Transactions, SMiRT-23
Manchester, United Kingdom - August 10-14, 2015

Division V, Paper ID 713

A Relay Fragility Test Experience of Nuclear Power Plant in Taiwan

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Abstract

A seismic fragility testing addressed in this study is intended to determine the fragility level of relays used in Kuosheng nuclear power plant in Taiwan. Two types of Agastat relay that are used as test items, one is ETR14D3B004, and the other is ETR14B1A004. This testing is in accordance with IEEE Std. 344-1987, ANSI/ IEEE C37.98-1987 and EPRI NP-7147-SL, V2-1995 and is also performed by steps of increasing levels of seismic input until a failure (or malfunction) occurs or the shaking table reached its displacement limit of 6 inches. Four steps of seismic input in terms of Zero-Period Acceleration (ZPA) are chosen, i.e., 3.36 g, 4.4 g, 5.5 g and 6.6 g. Broadband multi-frequency seismic testing is conducted by dependent biaxial shake table, therefore, four orientations with respect of the vertical axis of the test items are accounted when subjected to a normalized relay GERS at specified ZPA levels. During the test, the functionality of test items with normally open contacts is monitored. Result shows that there is no structural or functional failure occurred during the tests. It demonstrates that two Agastat relays have a seismic ZPA rating greater than 6.6g according to ANSI/IEEE C37.98 for broad-band multi-frequency fragility testing.

INTRODUCTION

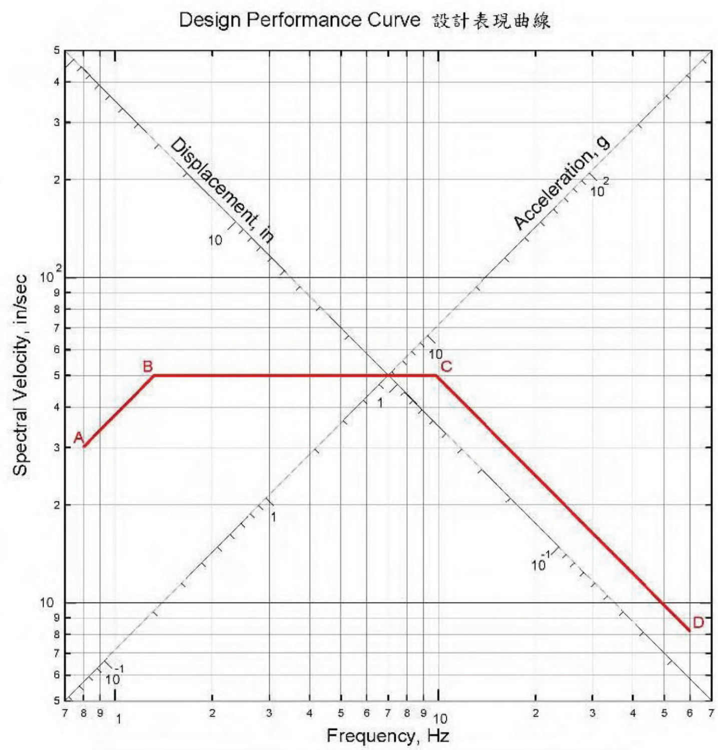
After Fukoshima earthquake event，all three operating nuclear power plants of Taiwan Power Company were asked for conducting Seismic Margin Assessment (SMA) to meet the regulatory requirement of nuclear safety by Atomic Energy Council in Taiwan. The evaluation results of Kuosheng Nucleaer Power Plant showed two AGASTAT's relays (Model No. ETR14D3B004 and ETR14B1A0040) used in the two shutdown paths were in the outlier list, which means their seismic capacity were questioned while subject to the Review Level Earthquake (RLE).The Seismic Testing Laboratory of Institute of Nuclear Energy Research was contracted by Kuosheng Nuclear Power Station to perform a seismic fragility testing for these two relays. This paper briefly depict the setup and test results of this relay fragility testing, and wrap up with a conclusion of this experience.

