HF Controls

HFC-6000 Control System

Seismic Qualification Test Procedure

TP901-200-04 Rev D

Effective Date: 1/26/16

Prepared By: _____

Reviewed By: _____

Approved By: _____

[XXXXXXXXXXXXXX]

Revision History

Date	Revision	Author	Changes
02/03/2012	A	R. McClanahan	Initial Release
10/15/2013	B	Ivan Chow	Revised Required Seismic Spectrum as specified by EPRI updated information
10/22/2013	C	Ivan Chow	Revised due to Microsoft Word formatting errors. CR 2013-0220
1/26/16	D	E. O'Donnell	Clarification of use of bezels during testing per NRC comment

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1.0 PURPOSE AND SCOPE

This test procedure is designed to provide data necessary to qualify an HFC-6000 control system for Safety-related Class 1E applications in nuclear power plants, according to the seismic testing requirements detailed in EPRI TR-107330. Seismic testing exposes a specially configured HFC-6000 control system (Test Specimen) to a set of dynamic spectra designed to simulate an Operating Basis Earthquake (OBE) and a Safety Shutdown Earthquake (SSE). The dynamic spectra will consist of tri-axial, random, multi frequency waveforms that will be transmitted to the Test Specimen by means of hydraulic actuators attached to a Seismic Simulator Table. The overall scope of testing will consist of the following phases:

- Initial setup and pretest for equipment verification
- Low amplitude resonance search to identify critical frequencies below 100 Hz
- Five OBE
- One SSE with prudency and operability tests running
- Post seismic test inspection and operability test.
- Analysis of the seismic test spectra with various damping factors

The following references in the EPRI TR-107330 specification define the content and scope of this test procedure: 4.3.9, 4.4.6.1, 4.6.1.1, Figure 4-5, Table 5-1, 6.2.1.1.A, 6.3.1.C, 6.3.4

2.0 REFERENCES ABBREVIATIONS, AND ACRONYMS

2.1 REFERENCES

EPRI TR-107330	Generic Requirements Specification for Qualifying a Commercially Available PLC for Safety-Related Applications in Nuclear Power Plants
IEEE 323-1983	IEEE Standard for Qualifying Class 1E Equipment for Nuclear Power Generating Stations
IEEE 344-1987	IEEE Recommended Practice for Seismic Qualification of Class 1E Equipment for Nuclear Power Generating Stations
NRC RG 1.100	Seismic Qualification of Electric and Mechanical Equipment for Nuclear Power Plants
WI-ENG-815	Red Line Procedure

2.2 ABBREVIATIONS, AND ACRONYMS

CSM	Control Switch Module
HAS	Historical Archiving System
HPAT	HFC Plant Automated Tester
M/A	Manual/Automatic
MCL	Master Configuration List
OBE	Operating Basis Earthquake
RRS	Required Response Spectrum
SOE	Sequence of Events
SSE	Safe Shutdown Earthquake
Test Specimen	A specific combination of hardware and software components to be subjected to specified test conditions
TRS	Test Response Spectrum
TSAP	Test System Application Program

3.0 TEST PREREQUISITES

The following paragraphs identify the equipment required to perform this test and provide detailed instructions for setup of the Test Specimen prior to starting the test sequences.

3.1 EQUIPMENT REQUIRED

A detailed listing of hardware and software components of the Test Specimen is provided in the Master Configuration List listed in Attachment 7.4. The automated Operability, Prudency, and TSAP Validation tests are also listed in Attachment 7.4. Test equipment required during execution of these tests is listed in Attachment 7.3.

The Seismic Simulator Table, operating controls, accelerometers, and recording equipment (or equivalent) will be provided by a qualified Test Laboratory. The Test Lab and their test plan are listed in Attachment 7.2. This vendor will be responsible for the following:

- Identifying all measuring and test equipment (except the HPAT, SOE, and HAS) to be used.
- Certifying current calibration of all test equipment supplied by the Test Lab.
- Mounting accelerometers on the Test Specimen.
- Providing the test fixture for mounting the Test Specimen on the Seismic Simulator Table.
- Providing appropriate recorders for the accelerometers.
- Providing ac power sources for the Test Specimen.

- Providing a grounding system that meets requirements of the HFC power distribution diagrams.

