltage, if other than nominal.
   a. For testing the synchronization of voltage, the SS will be energized on the utility side through the variac to nominal voltage. The Manta will energize the Microgrid side of the SS with a frequency and phase locked voltage. This voltage magnitude will be ramped from out of tolerance to in to tolerance. The magnitude of the ramp at the command to "close" the SS will be recorded for 5 test runs. Each phase will be tested, individually, as well as all three phases together.
   b. For testing the synchronization of frequency and phase angle, the SS will be energized on the utility side through the variac to nominal voltage. The Manta will energize the Microgrid side of the SS with the nominal voltage and a frequency that is outside the synchronization criteria. The frequency will then be ramped from out of tolerance and

in to tolerance. The magnitude of the ramp and the phase angle at the command to "close" the SS will be recorded for 5 test runs. All three phases will be tested together.

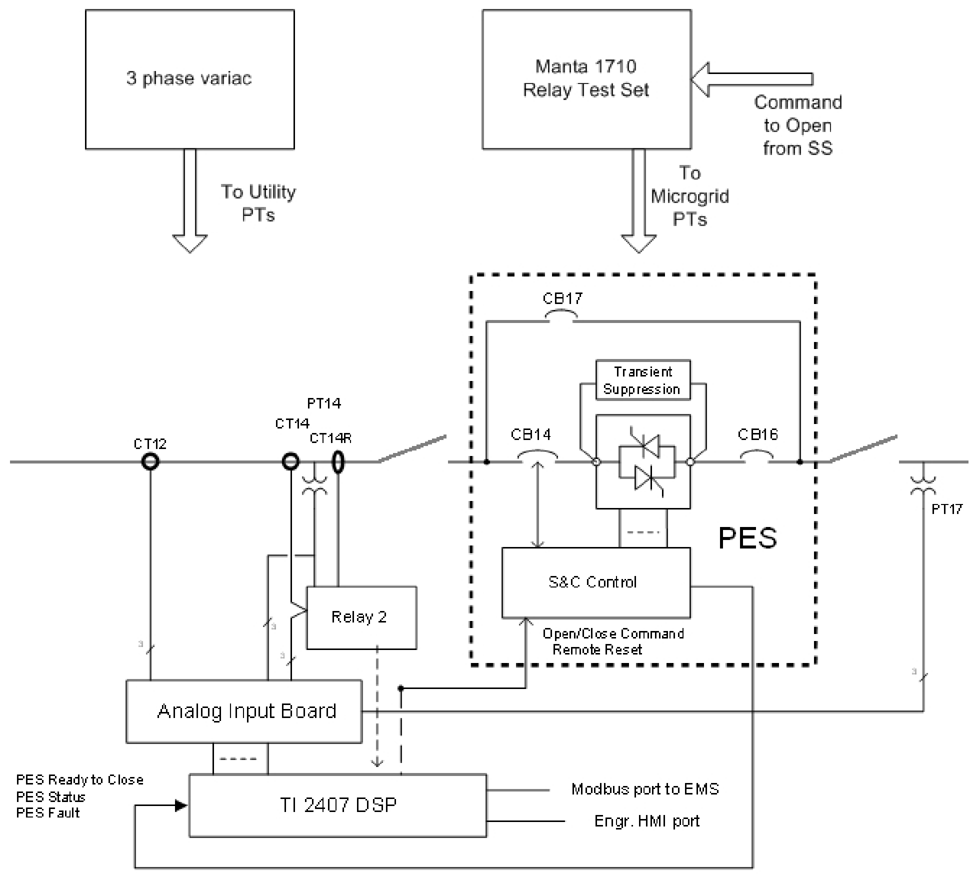

Figure 2: Test Setup for Synchronization to the utility grid.

3) **Power Quality Events.** This testing is used to determine how the SS will respond to power quality events within the utility system. The test setup for both sags and swells in voltage and frequency, as well as switching and line transients will be similar to the voltage and frequency ramp testing, described above. This will require only the Manta 1710 Relay Test Set. The measurement PTs of the SS will be disconnected and the Manta connected in their place. The Manta will be configured to deliver the same stimuli to both sides of the SS. These stimuli will need to be decided, prior to testing. A recommendation follows:

   a. Voltage sags and swells for at least 7 points on the ITIC or CBEMA curve
   b. If desired, voltage sags at 3 points for the SEMIF47 curve.
   c. Frequency sags and swells for at least 3 points to meet IEEE Standard 1547.

d. At least 6 switching and line transients to be decided upon.

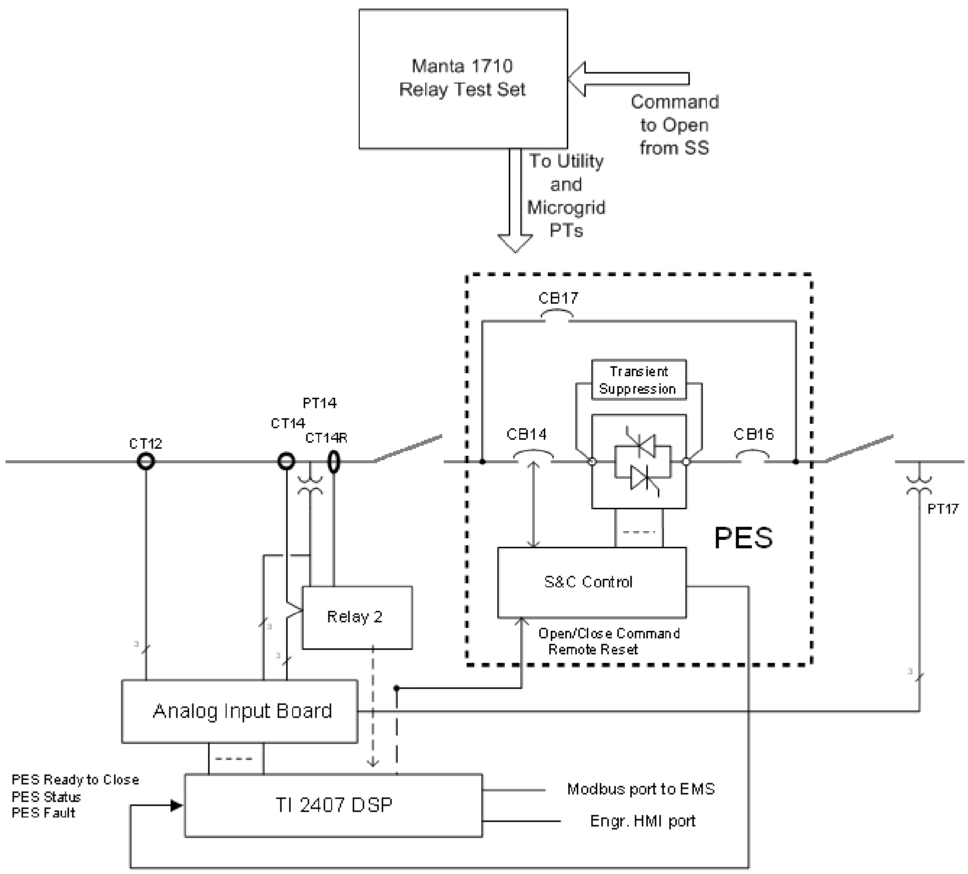

Figure 3: Test Setup for Power Quality Events.