BACKGROUND OF TEST SPECIFICATION

Kuosheng's bidding specification requires the test shall be performed according to IEEE Std. 344-1987(1), ANSI/ IEEE C37.98-1987(2) and EPRI NP-7147-SL, V2-1995(3), other provision for test state of relay is only in the nonoperating mode, obviously the required test content is not fully cover ANSI/ IEEE C37.98. The plant's intention to do fragility test for these two relays is to qualify their fragility level, make sure their seismic capacity meet with the demand and eliminate these two items from chattering outlier list of SMA results. The function of these two relays is to open the minimum flow valve of RHR system when they are energized, normal operation they are in deenergized state. If chattering occur during earthquake, the minimum flow valve will open. The seismic capacity of ETR14D3B004 and ETR14B1A0040 relays are 3.8g both as evaluated by SMA, and demand value are 5.2g the same.

TEST FACILITY

This fragility test was conducted at Seismic Testing Laboratory of Institute of Nuclear Energy Research, a dependent biaxial shake table was used to simulate the desired earthquake environment, Figure 1 is its performance curve.

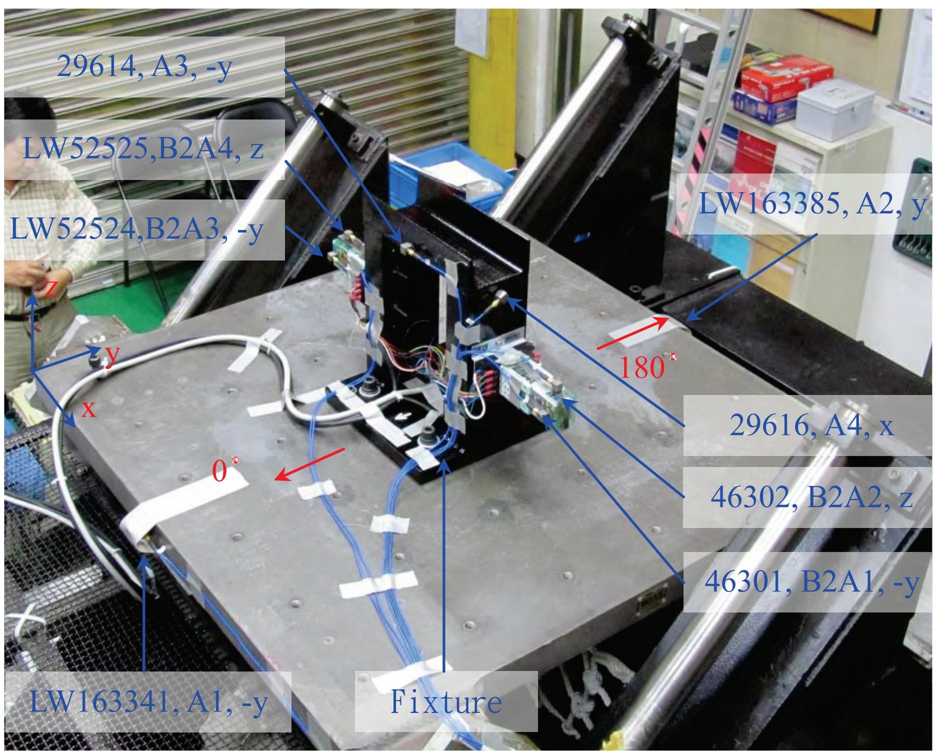


Control Point				
Point	Frequency, Hz	SV, in/sec	SD, in	SA, g
A	0.8	30.16	6	0.39
B	1.32	50	6	1.08
C	9.84	50	0.81	8
D	60	8.20	0.02	8

Figure 1. Performance curve of INER'S dependent biaxial shake table.

TEST CONFIGURATION

Figure 2 shown the relays installed on a rigid small window like fixture, the mounting manner is the same as relay's in service mounting. 8 calibrated accelarometers were installed to measure the response of table(2 in opposite horizontal direction of table, for TRS data)、fixture(3 in each axis direction of fixture, for resonance search)、relay(3 in each axis direction of relay, for resonance search) while performing sinesweep test, after that, accelarometers on fixture and relay were removed, since its mass could affect the dynamic behaviour of relay. The side-to-side test configuration means the longitude line of relay is perpendicular to the movement direction of table, and front-to-back is parallel.