The seismic test will be conducted in a mild environment with no special temperature or humidity stress conditions applied.

3.2 PRECAUTIONS

The following precautions relate to execution of various phases of the seismic test procedure:

- Performance of certain test sequences requires test personnel to measure elevated voltage levels at power supply and I/O terminals. Exercise caution to avoid exposure to potentially lethal shock.

- The Seismic Simulator Table produces large amplitude vibrations. Contact with this test fixture or attached cables could result in serious injury.

- I/O and communication cables are routed from the Test Specimen on the Seismic Simulation Table to monitoring equipment. The cables must be carefully secured in place to prevent damage during the seismic test and to prevent them from becoming a trip hazard.

3.3 TEST PERSONNEL

The seismic test will be conducted at the Test Lab using the Seismic Simulator Table at that facility. One or more qualified test engineers supplied by the Test Lab will control and monitor test conditions in accordance with the Test Lab Test Procedure listed in Attachment 7.2. A qualified test engineer from HFC will oversee setup of the Test Specimen, conduct all functional tests, and certify all test records produced during the test period.

3.4 RED-LINE POLICY

The HFC policy for introducing red-line corrections into a test procedure are presented in WI-ENG-815. Such entries may be used to correct errors of content and procedural sequence in test documents or in engineering drawings to prevent disruption of a test in progress.

3.5 EQUIPMENT SETUP

3.5.1 Mechanical Installation

The Test Specimen will be assembled for prequalification testing at HFC. After completion of the prequalification tests required by the Qualification Master Plan listed in Attachment 7.5, the assembly, HPAT cabinet, PC workstation, interconnecting cables and any necessary support equipment will be shipped to the Test Lab for execution of the qualification tests. The Test Specimen will be received and mounted on the test fixture

supplied by the Test Lab. The following steps outline general setup requirements for the seismic test. The procedure is based on the following presumptions:

- Test Specimen components (panels and chassis) are transported to the Seismic Simulator Table without disassembly from their test fixtures.
- The mechanical test fixtures will be welded to the top of the Seismic Simulator Table, and the HPAT and monitoring equipment will be located in a designated area near the table.
- The test fixture will provide support bars that will permit securing each cable within 6 inches from the connector or terminal point.
- System configuration will consist merely of reconnecting electrical, communication, and power cables.
- All rack-mounted cards will be tested with bezels. Bezels will be screwed into the rack with a minimum of hand tight torque.

1. Verify that the copy of this Test procedure and the Test Lab Procedure listed in Attachment 7.2 in hand are the latest approved versions.	_____
2. Position the test fixtures for the Test Specimen chassis and panel-mounted equipment on the Seismic Simulator Table.	_____
3. Verify that test cables can reach from the test fixture to the HPAT and PCs before welding starts.	_____
4. Test Lab personnel are setting up the test fixtures to the Seismic Simulator Table. List their method: _____	_____
5. Inspect each component for obvious signs of physical damage prior to installing interconnecting cables. If any damage is detected, record the serial number of the component affected and the nature of the damage in the Pre-test records in Attachment 7.7. Replace the damaged component with a spare, and record that change in status in the Pre-test records in Attachment 7.7.	_____
6. Use a torque screwdriver or wrench to verify that each panel mounting fastener is torqued to the level indicated on Attachment 7.1.	_____
7. If any rack-to-rack or rack-to-panel cable was disconnected to facilitate transport, reconnect those cables in accordance with drawings listed on Attachment 7.1.	_____
8. Install communication wiring between the Test Specimen and the HPAT as shown on drawing listed on Attachment 7.1.	_____

9. Mount I/O cables to the connectors on the back of each rack. Ensure that each cable is connected to the correct rack and slot and that the connector lock engages securely. **Caution**: Each I/O cable is marked with a cable tag at both ends that identifies the rack and slot assignment for that cable. Every cable must be connected at the correct slot in order to produce the correct interconnection with the HPAT.	_____
10. Route I/O cables from the Seismic Simulator Table to the HPAT. Connect the I/O cables to the HPAT bezels in accordance with drawing listed on Attachment 7.1.	_____
11. Connect designated Test Specimen relay DO channels to the Test Lab Chatter Box monitor. (Refer to Operability Test BOE points on Attachment 7.4.)	_____
12. Route power cables from the AC power source to the Test Specimen. Connect the power lines to the Test Specimen power supplies as shown on drawing listed on Attachment 7.1.	_____
13. Ensure that all I/O, communication, and power cables are supported to relieve stress from the connectors and terminal attachment points. Ensure that enough slack is present to prevent table motion from damaging the cables.	_____
14. Use cable ties to secure each cable connected to the Test Specimen to a support bar within 6 inches from its connector or terminal point. Ensure that the cables are secured to prevent whipping during dynamic runs.	_____
15. Apply operating power to the Test Specimen and the HPAT.	_____
16. Monitor card edge LEDs to verify that both the HPAT controller and the Test Specimen complete initialization and begin normal operation.	_____