4) **Utility and Microgrid Faults.** Test setup for simulated Utility and Microgrid Faults will be similar to the sag and swell testing above, except the measurement CTs of the SS will also be disconnected and the Manta connected in their place. This test setup is shown in Figure 4. The Manta will be configured to deliver the same voltage stimuli to both sides of the SS and current stimuli to the utility side. The stimulus will match what the anticipated faults will look like within the Microgrid. Testing of each type of fault, as well as three different levels of fault currents will be performed. For simulating the utility faults, data from past test and

the simulation of the Microgrid Test bed will be used to design the stimuli. This test will take into account the effect of the Reverse power relay.

The SS will be energized to nominal conditions and then the power quality event will be triggered. The event details (type, magnitude, duration, etc.) and the response of the SS will be recorded for each of the 5 test runs.

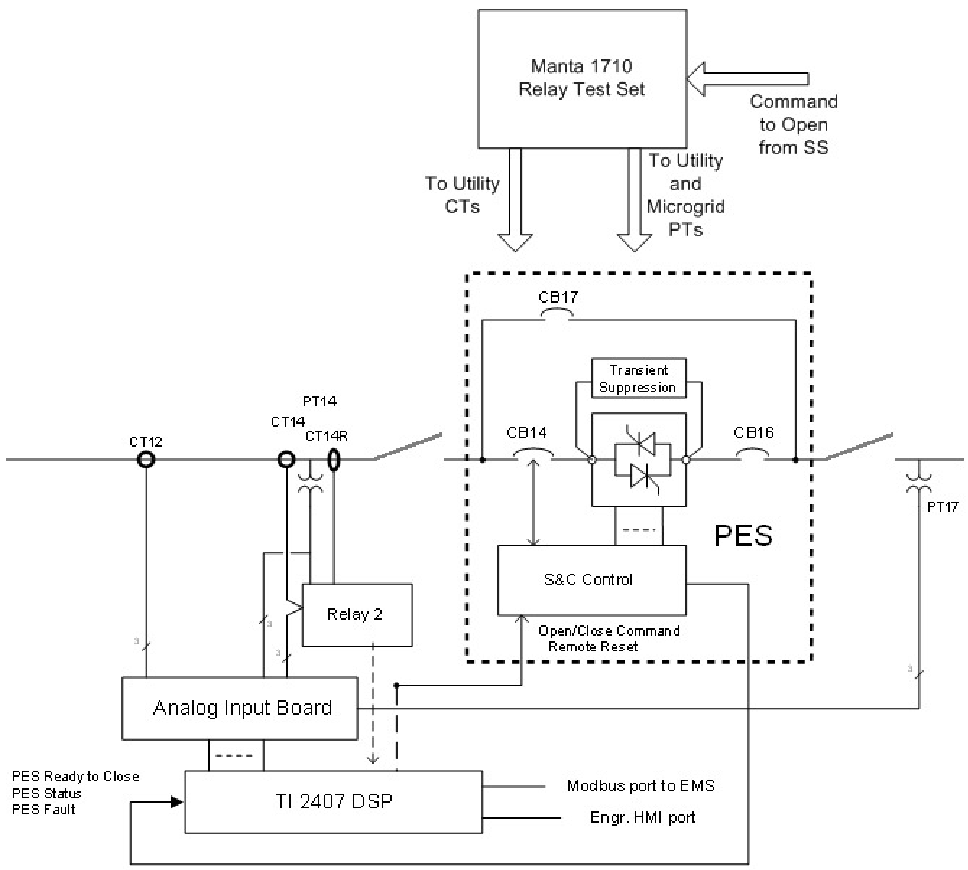

Figure 4: Test Setup for Utility and Microgrid Faults.

SUMMARY OF CERTS MICROGRID STATIC SWITCH POWER QUALITY TESTS @ AEP DOLAN
Notes: AEP EMS is setup with only PQ Events Enableded, The SS Parameters for CBEMA#7 Time was changed to 3.0223 and CBEMA#2 Voltage was changed to 470 Volts

The Manta has been setup to deliver secondary voltages and currents to the DSP and Relay 2

CBEMA/ITIC/SEMI VOLTAGE SAG/SWELL TESTS (AVERAGES FROM 5 TRIES)					
Test	**Voltage**	**Cycles**	**Average Trip Time (ms)**	**Standard Deviation (ms)**	**Pass / Fail**
Undervoltage 0%, Three Phase	0.0 Peak	0.5	N/A	N/A	Pass
Undervoltage 0%, Three Phase	0.0 Peak	2	N/A	N/A	Fail
Undervoltage 30%, Three Phase	117.5 Peak	5	N/A	N/A	Fail
Undervoltage 67%, Three Phase	262.5 Peak	15	0.2084	0.0004	Pass
Undervoltage 73%, Three Phase	286.0 Peak	3	N/A	N/A	Pass
Undervoltage 77%, Three Phase	213.3 RMS	35	0.4582	0.0008	Pass
Undervoltage 83%, Three Phase	229.9 RMS	45	N/A	N/A	Pass
Overvoltage 107%, Three Phase	296.4 RMS	60	N/A	N/A	Pass
Overvoltage 113%, Three Phase	313.0 RMS	45	N/A	N/A	Fail
Overvoltage 117%, Three Phase	458.3 Peak	20	N/A	N/A	Pass
Overvoltage 123%, Three Phase	481.8 Peak	10	N/A	N/A	Fail
Undervoltage 0%, Single Phase A	0.0 Peak	0.5	N/A	N/A	Pass
Undervoltage 45%, Single Phase B	176.3 Peak	20	0.1415	0.0006	Pass
Undervoltage 67%, Single Phase C	185.6 RMS	40	0.1848	0.0004	Pass
Undervoltage 77%, Single Phase A	213.3 RMS	45	0.4376	0.0004	Pass
Undervoltage 83%, Single Phase B	229.9 RMS	70	N/A	N/A	Pass
Undervoltage 0%, Single Phase A	0.0 Peak	2	N/A	N/A	Fail
Undervoltage 0%, Single Phase A	0.0 Peak	3	N/A	N/A	Fail
Undervoltage 0%, Single Phase A	0.0 Peak	4	N/A	N/A	Fail
Undervoltage 0%, Single Phase A	0.0 Peak	5	N/A	N/A	Fail
Undervoltage 0%, Single Phase A	0.0 Peak	6	N/A	N/A	Fail
Undervoltage 0%, Single Phase A	0.0 Peak	7	0.1077	0.0006	Pass
Undervoltage 0%, Single Phase A	0.0 Peak	8	0.1081	0.0010	Pass
Undervoltage 0%, Single Phase A	0.0 Peak	9	0.1082	0.0004	Pass
Undervoltage 0%, Single Phase A	0.0 Peak	10	0.1079	0.0008	Pass
Overvoltage 120%, Three Phase	470.1 Peak	20	N/A	N/A	Fail