Note：(29614, A3, -y) (Accelarometer Series No., Channel No., Coordinate)

Figure2. Photo of side-to-side test configuration

TEST METHOD AND REQUIRE RESPONSE SPECTRUM

The broadband multifrequency fragility testing approach in ANSI/ IEEE C37.98 is selected, and RRS is provided by Kuosheng plant using Modified GERS of EPRI NP-7147-SL, V2 as shown on figure 3. Test input motion derived from 4 modified GERS of ZPA level at 3.36 g, 4.4 g, 5.5 g and 6.6 g.

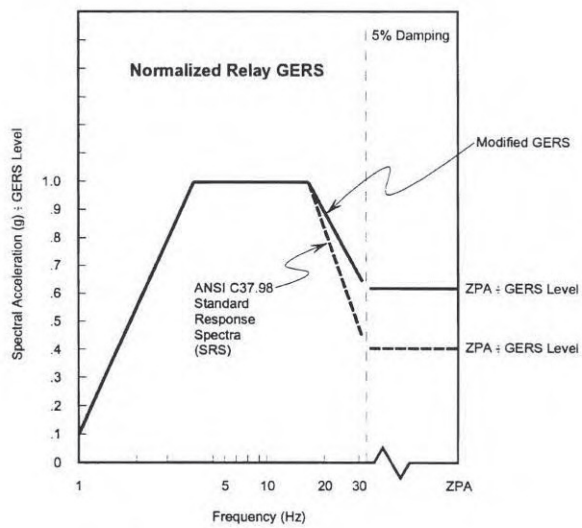


Figure 2-1
Standard normalized GERS Spectrum

Figure3. RRS for fragility tests

TEST STEPS

Tests are divided into two phase, first phase is the sinesweep to find out the natural frequency of fixture and relay. Second phase is the relay fragility test. Sinesweep test follow IEEE Std. 344, and according to ANSI/ IEEE C37.98 paragraph 5.2.2, the fragility test steps for each desired level as following:

(1) With relays at 0^0 position(front-to back orientation, as 0^0 red arrow mark shown in figure 2)
(2) With relays rotated 180^0 about the vertical axis
(3) With relays rotated 90^0 about the vertical axis (side-to-side orientation)
(4) With relays rotated 180^0 about the vertical axis again

The testing shake table has only one actuator, so the 180^0 out of phase input is achieved by rotating relays about the vertical axis .

TEST RESULTS

Test results are summarized in Table 1. Run log of tests., some further detailed information is described in the following paragraph.

Table 1: Run log of tests

Date of test ：April 23th,2014.			
Sine sweep			
File name	Time	Test direction	Result
FB_Sine.001.sef	10:38	Front to Back	Completed
SS_Sine.001.sef	10:21	Side to Side	Completed
Fragility test			
File name	Time	Test direction and orientation	Result
FB_3.63g.001.sef	10:45	Front to Back 0°	Valid
FB_3.63g.002.sef	10:53	Front to Back 180°	TRS<RRS
FB_3.63g.003.sef	10:54	Front to Back 180°	TRS<RRS
FB_3.63g.004.sef	10:57	Front to Back 180°	TRS<RRS
FB_3.63g.005.sef	10:59	Front to Back 180°	Valid
SS_3.63g.001.sef	11:05	Side to Side 0°	Valid
SS_3.63g.002.sef	11:10	Side to Side 180°	Valid
SS_4.4g.001.sef	11:12	Side to Side 180°	TRS<RRS
SS_4.4g.002.sef	11:14	Side to Side 180°	Valid
SS_4.4g.003.sef	11:32	Side to Side 0°	Valid
FB_4.4g.001.sef	11:37	Front to Back 180°	Valid
FB_4.4g.002.sef	11:43	Front to Back 0°	Valid
FB_5.5g.001.sef	11:44	Front to Back 0°	Valid
FB_5.5g.002.sef	13:43	Front to Back 180°	Valid
SS_5.5g.001.sef	13:48	Side to Side 0°	Valid
SS_5.5g.002.sef	13:52	Side to Side 180°	Valid
SS_6.6g.001.sef	13:54	Side to Side 180°	Valid
SS_6.6g.002.sef	14:01	Side to Side 0°	Chatter monitoring failed
SS_6.6g.003.sef	14:04	Side to Side 0°	Valid
FB_6.6g.001.sef	14:09	Front to Back 180°	Valid
FB_6.6g.002.sef	14:14	Front to Back 0°	Hydraulic power trip
FB_6.6g.003.sef	14:17	Front to Back 0°	Valid