Validation that test setup is completed: _____

Name/date

3.5.2 Test Specimen Performance Monitoring

The following equipment will be used for performance monitoring of the Test Specimen:

- A total of _____ accelerometers _____ Initial/Date

- An SOE logger is a software utility provided in the HPAT and is used to monitor digital events. Wiring to these channels is shown on drawing listed on Attachment 7.1 and the configuration of the SOE channels is described in the tests listed on Attachment 7.4.

- An HAS that has the capacity to log any point available from C-link DDB. The HAS is a software utility of the PC workstation that operates with the HPAT. Configuration of points for logging by the HAS is covered by tests listed on Attachment 7.4.

- A Chatter Box monitor (provided by the Test Lab) to monitor relay on the DO channels.

The following steps define setup requirements for the monitoring equipment.

1. The Test Lab personnel are responsible for installing accelerometers on the Test Specimen agreed upon with the HFC representative. These accelerometers and will be used to monitor individual components in the Test Specimen. These accelerometers are in addition to the basic ones required to monitor the test bed itself.	_____
2. Record the reference designation and specific position for each accelerometer mounted on the Test Specimen components on Attachment 7.2.	_____
3. The Test Lab personnel are responsible for installing monitoring wires from a separate recorder to each accelerometer. Record the reference designation for the recorder associated with each accelerometer on Attachment 7.2.	_____

Validate that installation of the monitoring equipment is complete:

_____

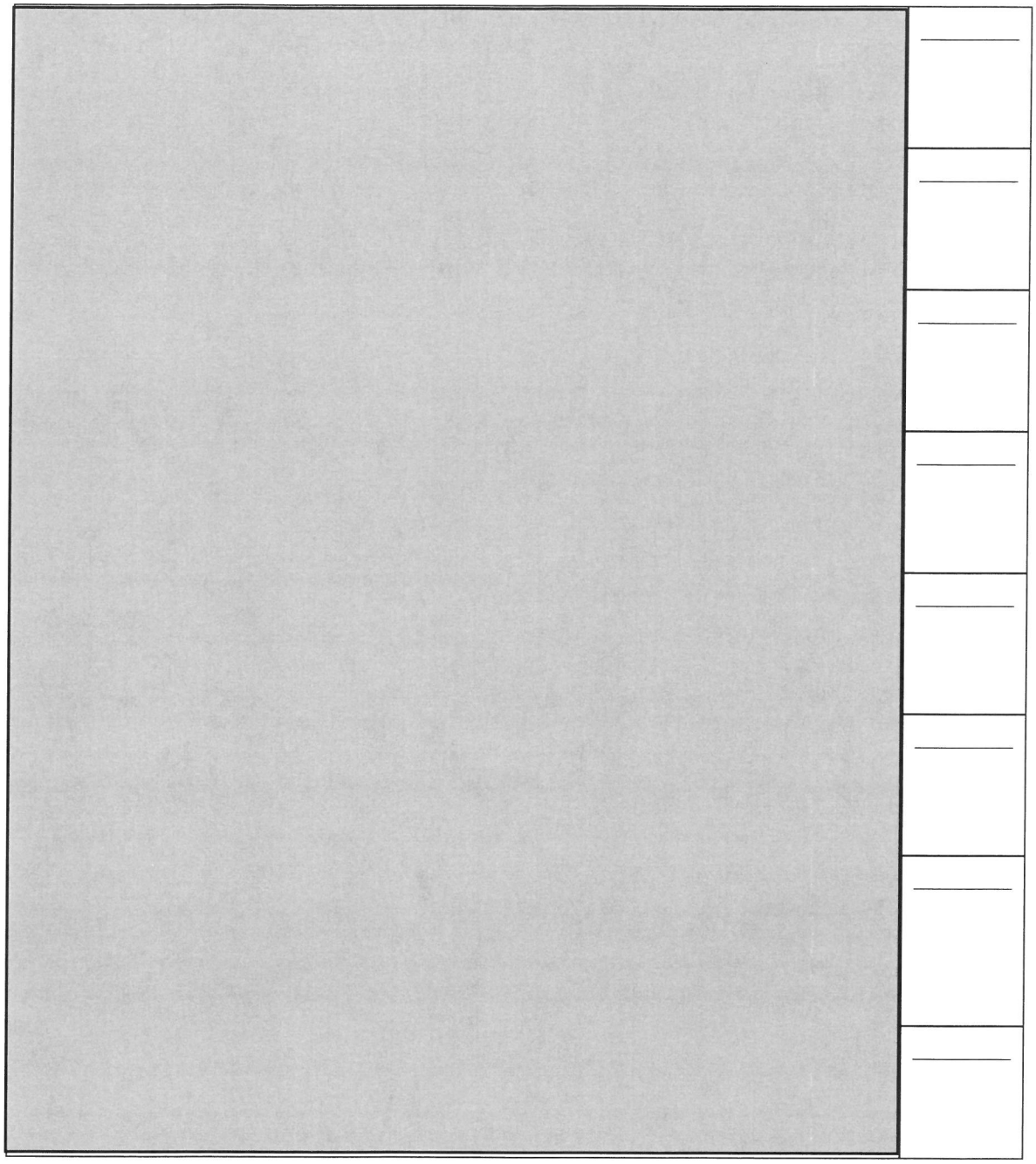
Name/date

4.0 SEQUENCE OF TESTING

4.1 PRE TEST

After the Test Specimen is installed on the Seismic Simulator Table and interconnected with the test equipment, the following tests shall be run to verify that all components are

fully operational and to establish a performance baseline for the seismic test results (see Attachment 7.6).



NOTE

The HAS is implemented with an Excel database; the SOE is implemented with a separate circular memory buffer on the individual DI cards. The SOE test report must be run following each test to prevent overwriting the circular buffer.

Tests 1 through 4 and 7 should be run concurrently to obtain a baseline record. Tests 5 and 6 should be run separately after obtaining the baseline data. All data generated during execution of these tests shall be recorded as specified in Attachment 7.6.

4.2 RESONANCE SEARCH

A preliminary resonance test will be conducted to determine if the Test Specimen components have any resonant frequencies within the RRS. The test will be conducted by the Test Lab personnel by imposing a low level sinusoidal sweep. If one or more resonant frequencies are detected, the Test Response Spectrum (TRS) will be centered on the resonant frequency that produces the maximum response in the Test Specimen. Overall requirements for the resonance search will be governed by IEEE 344. Detailed procedures for conducting the resonance search are covered by the Test Lab Test Procedure listed in Attachment 7.2. Requirements are as follows:

1. Leave the Test Specimen powered up during the resonance search, but stop the automated tests.	_____
2. While the resonance search is running, monitor internal status to detect any disruption that might indicate loose connections.	_____
3. The test waveform will have the following characteristics: • [redacted] • •	_____
4. The sweep waveform will be applied to each of the three axes separately with all of the accelerometers monitoring the amplitude of the Test Specimen response.	_____
5. The response graphs will be analyzed to identify all resonant frequencies within the range of the Required Response Spectrum (Figure 1) and recorded in Attachment 7.5.	_____
6. The TRS will be composed of a random spectrum with sine spectra at the specific frequency of the major resonance frequencies of the Test Specimen (if any). The resulting TRS should completely envelope the RRS.	_____
7. If any disruption in internal system status is detected during resonance search resolve the problem before the start of the first OBE run.	_____