SUMMARY OF CERTS MICROGRID STATIC SWITCH POWER QUALITY TESTS @ AEP DOLAN
Notes: AEP EMS is setup with only PQ Events Enableded, The SS Parameters for CBEMA#7 Time was changed to 3.0223 and CBEMA#2 Voltage was changed to 470 Volts

The Manta has been setup to deliver secondary voltages and currents to the DSP and Relay 2

Overvoltage 121%, Three Phase	474.0 Peak	20	N/A	N/A	Fail
Overvoltage 122%, Three Phase	477.9 Peak	20	N/A	N/A	Fail
Overvoltage 123%, Three Phase	481.8 Peak	20	N/A	N/A	Fail
Overvoltage 124%, Three Phase	485.8 Peak	20	N/A	N/A	Fail
Overvoltage 125%, Three Phase	489.7 Peak	20	N/A	N/A	Fail
Overvoltage 126%, Three Phase	493.6 Peak	20	N/A	N/A	Fail
Overvoltage 127%, Three Phase	497.5 Peak	20	N/A	N/A	Fail
Overvoltage 128%, Three Phase	501.4 Peak	20	0.3248	0.0008	Pass
Overvoltage 129%, Three Phase	505.3 Peak	20	0.3253	0.0004	Pass
Overvoltage 130%, Three Phase	509.3 Peak	20	0.3083	0.0008	Pass

Table 1: Voltage Sag/Swell Test Results

SIMULATED FAULT TESTS (AVERAGES FROM 5 TRIES)					
Test	**Current**	**Cycles**	**Average Trip Time (ms)**	**Standard Deviation (ms)**	**Pass / Fail**
Phase A to B, Bolted Fault		300	0.0231	0.0002	Pass
Phase A to Ground, Bolted Fault		300	0.0214	0.0005	Pass
Phase A to B to Ground, Bolted Fault		300	0.0224	0.0012	Pass
Phase A to B to C to Ground, Bolted Fault		300	0.0212	0.0010	Pass
Phase A to B to Ground, High Impedance Fault		300	0.0235	0.0006	Pass
Phase A to B to C to Ground, High Impedance Fault		300	0.0214	0.0007	Pass

Table 2: Simulated Fault Test Results

OPEN PHASE TESTS (AVERAGES FROM 5 TRIES)					
Test		**Cycles**	**Average Trip Time (ms)**	**Standard Deviation (ms)**	**Pass / Fail**
Open Phase A in Delta-Delta Feed		300	0.1582	0.0006	Pass
Open Phase A in Wye Secondary Feed		300	0.1074	0.0005	Pass
Open Phase A and B in Wye Secondary Feed		300	0.1075	0.0008	Pass

Table 3: Open Phase Test Results

SUMMARY OF CERTS MICROGRID STATIC SWITCH POWER QUALITY TESTS @ AEP DOLAN
Notes: AEP EMS is setup with only PQ Events Enableded, The SS Parameters for CBEMA#7 Time was changed to 3.0223 and CBEMA#2 Voltage was changed to 470 Volts

The Manta has been setup to deliver secondary voltages and currents to the DSP and Relay 2

VOLTAGE TRANSIENT/DISTORTION TESTS (AVERAGES FROM 5 TRIES)					
Test	**Cycles**	**Trip**	**Average Trip Time (ms)**	**Standard Deviation (ms)**	**Pass / Fail**
Lightning Surge 1.2-50us	<1	No	N/A	N/A	N/A
900 MVar Capacitor Switch	<1	No	N/A	N/A	N/A
Motor Start Non-CBEMA/ITIC/SEMI Violation	40	Yes	0.4749	0.0007	N/A
Motor Start CBEMA/ITIC/SEMI Violation	40	Yes	0.1918	0.0010	Pass
Six Pulse Bridge Load	300	No	N/A	N/A	N/A
Harmonic Distortion	240	No	N/A	N/A	N/A

Table 4: Voltage Transient/Distortion Test Reults

SUMMARY OF CBEMA/ITIC/SEMI VOLTAGE SAG/SURGE TESTS

UNDERVOLTAGE SAG 0%, Three Phase, 0.5 Cycle

Name	Anticipated Reaction	Actual Reaction	Reaction Time	Pass / Fail
Test 1	Remain Online	Remain Online	N/A	Pass
Test 2	Remain Online	Remain Online	N/A	Pass
Test 3	Remain Online	Remain Online	N/A	Pass
Test 4	Remain Online	Remain Online	N/A	Pass
Test 5	Remain Online	Remain Online	N/A	Pass

AVERAGE TRIP TIME N/A **ST DEV** N/A

UNDERVOLTAGE SAG 0%, Three Phase, 2 Cycles

Name	Anticipated Reaction	Actual Reaction	Reaction Time	Pass / Fail
Test 1	Trip Open	Remain Online	N/A	Fail
Test 2	Trip Open	Remain Online	N/A	Fail
Test 3	Trip Open	Remain Online	N/A	Fail
Test 4	Trip Open	Remain Online	N/A	Fail
Test 5	Trip Open	Remain Online	N/A	Fail

AVERAGE TRIP TIME N/A **ST DEV** N/A

UNDERVOLTAGE SAG 30%, Three Phase, 5 Cycles

Name	Anticipated Reaction	Actual Reaction	Reaction Time	Pass / Fail
Test 1	Trip Open	Remain Online	N/A	Fail
Test 2	Trip Open	Remain Online	N/A	Fail
Test 3	Trip Open	Remain Online	N/A	Fail
Test 4	Trip Open	Remain Online	N/A	Fail
Test 5	Trip Open	Remain Online	N/A	Fail

AVERAGE TRIP TIME N/A **ST DEV** N/A

UNDERVOLTAGE SAG 67%, Three Phase, 15 Cycles

Name	Anticipated Reaction	Actual Reaction	Reaction Time	Pass / Fail
Test 1	Trip Open	Trip Open	0.2085	Pass
Test 2	Trip Open	Trip Open	0.208	Pass
Test 3	Trip Open	Trip Open	0.2085	Pass
Test 4	Trip Open	Trip Open	0.208	Pass
Test 5	Trip Open	Trip Open	0.209	Pass

AVERAGE TRIP TIME 0.2084 **ST DEV** 0.0004

UNDERVOLTAGE SAG 73%, Three Phase, 3 Cycles

Name	Anticipated Reaction	Actual Reaction	Reaction Time	Pass / Fail
Test 1	Remain	Remain	N/A	Pass