Sinesweep Test

To minimize amplification and spurious motion within the frequency range of the test, the test fixture must be a rigid structure. A sine wave input motion of 1.96 m/s^2 (0.2 g) was induced to the table from 1

Hz to 64 Hz with 1 octave/min sweep rate. The natural frequency of fixture was found at 64 Hz, please see figure 4. and figure 5, so the test fixture is a rigid structure to do the fragility tests. Apparently, the response of relay came from fixture, the FRF of relays in horizontal direction is not obvious, so did not put in this paper, on the contrary, the fixture has greater response in horizontal direction.

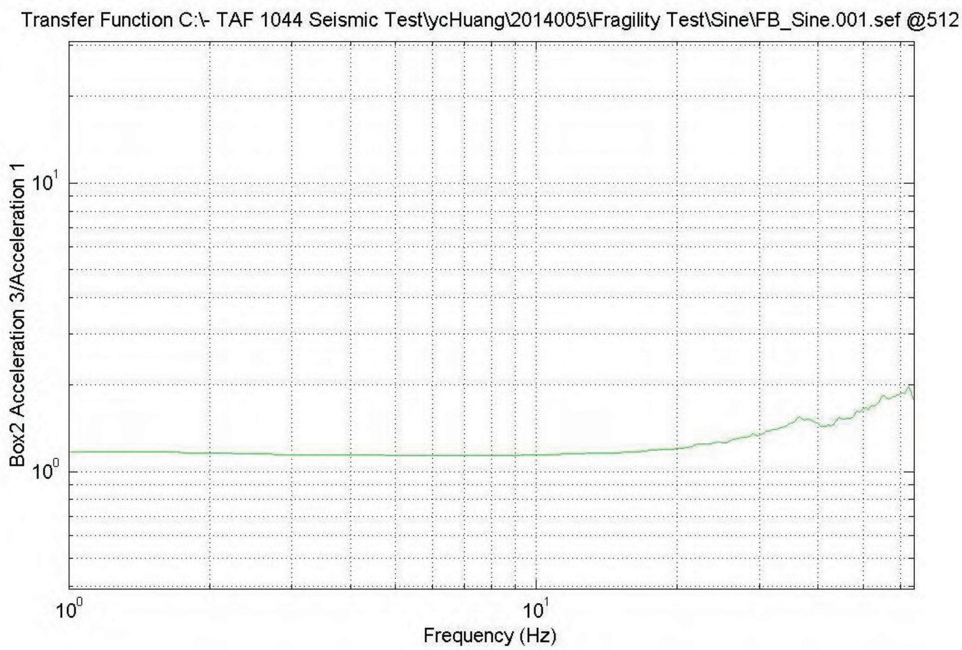


Figure4. FRF of relays in vertical direction (front-to-back)