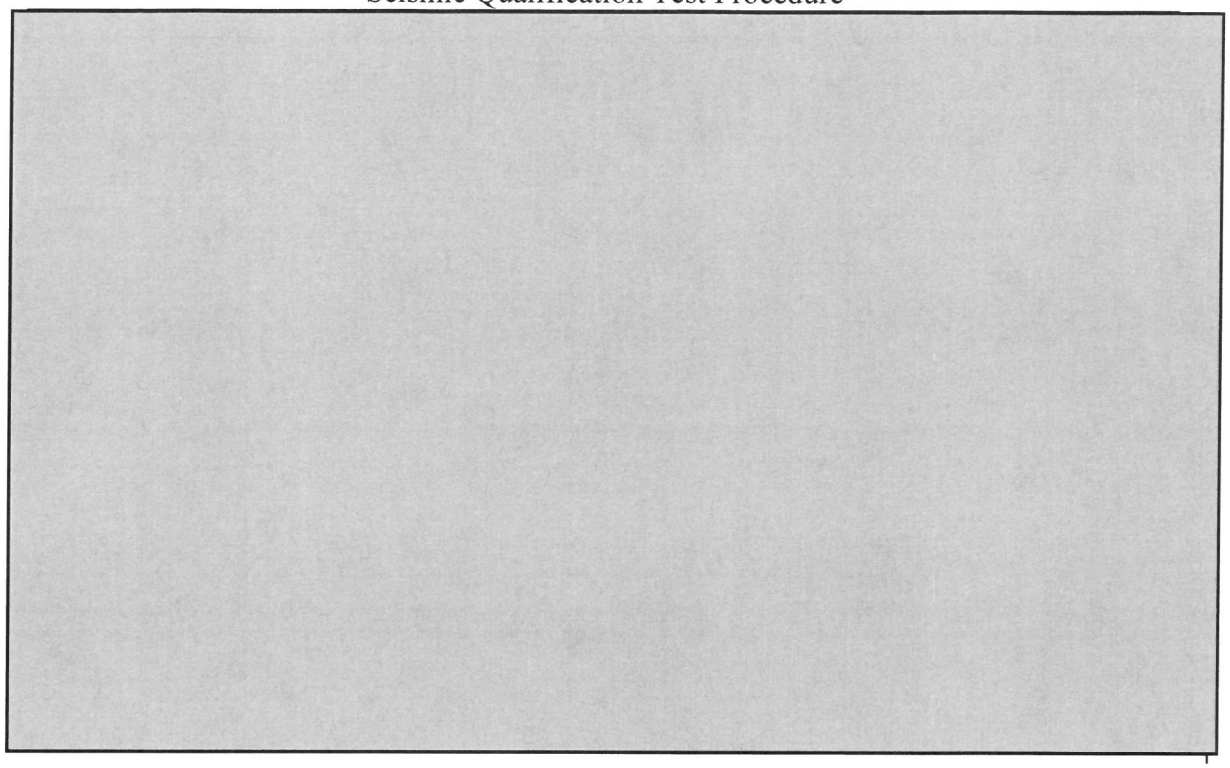


Figure 1. RRS Test Spectrum

4.3 DYNAMIC TESTS

The Test Lab personnel will conduct the dynamic seismic tests using the TRS established as the result of the resonance sweep test in accordance with their Test Procedure. The Test Lab personnel will perform five tests based on the OBE RRS and one test based on the SSE RRS as shown in Figure 1. The response spectrum of the Test Specimen will be reported for [XXXXXXXXXXXXXXXXX] damping factors. While any particular dynamic test is in progress, an HFC test engineer will run the specified combination of automated tests (Table 1) to verify overall system performance. Following each dynamic test, the entire Test Specimen will be examined for mechanical damage, and the results of the automated test will be compared with the required acceptance criteria. Any mechanical damage sustained during testing will be recorded and reported in detail in the seismic test report. If some portion of the functional performance test fails to meet the acceptance criteria, the peak acceleration of the TRS will be reduced in steps of no more than 2 g per step, and the test will be repeated until the Test Specimen passes the automated test. However, the peak acceleration of the TRS will not be reduced below 8 g under any condition.