UNDERVOLTAGE SAG 77%, Three Phase, 35 Cycles

Name	Anticipated Reaction	Actual Reaction	Reaction Time	Pass / Fail
Test 1	Trip Open	Trip Open	0.4585	Pass

SUMMARY OF CBEMA/ITIC/SEMI VOLTAGE SAG/SURGE TESTS

	Online	Online		
Test 2	Remain Online	Remain Online	N/A	Pass
Test 3	Remain Online	Remain Online	N/A	Pass
Test 4	Remain Online	Remain Online	N/A	Pass
Test 5	Remain Online	Remain Online	N/A	Pass

AVERAGE TRIP TIME N/A **ST DEV** N/A

Test 2	Trip Open	Trip Open	0.4575	Pass
Test 3	Trip Open	Trip Open	0.4575	Pass
Test 4	Trip Open	Trip Open	0.4595	Pass
Test 5	Trip Open	Trip Open	0.458	Pass

AVERAGE TRIP TIME 0.4582 **ST DEV** 0.0008

UNDERVOLTAGE SAG 83%, Three Phase, 45 Cycles

Name	Anticipated Reaction	Actual Reaction	Reaction Time	Pass / Fail
Test 1	Remain Online	Remain Online	N/A	Pass
Test 2	Remain Online	Remain Online	N/A	Pass
Test 3	Remain Online	Remain Online	N/A	Pass
Test 4	Remain Online	Remain Online	N/A	Pass
Test 5	Remain Online	Remain Online	N/A	Pass

AVERAGE TRIP TIME N/A **ST DEV** N/A

OVERVOLTAGE SURGE 107%, Three Phase, 60 Cycles

Name	Anticipated Reaction	Actual Reaction	Reaction Time	Pass / Fail
Test 1	Remain Online	Remain Online	N/A	Pass
Test 2	Remain Online	Remain Online	N/A	Pass
Test 3	Remain Online	Remain Online	N/A	Pass
Test 4	Remain Online	Remain Online	N/A	Pass
Test 5	Remain Online	Remain Online	N/A	Pass

AVERAGE TRIP TIME N/A **ST DEV** N/A

OVERVOLTAGE SURGE 113%, Three Phase, 45 Cycles

Name	Anticipated Reaction	Actual Reaction	Reaction Time	Pass / Fail
Test 1	Trip Open	Remain Online	N/A	Fail
Test 2	Trip Open	Remain Online	N/A	Fail
Test 3	Trip Open	Remain Online	N/A	Fail

OVERVOLTAGE SAG 117%, Three Phase, 20 Cycles

Name	Anticipated Reaction	Actual Reaction	Reaction Time	Pass / Fail
Test 1	Remain Online	Remain Online	N/A	Pass
Test 2	Remain Online	Remain Online	N/A	Pass
Test 3	Remain Online	Remain Online	N/A	Pass

SUMMARY OF CBEMA/ITIC/SEMI VOLTAGE SAG/SURGE TESTS

Test 4	Trip Open	Remain Online	N/A	Fail
Test 5	Trip Open	Remain Online	N/A	Fail

AVERAGE TRIP TIME N/A **ST DEV** N/A

Test 4	Remain Online	Remain Online	N/A	Pass
Test 5	Remain Online	Remain Online	N/A	Pass

AVERAGE TRIP TIME N/A **ST DEV** N/A

OVERVOLTAGE SAG 123%, Three Phase, 10 Cycles

Name	Anticipated Reaction	Actual Reaction	Reaction Time	Pass / Fail
Test 1	Trip Open	Remain Online	N/A	Fail
Test 2	Trip Open	Remain Online	N/A	Fail
Test 3	Trip Open	Remain Online	N/A	Fail
Test 4	Trip Open	Remain Online	N/A	Fail
Test 5	Trip Open	Remain Online	N/A	Fail

AVERAGE TRIP TIME N/A **ST DEV** N/A

UNDERVOLTAGE SAG 0%, Single Phase A, 0.5 Cycle

Name	Anticipated Reaction	Actual Reaction	Reaction Time	Pass / Fail
Test 1	Remain Online	Remain Online	N/A	Pass
Test 2	Remain Online	Remain Online	N/A	Pass
Test 3	Remain Online	Remain Online	N/A	Pass
Test 4	Remain Online	Remain Online	N/A	Pass
Test 5	Remain Online	Remain Online	N/A	Pass

AVERAGE TRIP TIME N/A **ST DEV** N/A

UNDERVOLTAGE SAG 45%, Single Phase B, 20 Cycles

Name	Anticipated Reaction	Actual Reaction	Reaction Time	Pass / Fail
Test 1	Trip Open	Trip Open	0.142	Pass
Test 2	Trip Open	Trip Open	0.142	Pass
Test 3	Trip Open	Trip Open	0.1405	Pass
Test 4	Trip Open	Trip Open	0.1415	Pass
Test 5	Trip Open	Trip Open	0.1415	Pass

UNDERVOLTAGE SAG 67%, Single Phase C, 40 Cycles

Name	Anticipated Reaction	Actual Reaction	Reaction Time	Pass / Fail
Test 1	Trip Open	Trip Open	0.18425	Pass
Test 2	Trip Open	Trip Open	0.185	Pass
Test 3	Trip Open	Trip Open	0.185	Pass
Test 4	Trip Open	Trip Open	0.1845	Pass
Test 5	Trip Open	Trip Open	0.185	Pass

SUMMARY OF CBEMA/ITIC/SEMI VOLTAGE SAG/SURGE TESTS

AVERAGE TRIP TIME 0.1415 **ST DEV** 0.0006

AVERAGE TRIP TIME 0.1848 **ST DEV** 0.0004

UNDERVOLTAGE SAG 77%, Single Phase A, 45 Cycles

Name	Anticipated Reaction	Actual Reaction	Reaction Time	Pass / Fail
Test 1	Trip Open	Trip Open	0.4375	Pass
Test 2	Trip Open	Trip Open	0.438	Pass
Test 3	Trip Open	Trip Open	0.437	Pass
Test 4	Trip Open	Trip Open	0.4375	Pass
Test 5	Trip Open	Trip Open	0.438	Pass

AVERAGE TRIP TIME 0.4376 **ST DEV** 0.0004

UNDERVOLTAGE SAG 83%, Single Phase B, 70 Cycles

Name	Anticipated Reaction	Actual Reaction	Reaction Time	Pass / Fail
Test 1	Remain Online	Remain Online	N/A	Pass
Test 2	Remain Online	Remain Online	N/A	Pass
Test 3	Remain Online	Remain Online	N/A	Pass
Test 4	Remain Online	Remain Online	N/A	Pass
Test 5	Remain Online	Remain Online	N/A	Pass

