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Seismic

EQUIPMENT QUALIFICATION BY THE COMBINED ANALYSIS AND TEST APPROACH FOR THE FOUR-BAY CABINET OF THE TWO-TRAIN SOLID STATE PROTECTION SYSTEM (SSPS)

(SEISMIC DESIGN VERIFICATION ANALYSIS AND DESIGN)

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1.0 OBJECTIVE

The objective of this qualification program is to demonstrate that the four-bay cabinet of the Two-Train Solid State Protection System (SSPS) will experience the comparable in-equipment seismic responses to those of the three-bay SSPS cabinet which has been demonstrated to be seismically adequate in the previous tests. A qualification program based on the combined analysis and test approach was employed to establish the in-equipment response spectrum comparison for the seismic service conditions defined in Figure 1.

2.0 EQUIPMENT QUALIFIED

2.1 The four-bay cabinet of the Two-Train Solid State Protection System (SSPS) results from bolting together a one-bay and a three-bay cabinet. The complete assembly is attached to a common base which in turn is fastened to the floor.

2.2 The mechanical drawings applicable to the equipment are listed in Table I.

3.0 PERFORMANCE SPECIFICATIONS

The seismic behavior of the four-bay cabinet of the Two-Train Solid State Protection System was investigated through the combined analysis and test approach for the seismic service conditions defined by the required response spectra for Safe Shutdown Earthquake (SSE) of Figure 1.

4.0 DESCRIPTION OF PREVIOUS TESTS

The equipment, facilities and procedures used in the previous test are summarized in the following sections.

4.1 Three-Bay SSPS Cabinet Tests

The three bay cabinet seismic tests are reported in references 3 and 4.

4.1.1 Test Equipment

A list of all test equipment used during previous testing appears in Table II.

4.1.2 Mo[illegible]

The three-bay cabinet mounted on a 30 inch x 90 inch x 4 inch steel mounting bracket was bolted to the vibration table to simulate field conditions.

4.1.3 Test Procedure

4.1.3.1 Vibration Input

[ ]a,b,c

4.1.3.2 Vibration Monitoring

Time histories of the accelerometer outputs were obtained during each vibration input test and were used as an aid in determining resonant conditions if any, and provided additional information as to the localized acceleration intensities in the equipment.

4.2 Rotary Relay Tests

The time histories and response spectra at various locations in the three bay cabinet reported as part of the rotary relay test program (Reference 1) were used to develop the in-equipment seismic responses for this program.

5.0 PROCEDURES FOR THE COMBINED ANALYSIS AND TEST APPROACH

The combined analysis and test approach is employed to demonstrate that both the three-bay and four-bay cabinets are to experience the comparable in-equipment seismic responses when subjected to the same seismic inputs. The two cabinet modules, the three-bay and the one-bay cabinet which comprise the four-bay cabinet have been previously qualified as described in references 3 and 4. In view of this, if it can be shown that, under the same seismic condition, the four-bay cabinet will undergo comparable seismic responses to that of the three-bay cabinet, then the three-bay qualification results can be used to demonstrate the seismic adequacy of the four-bay cabinet. The following is a discussion of the the procedure which leads to this conclusion.

5.1 Validation of Cabinet Analytical Models

Finite element models were first devised for each of the individual three-bay and one-bay cabinets. The adequacy of the models were verified by a comparison of the computed and measured natural frequencies. This correlation was carried out for both the three-bay and the one-bay cabinets for the lowest few modes of vibration. The two cabinet models were then coupled to form the four-bay analytical model.

5.2 Boundary Conditions

The bolted base boundary conditions and the mass and stiffness properties of this four-bay cabinet model are kept compatible to those used in the individual three-bay and one-bay models.

5.3 Modal Analysis of the Cabinets

Modal analysis of the four-bay, the three-bay and the one-bay cabinets were performed. Seismic response properties such as natural frequencies, mode shapes and participation factors were generated for all the modes with frequencies less than [ ]a,b,c.

5.4 Assumptions

Similar to the procedure (reference 2) used in generating the multi-frequency and multi-axial test inputs by means of test data an analytical equivalent of the procedure was developed to compute the in-equipment required response spectra at device locations. In this case, the test validated modeling criteria for the three-bay cabinet are assumed to be valid for the four-bay applications.