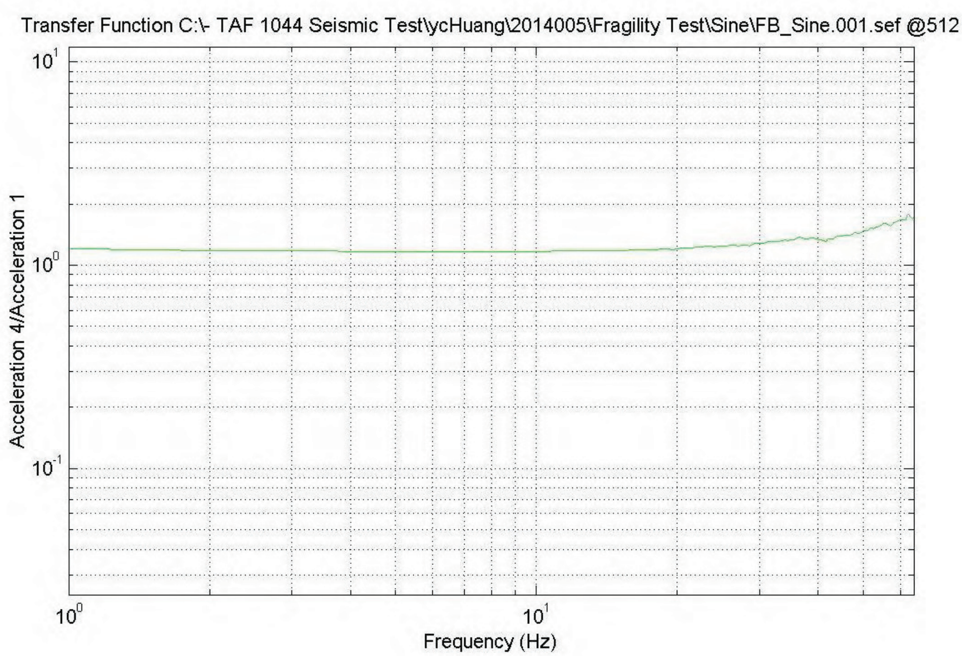


Figure5. FRF of fixture in horizontal direction (front-to-back)

Fragility Test

The duration of input seismic wave is 32 seconds, please see figure 6. TRS was plotted at 5% damping ratio and 1/6 octave frequency interval. Figure 7 shows the TRS plot of 6.6 g test with relay in front-to-back 180^0 orientation.