AVERAGE TRIP TIME N/A **ST DEV** N/A

UNDERVOLTAGE SAG 0%, Single Phase A, 2 Cycles

Name	Anticipated Reaction	Actual Reaction	Reaction Time	Pass / Fail
Test 1	Trip Open	Remain Online	N/A	Fail
Test 2	Trip Open	Remain Online	N/A	Fail
Test 3	Trip Open	Remain Online	N/A	Fail
Test 4	Trip Open	Remain Online	N/A	Fail
Test 5	Trip Open	Remain Online	N/A	Fail

AVERAGE TRIP TIME N/A **ST DEV** N/A

UNDERVOLTAGE SAG 0%, Single Phase A, 3 Cycles

Name	Anticipated Reaction	Actual Reaction	Reaction Time	Pass / Fail
Test 1	Trip Open	Remain Online	N/A	Fail
Test 2	Trip Open	Remain Online	N/A	Fail
Test 3	Trip Open	Remain Online	N/A	Fail
Test 4	Trip Open	Remain Online	N/A	Fail
Test 5	Trip Open	Remain Online	N/A	Fail

AVERAGE TRIP TIME N/A **ST DEV** N/A

UNDERVOLTAGE SAG 0%, Single Phase A, 4 Cycles

UNDERVOLTAGE SAG 0%, Single Phase A, 5 Cycles

SUMMARY OF CBEMA/ITIC/SEMI VOLTAGE SAG/SURGE TESTS

Name	Anticipated Reaction	Actual Reaction	Reaction Time	Pass / Fail
Test 1	Trip Open	Remain Online	N/A	Fail
Test 2	Trip Open	Remain Online	N/A	Fail
Test 3	Trip Open	Remain Online	N/A	Fail
Test 4	Trip Open	Remain Online	N/A	Fail
Test 5	Trip Open	Remain Online	N/A	Fail

AVERAGE TRIP TIME N/A **ST DEV** N/A

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Name	Anticipated Reaction	Actual Reaction	Reaction Time	Pass / Fail
Test 1	Trip Open	Remain Online	N/A	Fail
Test 2	Trip Open	Remain Online	N/A	Fail
Test 3	Trip Open	Remain Online	N/A	Fail
Test 4	Trip Open	Remain Online	N/A	Fail
Test 5	Trip Open	Remain Online	N/A	Fail

AVERAGE TRIP TIME N/A **ST DEV** N/A

UNDERVOLTAGE SAG 0%, Single Phase A, 6 Cycles

Name	Anticipated Reaction	Actual Reaction	Reaction Time	Pass / Fail
Test 1	Trip Open	Remain Online	N/A	Fail
Test 2	Trip Open	Remain Online	N/A	Fail
Test 3	Trip Open	Remain Online	N/A	Fail
Test 4	Trip Open	Remain Online	N/A	Fail
Test 5	Trip Open	Remain Online	N/A	Fail

AVERAGE TRIP TIME N/A **ST DEV** N/A

UNDERVOLTAGE SAG 0%, Single Phase A, 7 Cycles

Name	Anticipated Reaction	Actual Reaction	Reaction Time	Pass / Fail
Test 1	Trip Open	Trip Open	0.108	Pass
Test 2	Trip Open	Trip Open	0.1075	Pass
Test 3	Trip Open	Trip Open	0.107	Pass
Test 4	Trip Open	Trip Open	0.1085	Pass
Test 5	Trip Open	Trip Open	0.1075	Pass

AVERAGE TRIP TIME 0.1077 **ST DEV** 0.0006

UNDERVOLTAGE SAG 0%, Single Phase A, 8 Cycles

Name	Anticipated Reaction	Actual Reaction	Reaction Time	Pass / Fail
Test 1	Trip Open	Trip Open	0.108	Pass

UNDERVOLTAGE SAG 0%, Single Phase A, 9 Cycles

Name	Anticipated Reaction	Actual Reaction	Reaction Time	Pass / Fail
Test 1	Trip Open	Trip Open	0.108	Pass

SUMMARY OF CBEMA/ITIC/SEMI VOLTAGE SAG/SURGE TESTS

Test 2	Trip Open	Trip Open	0.107	Pass
Test 3	Trip Open	Trip Open	0.1085	Pass
Test 4	Trip Open	Trip Open	0.1075	Pass
Test 5	Trip Open	Trip Open	0.1095	Pass

AVERAGE TRIP TIME 0.1081 **ST DEV** 0.0010

Test 2	Trip Open	Trip Open	0.108	Pass
Test 3	Trip Open	Trip Open	0.108	Pass
Test 4	Trip Open	Trip Open	0.108	Pass
Test 5	Trip Open	Trip Open	0.109	Pass

AVERAGE TRIP TIME 0.1082 **ST DEV** 0.0004

UNDERVOLTAGE SAG 0%, Single Phase A, 10 Cycles

Name	Anticipated Reaction	Actual Reaction	Reaction Time	Pass / Fail
Test 1	Trip Open	Trip Open	0.1085	Pass
Test 2	Trip Open	Trip Open	0.109	Pass
Test 3	Trip Open	Trip Open	0.1075	Pass
Test 4	Trip Open	Trip Open	0.107	Pass
Test 5	Trip Open	Trip Open	0.1075	Pass

AVERAGE TRIP TIME 0.1079 **ST DEV** 0.0008

OVERVOLTAGE SAG 120%, Three Phase, 20 Cycles

Name	Anticipated Reaction	Actual Reaction	Reaction Time	Pass / Fail
Test 1	Trip Open	Remain Online	N/A	Fail
Test 2	Trip Open	Remain Online	N/A	Fail
Test 3	Trip Open	Remain Online	N/A	Fail
Test 4	Trip Open	Remain Online	N/A	Fail
Test 5	Trip Open	Remain Online	N/A	Fail

AVERAGE TRIP TIME N/A **ST DEV** N/A

OVERVOLTAGE SAG 121%, Three Phase, 20 Cycles

Name	Anticipated Reaction	Actual Reaction	Reaction Time	Pass / Fail
Test 1	Trip Open	Remain Online	N/A	Fail
Test 2	Trip Open	Remain Online	N/A	Fail
Test 3	Trip Open	Remain Online	N/A	Fail
Test 4	Trip Open	Remain	N/A	Fail

OVERVOLTAGE SAG 122%, Three Phase, 20 Cycles

Name	Anticipated Reaction	Actual Reaction	Reaction Time	Pass / Fail
Test 1	Trip Open	Remain Online	N/A	Fail
Test 2	Trip Open	Remain Online	N/A	Fail
Test 3	Trip Open	Remain Online	N/A	Fail
Test 4	Trip Open	Remain	N/A	Fail

SUMMARY OF CBEMA/ITIC/SEMI VOLTAGE SAG/SURGE TESTS

Test 5	Trip Open	Online Remain Online	N/A	Fail

AVERAGE TRIP TIME N/A **ST DEV** N/A

Test 5	Trip Open	Online Remain Online	N/A	Fail

AVERAGE TRIP TIME N/A **ST DEV** N/A

OVERVOLTAGE SAG 123%, Three Phase, 20 Cycles

Name	Anticipated Reaction	Actual Reaction	Reaction Time	Pass / Fail
Test 1	Trip Open	Remain Online	N/A	Fail
Test 2	Trip Open	Remain Online	N/A	Fail
Test 3	Trip Open	Remain Online	N/A	Fail
Test 4	Trip Open	Remain Online	N/A	Fail
Test 5	Trip Open	Remain Online	N/A	Fail