5.5 In-Equipment Required Response Spectra

The response spectrum analyses for a group of sine-beat input waveforms were performed to compute the most probable maximum in-equipment accelerations. W WECAN Computer Code was used for finite element modeling. Computations were done for a number of device mount locations. The responses as functions of sine-beat frequencies and amplitudes were first generated for all the cabinets involved. The in-equipment response spectral peaks were then generated for all the device locations of interest. The inputs associated with all the equipment principal axis directions were considered. Use had been made of the previously available seismic cabinet amplification data to arrive at a conservative estimate of the spectral peaks and the frequency content of the in-equipment response spectra. Finally, the envelopes of the spectral peaks were established.

5.6 Structural Integrity and Functional Operability Considerations

The seismic structural integrity of the four-bay cabinet is evaluated by reviewing the response characteristics for both the three-bay and the four-bay cabinet. Geometrical properties such as the aspect ratios of the individual cabinets were considered for determining the overturning effects on the structural adequacy.

For electrical operability considerations, a comparison is made on the spectral intensity and frequency contents of the in-equipment response spectra computed for both the three-bay and the four-bay cabinets.

6.0 RESULTS

The detailed finite element models have been developed to compute seismic behavior of the Solid State Protection Cabinets. These test validated models are considered adequate for establishing the comparison between the in-equipment required response spectra of the three-bay and the four-bay cabinets. Table III lists the measured and the computed natural frequencies for the cabinets. Vertical modes are found to have frequencies higher than [ ]a,b,c. They are not seismically significant and are considered inconsequential.

It is shown that for the floor seismic service conditions defined in Figure 1, the four-bay cabinet will experience less severe seismic overturning response than the three-bay cabinet previously qualified for structural integrity. Hence, the four-bay cabinet is structurally qualified.

Figure 2 shows the comparison of the in-equipment response spectra for the cabinets corresponding to the Figure 1 seismic conditions. Since there exists essentially the same envelope spectral curve both in intensity and frequency content, operability qualification previously achieved for the three-bay configuration in references 3 and 4 are considered applicable to the four-bay cabinet.

7.0 SUMMARY

The combined analysis and test approach has been introduced to generate the in-equipment required response spectra for the generic floor seismic service conditions. In-equipment envelope response spectra for the Solid State Protection System (SSPS) cabinets were developed. Structural integrity qualification was obtained by considering the overturning moment effects. The operability of the three-bay cabinet was demonstrated in previous tests. Since comparable in-equipment response spectrum envelopes are seen to exist for the three-bay and the four-bay cabinet configurations, the operability seismic qualification previously achieved for the three-bay configuration is considered applicable to the four-bay cabinet.

8.0 REFERENCES

(1) WCAP-8694, "Seismic Qualification of the Rotary Relay for Use in the Solid State Protection System," by E. L. Vogeding and S. J. Jarecki, January 1976.

(2) WCAP-8624 "General Method of Developing Multifrequency Biaxial Test Inputs for Bistables".

(3) WCAP-7817 and supplements, "Seismic Testing of Electrical and Control Equipment (Low Seismic Plants)," by E. L. Vogeding, December 1971.

(4) WCAP-7821 and supplements, "Seismic Testing of Electrical and Control Equipment (High Seismic Plants)," by L. M. Potochnik, December 1971.

TABLE I

FOUR-BAY CABINET OF THE TWO-TRAIN
SOLID STATE PROTECTION SYSTEM - MECHANICAL DRAWINGS

Outline and Installation	Drawing Number	Revision
	7245D75, sh. 1	10
	2	7
	3	7
	4	9
	5	7
	6	8
	7	6
	8	2
Assembly (SNUPPS)	1061E13, sh. 1	B
	2	A
	3	A
	4	B
Cabinet Sub-assembly	1048F78-G01	B
Cabinet Weldment Output II	1057E81-G01	
	sh. 1	D
	2	A
	3	C
Cabinet Weldment Three-Bay Cabinet	1057E81-G01	
	sh. 1	H
	2	J
	3	G
	4	H
	5	G
	6	J
	7	H

TABLE II

TEST EQUIPMENT FOR THE THREE-BAY CABINET
OF THE SOLID STATE PROTECTION SYSTEM

a,b,c

TABLE III

COMPUTED AND MEASURED NATURAL FREQUENCIES

a,b,c

a,b,c

Figure 1 Required Response Spectrum Envelopes-
Four Bay Solid State Protection System

18,096-8

a,b,c

Figure 2 Comparison of the Three-Bay and the Four-Bay In-Equipment Horizontal Required Response Spectra

18,096-10