Table 1. Functional Test Requirements

Test Condition	Static Test	Operability Test	Prudency Test

The overall dynamic test sequence shall be as follows:

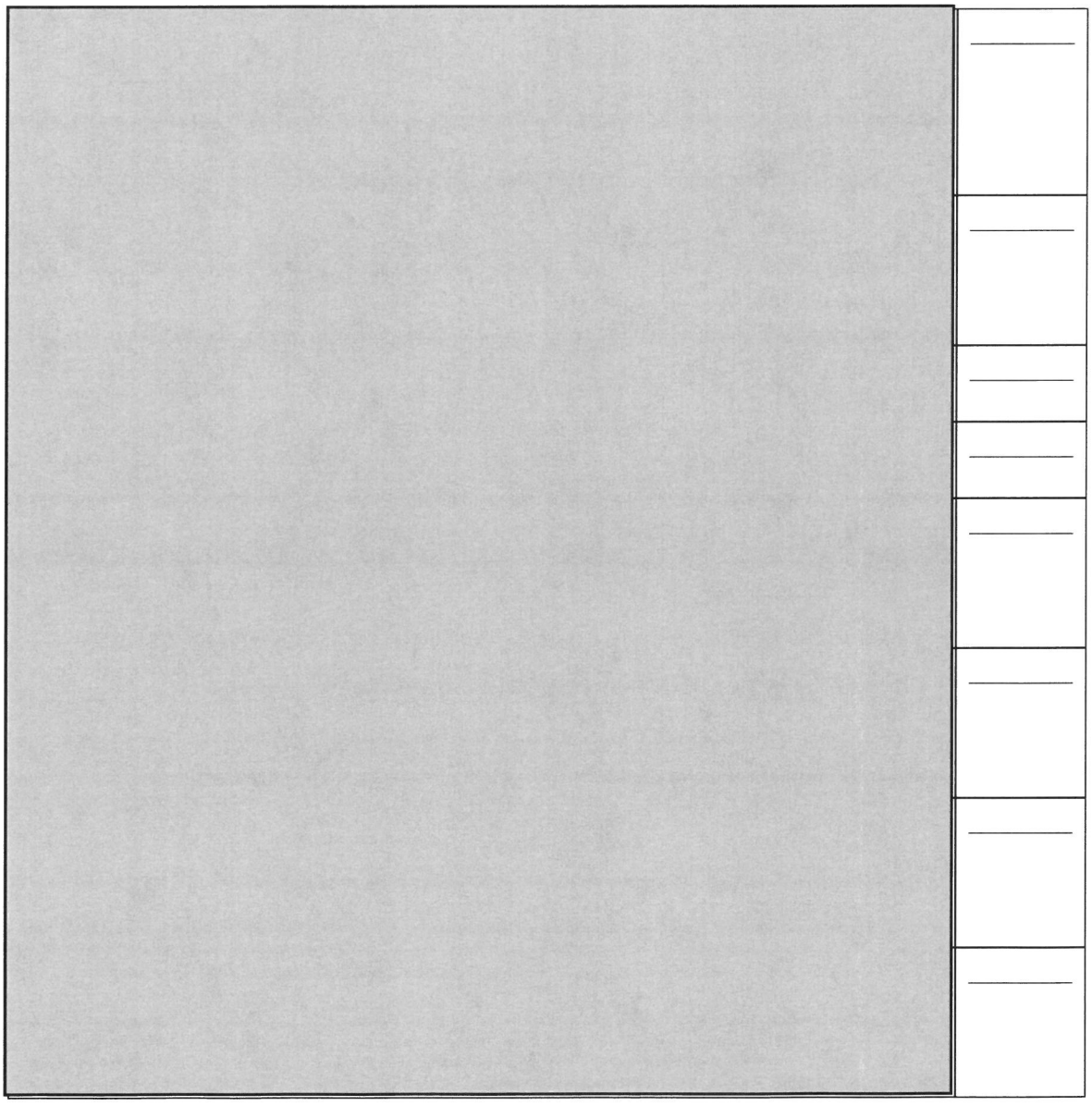
1. Set the ac power sources for the Test Specimen to supply 90 vac at 57 Hz before the start of the seismic test runs.	_____
2. Apply operating power to the Test Specimen.	_____
3. Start the following automated tests	_____
[redacted]	_____
	_____
	_____
	_____
	_____
EPRI TR-107330 paragraph 6.3.4.2 requires that ½ of the relay DO channels be transitioning during OBE and SSE tests. The Burst of Events test will be used to ensure that an adequate number of channels are transitioning on-off and off-on throughout the test period.	
4. Set static conditions for the three simulated analog loops as follows: a. At each M/A station, press the A switch to select Auto mode. b. Verify that the setpoint is at the default value or at mid range. c. Allow the controlled output (CO) and process variable (PV) signals to stabilize.	_____