AVERAGE TRIP TIME N/A **ST DEV** N/A

OVERVOLTAGE SAG 124%, Three Phase, 20 Cycles

Name	Anticipated Reaction	Actual Reaction	Reaction Time	Pass / Fail
Test 1	Trip Open	Remain Online	N/A	Fail
Test 2	Trip Open	Remain Online	N/A	Fail
Test 3	Trip Open	Remain Online	N/A	Fail
Test 4	Trip Open	Remain Online	N/A	Fail
Test 5	Trip Open	Remain Online	N/A	Fail

AVERAGE TRIP TIME N/A **ST DEV** N/A

OVERVOLTAGE SAG 125%, Three Phase, 20 Cycles

Name	Anticipated Reaction	Actual Reaction	Reaction Time	Pass / Fail
Test 1	Trip Open	Remain Online	N/A	Fail
Test 2	Trip Open	Remain Online	N/A	Fail
Test 3	Trip Open	Remain Online	N/A	Fail
Test 4	Trip Open	Remain Online	N/A	Fail
Test 5	Trip Open	Remain Online	N/A	Fail

OVERVOLTAGE SAG 126%, Three Phase, 20 Cycles

Name	Anticipated Reaction	Actual Reaction	Reaction Time	Pass / Fail
Test 1	Trip Open	Remain Online	N/A	Fail
Test 2	Trip Open	Remain Online	N/A	Fail
Test 3	Trip Open	Remain Online	N/A	Fail
Test 4	Trip Open	Remain Online	N/A	Fail
Test 5	Trip Open	Remain Online	N/A	Fail

SUMMARY OF CBEMA/ITIC/SEMI VOLTAGE SAG/SURGE TESTS

AVERAGE TRIP TIME N/A **ST DEV** N/A

AVERAGE TRIP TIME N/A **ST DEV** N/A

OVERVOLTAGE SAG 127%, Three Phase, 20 Cycles

Name	Anticipated Reaction	Actual Reaction	Reaction Time	Pass / Fail
Test 1	Trip Open	Remain Online	N/A	Fail
Test 2	Trip Open	Remain Online	N/A	Fail
Test 3	Trip Open	Remain Online	N/A	Fail
Test 4	Trip Open	Remain Online	N/A	Fail
Test 5	Trip Open	Remain Online	N/A	Fail

AVERAGE TRIP TIME N/A **ST DEV** N/A

OVERVOLTAGE SAG 128%, Three Phase, 20 Cycles

Name	Anticipated Reaction	Actual Reaction	Reaction Time	Pass / Fail
Test 1	Trip Open	Trip Open	0.325	Pass
Test 2	Trip Open	Trip Open	0.326	Pass
Test 3	Trip Open	Trip Open	0.3245	Pass
Test 4	Trip Open	Trip Open	0.3245	Pass
Test 5	Trip Open	Trip Open	0.324	Pass

AVERAGE TRIP TIME 0.3248 **ST DEV** 0.0008

OVERVOLTAGE SAG 129%, Three Phase, 20 Cycles

Name	Anticipated Reaction	Actual Reaction	Reaction Time	Pass / Fail
Test 1	Trip Open	Trip Open	0.3255	Pass
Test 2	Trip Open	Trip Open	0.3255	Pass
Test 3	Trip Open	Trip Open	0.3245	Pass
Test 4	Trip Open	Trip Open	0.3255	Pass
Test 5	Trip Open	Trip Open	0.3255	Pass

AVERAGE TRIP TIME 0.3253 **ST DEV** 0.0004

OVERVOLTAGE SAG 130%, Three Phase, 20 Cycles

Name	Anticipated Reaction	Actual Reaction	Reaction Time	Pass / Fail
Test 1	Trip Open	Trip Open	0.3075	Pass
Test 2	Trip Open	Trip Open	0.3075	Pass
Test 3	Trip Open	Trip Open	0.309	Pass
Test 4	Trip Open	Trip Open	0.309	Pass
Test 5	Trip Open	Trip Open	0.3085	Pass

AVERAGE TRIP TIME 0.3083 **ST DEV** 0.0008

Table 5: Detailed Voltage Sag/Swell Test Results

SUMMARY OF SIMULATED FAULT TESTS

PHASE A TO B, BOLTED, 300 Cycles

Name	Anticipated Reaction	Actual Reaction	Reaction Time	Pass / Fail
Test 1	Trip Open	Trip Open	0.0235	Pass
Test 2	Trip Open	Trip Open	0.023	Pass
Test 3	Trip Open	Trip Open	0.023	Pass
Test 4	Trip Open	Trip Open	0.023	Pass
Test 5	Trip Open	Trip Open	0.023	Pass

AVERAGE TRIP TIME 0.0231 **ST DEV** 0.0002

PHASE A TO GROUND, BOLTED, 300 Cycles

Name	Anticipated Reaction	Actual Reaction	Reaction Time	Pass / Fail
Test 1	Trip Open	Trip Open	0.022	Pass
Test 2	Trip Open	Trip Open	0.021	Pass
Test 3	Trip Open	Trip Open	0.021	Pass
Test 4	Trip Open	Trip Open	0.022	Pass
Test 5	Trip Open	Trip Open	0.021	Pass

AVERAGE TRIP TIME 0.0214 **ST DEV** 0.0005

PHASE A TO B TO GROUND, BOLTED, 300 Cycles

Name	Anticipated Reaction	Actual Reaction	Reaction Time	Pass / Fail
Test 1	Trip Open	Trip Open	0.021	Pass
Test 2	Trip Open	Trip Open	0.023	Pass
Test 3	Trip Open	Trip Open	0.024	Pass
Test 4	Trip Open	Trip Open	0.0215	Pass
Test 5	Trip Open	Trip Open	0.0225	Pass

AVERAGE TRIP TIME 0.0224 **ST DEV** 0.0012

PHASE A TO B TO C TO GROUND, BOLTED, 300 Cycles

Name	Anticipated Reaction	Actual Reaction	Reaction Time	Pass / Fail
Test 1	Trip Open	Trip Open	0.0205	Pass
Test 2	Trip Open	Trip Open	0.02	Pass
Test 3	Trip Open	Trip Open	0.0225	Pass
Test 4	Trip Open	Trip Open	0.022	Pass
Test 5	Trip Open	Trip Open	0.021	Pass