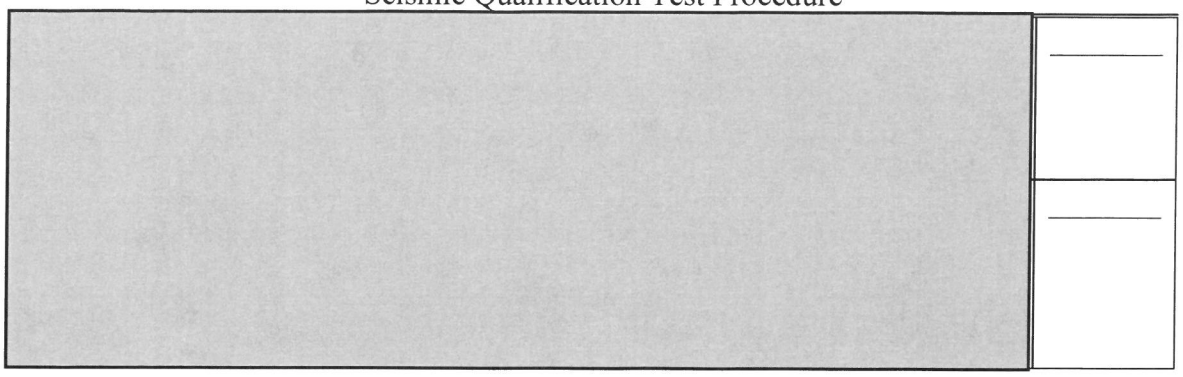
5. Set static conditions for all of the simulated digital loops as follows: a. At each CSM, press either switch to clear alarm status. b. Use the CSM to change control loop status from its starting default state (e.g., from closed to open) **Note**: The solenoid outputs for some of the simulated digital loops are overridden by the Burst of Events test and should not be used for static tests (see TSAP logic listed in Attachment 7.1).	_____
6. Enable dynamic HAS and SOE logging for all of the configured trends. Refer to the Manual Digital Response Time Test in the Operability Test listed in Attachment 7.4.	_____
7. The Test Lab personnel shall run the seismic spectrum for the current test.	_____
8. After completion of each test run, stop the automated tests and generate the SOE and Chatter Box logs for that test.	_____
9. Record the following identifying data for the current test run in the test report log on Attachment 7.7: • Current test run • Seismic spectrum being run (OBE or SSE) • Starting time of test run. • Concluding time of test run. • SOE log file name. • Chatter Box log file name.	_____
10. Inspect the Test Specimen for damage following each seismic test run. Make a detailed record on Attachment 7.7 of any damage detected.	_____
11. Check mounting screws of the Test Specimen following each test run for signs of loosening. Torque the mounting screws as required to meet torque levels indicated on Attachment 7.1. Make a detailed record on Attachment 7.7 of any mounting screws that become loosened during seismic excitation.	_____
12. If a failed component must be replaced from spares, record the serial number and part number of the replacement in Attachment 7.7.	_____

13. Compare the SOE and HAS reports with the acceptance criteria (paragraph 5.0). If any point fails to satisfy its acceptance criteria, the test run shall be repeated with reduced peak acceleration. The peak acceleration of the TRS may be reduced in steps of 2 g (max), but it shall not be reduced below 8 g.	_____
14. Repeat this test sequence for each OBE test and for the SSE test.	_____

4.4 POST SEISMIC TEST

After completion of the SSE and the post test inspections, HFC test personnel shall conduct the following functional test to detect any deterioration in Test Specimen performance (see Attachment 7.8).





5.0 ACCEPTANCE CRITERIA

Overall acceptance criteria for seismic testing are specified in paragraph 4.3.9 of EPRI TR-107730. These criteria are summarized as follows:

- The Test specimen shall meet its performance requirements during and following application of an SSE simultaneously applied in three orthogonal directions. The SSE shall be as shown in Figure 1 or the maximum capability of the Seismic Simulator Table. The Test Specimen shall withstand application of the SSE spectrum after application of five OBEs.

- All connections shall remain intact, all modules shall remain fully inserted, and no functional or non-functional parts shall fall off. Tightening fasteners between successive OBEs or before the SSE does not constitute a failure condition.