AVERAGE TRIP TIME 0.0212 **ST DEV** 0.0010

PHASE A TO B TO GROUND, HIGH IMPEDANCE, 300 Cycles

Name	Anticipated Reaction	Actual Reaction	Reaction Time	Pass / Fail
Test 1	Trip Open	Trip Open	0.0235	Pass
Test 2	Trip Open	Trip Open	0.024	Pass
Test 3	Trip Open	Trip Open	0.024	Pass
Test 4	Trip Open	Trip Open	0.0235	Pass
Test 5	Trip Open	Trip Open	0.0225	Pass

AVERAGE TRIP TIME 0.0235 **ST DEV** 0.0006

PHASE A TO B TO C TO GROUND, HIGH IMPEDANCE, 300 Cycles

Name	Anticipated Reaction	Actual Reaction	Reaction Time	Pass / Fail
Test 1	Trip Open	Trip Open	0.0205	Pass
Test 2	Trip Open	Trip Open	0.022	Pass
Test 3	Trip Open	Trip Open	0.021	Pass
Test 4	Trip Open	Trip Open	0.0215	Pass
Test 5	Trip Open	Trip Open	0.022	Pass

AVERAGE TRIP TIME 0.0214 **ST DEV** 0.0007

SUMMARY OF OPEN PHASE TESTS

OPEN PHASE A IN DELTA-DELTA FEED, 300 Cycles

Name	Anticipated Reaction	Actual Reaction	Reaction Time	Pass / Fail
Test 1	Trip Open	Trip Open	0.158	Pass
Test 2	Trip Open	Trip Open	0.1585	Pass
Test 3	Trip Open	Trip Open	0.159	Pass
Test 4	Trip Open	Trip Open	0.1575	Pass
Test 5	Trip Open	Trip Open	0.158	Pass

AVERAGE TRIP TIME 0.1582 **ST DEV** 0.0006

OPEN PHASE A IN WYE SECONDARY FEED, 300 Cycles

Name	Anticipated Reaction	Actual Reaction	Reaction Time	Pass / Fail
Test 1	Trip Open	Trip Open	0.107	Pass
Test 2	Trip Open	Trip Open	0.108	Pass
Test 3	Trip Open	Trip Open	0.108	Pass
Test 4	Trip Open	Trip Open	0.107	Pass
Test 5	Trip Open	Trip Open	0.107	Pass

AVERAGE TRIP TIME 0.1074 **ST DEV** 0.0005

PHASE A AND B IN WYE SECONDARY FEED, 300 Cycles

Name	Anticipated Reaction	Actual Reaction	Reaction Time	Pass / Fail
Test 1	Trip Open	Trip Open	0.107	Pass
Test 2	Trip Open	Trip Open	0.1085	Pass
Test 3	Trip Open	Trip Open	0.108	Pass
Test 4	Trip Open	Trip Open	0.1075	Pass
Test 5	Trip Open	Trip Open	0.1065	Pass

AVERAGE TRIP TIME 0.1075 **ST DEV** 0.0008

Table 6: Detailed Simulated Fault Test Results

SUMMARY OF SIMULATED FAULT TESTS

LIGHTNING SURGE 1.2-50us

Name	Anticipated Reaction	Actual Reaction	Reaction Time	Pass / Fail
Test 1	???	Remain Online	N/A	N/A
Test 2	???	Remain Online	N/A	N/A
Test 3	???	Remain Online	N/A	N/A
Test 4	???	Remain Online	N/A	N/A
Test 5	???	Remain Online	N/A	N/A

AVERAGE TRIP TIME N/A **ST DEV** N/A

900 MVAR CAPACITOR SWITCH

Name	Anticipated Reaction	Actual Reaction	Reaction Time	Pass / Fail
Test 1	???	Remain Online	N/A	N/A
Test 2	???	Remain Online	N/A	N/A
Test 3	???	Remain Online	N/A	N/A
Test 4	???	Remain Online	N/A	N/A
Test 5	???	Remain Online	N/A	N/A

AVERAGE TRIP TIME N/A **ST DEV** N/A

MOTOR START NON-CBEMA/ITIC/SEMI VIOLATION

Name	Anticipated Reaction	Actual Reaction	Reaction Time	Pass / Fail
Test 1	???	Trip Open	0.476	Pass
Test 2	???	Trip Open	0.475	Pass
Test 3	???	Trip Open	0.4745	Pass
Test 4	???	Trip Open	0.474	Pass
Test 5	???	Trip Open	0.475	Pass

AVERAGE TRIP TIME 0.4749 **ST DEV** 0.0007

MOTOR START CBEMA/ITIC/SEMI VIOLATION

Name	Anticipated Reaction	Actual Reaction	Reaction Time	Pass / Fail
Test 1	Trip Open	Trip Open	0.1925	Pass
Test 2	Trip Open	Trip Open	0.1925	Pass
Test 3	Trip Open	Trip Open	0.191	Pass
Test 4	Trip Open	Trip Open	0.1925	Pass
Test 5	Trip Open	Trip Open	0.1905	Pass

AVERAGE TRIP TIME 0.1918 **ST DEV** 0.0010

SIX PULSE BRIDGE LOAD

Name	Anticipated Reaction	Actual Reaction	Reaction Time	Pass / Fail
Test 1	???	Remain Online	N/A	N/A
Test 2	???	Remain Online	N/A	N/A
Test 3	???	Remain Online	N/A	N/A

HARMONIC DISTORTION

Name	Anticipated Reaction	Actual Reaction	Reaction Time	Pass / Fail
Test 1	???	Remain Online	N/A	N/A
Test 2	???	Remain Online	N/A	N/A
Test 3	???	Remain Online	N/A	N/A

SUMMARY OF SIMULATED FAULT TESTS

Test 4	???	Remain Online	N/A	N/A
Test 5	???	Remain Online	N/A	N/A

AVERAGE TRIP TIME N/A **ST DEV** N/A

Test 4	???	Remain Online	N/A	N/A
Test 5	???	Remain Online	N/A	N/A

AVERAGE TRIP TIME N/A **ST DEV** N/A

Table 7: Detailed Miscellaneous Test Results

Notes

Motor Start Non CBEMA/ITIC/SEMI Violation: The DSP tripped open even though this motor start does not violate CBEMA/ITIC/SEMI Curves

Motor Start CBEMA/ITIC/SEMI Violation: The DSP properly tripped open and reclosed after the event, but then tripped open again for unknown reasons

DTC Registered Test Procedure CERTS Microgrid Static Switch Testing		
Dolan Technology Center	Document No: DTC212812.206	
Written by: David A. Klapp	Effective Date: April 04, 2006	Target Group: Assigned
Approved by: K. P. Loving, P.E.	Procedure Review Date: As Needed	

Revision #	Date	Revision Description
0	04/04/06	Original

Team Members and Roles

3.0 Name	4.0 Group	5.0 Primary Roles
David Klapp	Operations	Test Engineer
Kevin Loving	Operations	Test Coordinator
CERTS	CERTS	Sponsor

6.0 Purpose, References, Definitions

Purpose: The purpose of this document is to define the procedure for testing the CERTS Microgrid Static Switch DSP and SEL-351 Relay for detection and reaction to various power quality events and simulated faults (see Figure 5).

This procedure defines the functional requirements for testing and documenting the results.

Criterion: The CERTS Microgrid Static Switch DSP or SEL-351 Relay should correctly identify and respond to predetermined power quality events and simulated faults, demonstrating its ability to island the Microgrid and properly protect the load.

Materials to be used include, but are not limited to; an Manta MTS 1710 relay test set, an Elgar SW 5250A Smart Wave, an Elgar SS-66 3-phase power supply, a 480 volt 3-phase variac, and a Wavetek Datron 195 Universal Waveform Generator.

Definition: The CERTS Microgrid Static Switch DSP and SEL-351 Relay located in Cabinet 2a.

Reference documents:

DTC Standard Operating Procedures
SOP – Barricades, Barriers and Guards, 204-DTC-011
SOP – Personal Protective Equipment, 204-DTC-032
SOP – Job Safety Analysis, 204-DTC-070

7.0 Responsibilities

Scheduling:	Test Coordinator
Parameter Specification:	Sponsor, Test Engineer
Setup:	Test Engineer
Execution:	Test Engineer
Report:	Test Engineer

2.1 The Test Engineer shall comply with all the appropriate DTC operating procedures that are listed above in Clause 1.6.

2.2 The Test Engineer in charge during a test must be familiar with the test plan.

2.3 All persons who are directly involved during the execution of the tests shall wear the appropriate personal protective equipment.

2.4 The Test Coordinator shall ensure the required qualifications of all participants are met.

2.5 The Test Coordinator shall be responsible for approving this procedure and any revisions to it.

8.0 Procedure

General Safety Requirements

Testing in Test Cell A shall be in accordance with:
SOP 204-DTC-011, Barricades, Barriers and Guards.
SOP 204-DTC-032, Personal Protective Equipment.

The proper operation of any associated test equipment based on the manufacturer's operator's manual.

A Job Safety Briefing shall be performed prior to testing.

Test Setup

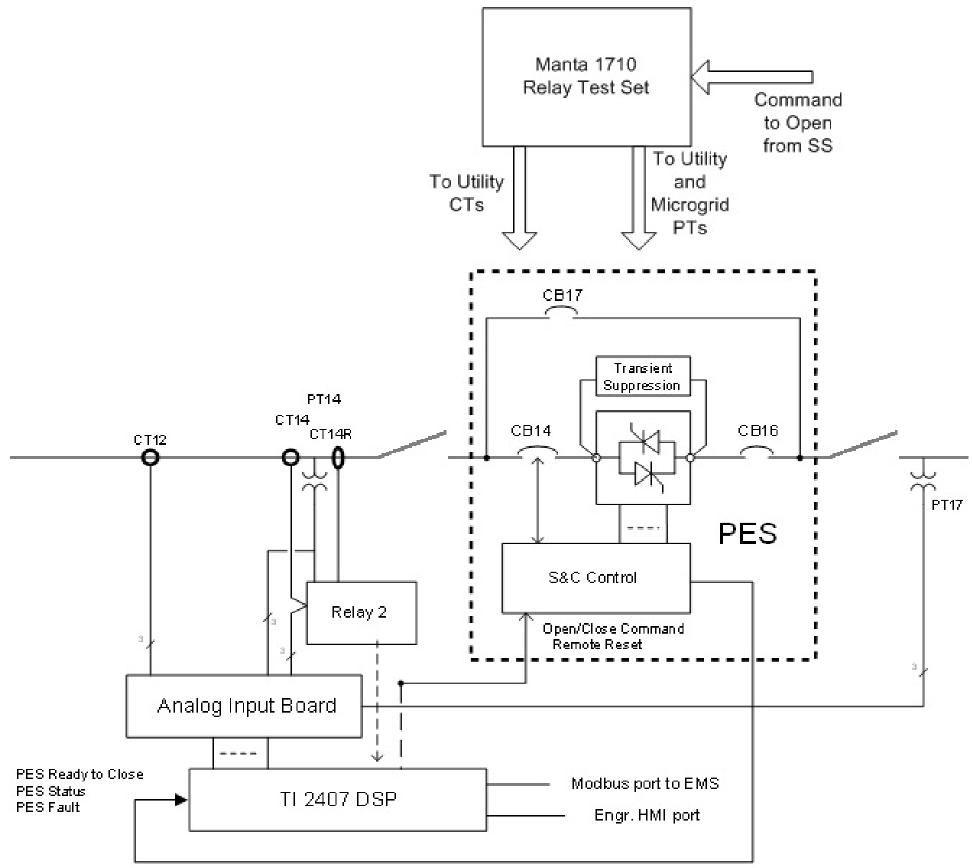

Figure 5: Test setup for Power Quality and Simulated Fault Testing.

All testing will be preformed at low power to reduce the possibility of damage to the SS and test equipment.

The SS should be assembled and connected to all of the appropriate control cabinets as needed for functionality.

The measurement PTs and CTs of the SS will be disconnected and the Manta relay test set will be connected in their place.

The reverse power relay will either be disabled or will be connected to a source to simulate continuous power import.

<u>Test Procedure</u>

The Manta will be configured to deliver the same stimulus to both sides of the SS.

Each individual test will consist of three parts, a pre-fault, a fault, and a post-fault. Note: the word “fault” as referred to above means the condition of abnormality under test. This is not solely limited to electrical faults but also includes the power quality events of interest.

The pre-fault configuration which will lie within the normal operation conditions where the Microgrid can be connected to the utility.

The fault configuration will consist of the desired power quality or simulated fault event

The post-fault configuration will return to the normal operation conditions where the Microgrid is connected to the utility.

The Manta will be set to the pre-fault configuration and the SS will be commanded closed.

The Manta will then be triggered into the fault configuration.

Once the SS responds to the fault configuration the Manta move to the post-fault configuration.

The SS response to the fault and the time for the response will be recorded in the results form, CERTS Static Switch PQ Results.xls.

This testing will not be concerned with whether or not the SS resynchronizes with the utility source once the Manta is in post-fault configuration.

The power quality and simulated fault tests in CERTS Static Switch PQ Tests.doc will be performed.

All results shall be recorded in the results form, CERTS Static Switch PQ Results.xls.

9.0 Hazards & Mitigation

Hazards that exist during testing of the "Purple Power Cleaner" include dangerous voltage levels and electrical flashover. These hazards are mitigated by the following measures:

Compliance with all applicable SOP's, including

204-DTC-11 Barricades, Barriers, and Guards
204-DTC-32 Personal Protective Equipment
204-DTC-70 Job Safety Analysis

10.0 Quality Assurance

Quality assurance is maintained by ensuring that:

The measurement equipment used is within the specified calibration interval.

Measurement uncertainty is appropriate to the needs of the test.

All appropriate information on the test results form is filled in.

All setup parameters, calculations and assumptions are fully documented.