- Relay contacts shall be capable of changing state from energized to deenergized and from deenergized to energized during application of OBEs and the SSE spectrum. Any spurious changes in state shall not last for longer than 2 ms for both energized and deenergized relays.

- Results of Operability and Prudency tests remain within acceptance criteria before, during, and after the seismic test runs.

6.0 QUALITY RECORDS

The following documentation will be generated during the seismic test:

- Historical archive database (electronic file)
- Pretest Test Results Record
- Resonance Search Test Results Record
- OBE Test Results Record (one for each test conducted)
- SSE Test Results Record
- Chatter Box Data Files (one for each dynamic test run)
- SOE Report Files (one for each Operability/Prudency test run)
- Accelerometer chart recordings for each dynamic test (part of the Test Lab test data).

The test report forms attached to this document and to the tests listed in Attachment 7.4 permit the test engineer to record time and date of each test and the names of the SOE and Chatter Box report files that contain the results of those tests. These records are essential to ensure that the electronic test records can be reliably associated with the corresponding test. The electronic files shall be copied to two CDs as soon as practical after completion of the test to ensure that the data is preserved without corruption following the test session. Both the written test report records and the CDs will become QA records, and these records will be filed in accordance with the Project Quality Plan.

7.0 ATTACHMENTS

Attachment 7.1 – Project Drawings
Attachment 7.2 – Test Lab Information
Attachment 7.3 – Test Equipment Log
Attachment 7.4 – Test Specimen Setup
Attachment 7.5 – Resonance Test Records
Attachment 7.6 – Seismic Pre-test Records
Attachment 7.7 – Seismic Test Records
Attachment 7.8 – Seismic Post Test Records

Attachment 7.1 – Project Drawings

Function	Drawing Number	Description
Assembly		
Torque Standards		
Cable Configuration		
Power Distribution		
I/O Wiring		
TSAP Logic		

Test Specimen: _____

Test specimen torque values:

Torque Fastener	Torque Required	Torque measured

_____ **Test Engineer /Date**

Attachment 7.2 – Test Lab Information

Test Lab	
Test Lab Procedure	
Test Lab Report	

Accelerometer Placement

No.	Accelerometer Tag	Recorder Channel	Location being Monitored
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
17			
18			
19			
20			

_____ **Test Engineer /Date**

Attachment 7.3 – Test Equipment Log

Test Equipment	Instrument ID	Cal Due Date
Multimeter		

_____ **Test Engineer /Date**

Attachment 7.4 – Test Specimen Setup

Test Specimen: _____ Equipment List and Test Plan

Master Configuration List	
Qualification Master Test Plan	

Required Documents

Operational Test Procedure	
Prudency Test Procedure	
TSAP Validation Test Procedure	

_____ Test Engineer /Date

Attachment 7.5 – Resonance Test Records

Resonance Frequency	Resonance Amplitude

_____ **Test Engineer /Date**

Attachment 7.6 – Seismic Pre-test Records

Item	Description	Signoff
1	Damage detected during pre-test examination:	Test Engineer
2	Record ID of any replacement module(s):	Test Engineer
3	Start Time of Pre Test: _____ Completion Time of Pre Test: _____	Test Engineer
4	SOE Report File Name(s):	Test Engineer
5	HAS Report File Name(s):	Test Engineer

_____ **Test Engineer /Date**

Attachment 7.7 – Seismic Test Records

Test Name: _____

Item	Description	Signoff
1	Peak Amplitude: _____ Damping Factor: _____	_____ Test Engineer
2	Start Time of Test: _____ Completion Time of Test: _____	_____ Test Engineer
3	Damage detected during post-test examination:	_____ Test Engineer
4	SOE Report File Name(s):	_____ Test Engineer
5	HAS Report File Name(s):	_____ Test Engineer
6	Fasteners checked and re-tightened following test run:	_____ Test Engineer
7	Record ID of replacement module(s):	_____ Test Engineer

_____ **Test Engineer /Date**

Attachment 7.8 – Seismic Post Test Records

Item	Description	Signoff
1	Record ID of any replacement module(s):	Test Engineer
2	Start Time of Post Test: _____ Completion Time of Post Test: _____	Test Engineer
3	SOE Report File Name(s):	Test Engineer
4	HAS Report File Name(s):	Test Engineer
5	Damage detected during Post-test examination:	Test Engineer

_____ **Test Engineer /Date**