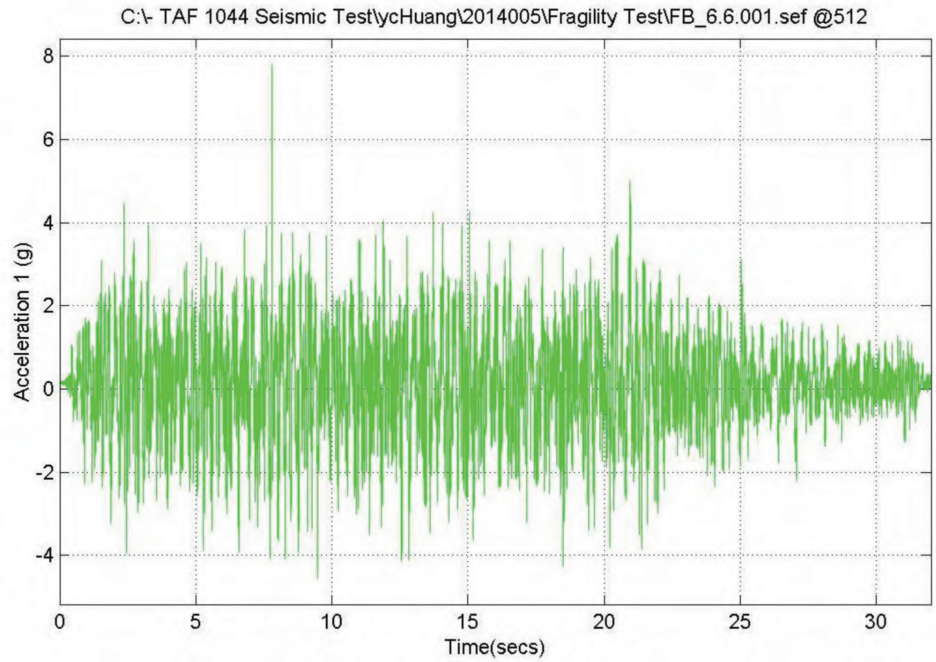


Figure6. Input motion seismic wave

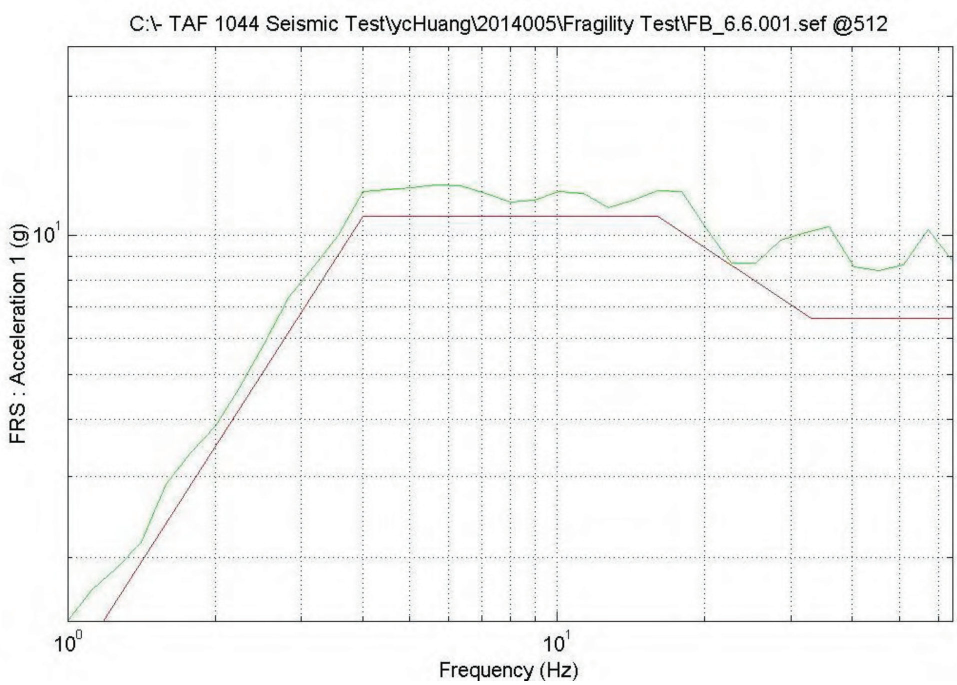


Figure7. TRS of 6.6 g test in front-to-back 180^0 orientation

FUNCTIONAL TEST AND CHATTER MINITORING

Before and after the whole tests, a functional test was conducted respectively. The functional test have been completed with relays at rated voltages and currents, and the contacts are demonstrated operating normally. During the tests, chatter monitoring performed simultaneously, figure 8 shown the sketch of monitoring circuit, in chatter monitoring, the relays are in deenergized state, the resistor was provided with 1 Ampere load for surveying open or contact of the contact points. And Table 2 summarized the monitoring results..

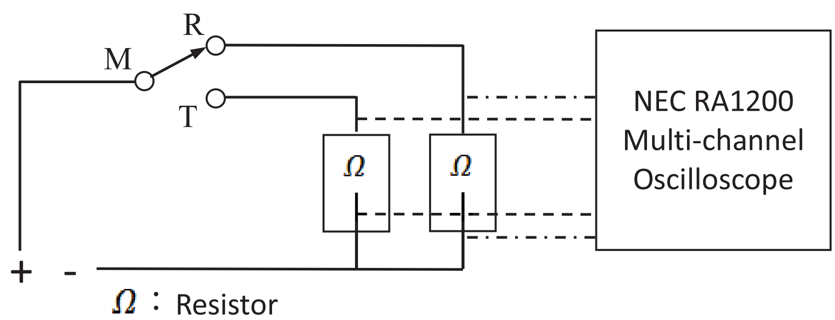


Figure8. Sketch of chatter monitoring

Table2: Result of chatter monitoring

Test Condition		Normally Close	Normally Open	Test Condition		Normally Close	Normally Open
3.63G	F-B 0°	chatter	OK	5.5G	F-B 0°	chatter	OK
	F-B 180°	chatter	OK		F-B 180°	chatter	OK
	S-S 0°	OK	OK		S-S 0°	chatter	OK
	S-S 180°	OK	OK		S-S 180°	OK	OK
4.4G	F-B 0°	chatter	OK	6.6G	F-B 0°	chatter	OK
	F-B 180°	chatter	OK		F-B 180°	chatter	OK
	S-S 0°	chatter	OK		S-S 0°	chatter	OK
	S-S 180°	OK	OK		S-S 180°	chatter	OK

CONCLUSION

Result shows that there is no structural or functional failure occurred during the tests. It demonstrates that two Agastat relays have a seismic ZPA rating greater than 6.6g according to ANSI/IEEE C37.98 for broad-band multi-frequency fragility testing.

The normally close contacts of tested relays has chattering phenomenon at a low rated ZPA of 3.63 g, when functionality using this contact point should be carefully reviewed.

Test orientation showed the front-to-back direction of relay is more vulnerable to chatter, the reason is the earthquake force in this direction is parallel to the direction of the relay's movement part.

REFERENCES

1. IEEE Std 344, "IEEE Recommended Practice for Seismic Qualification of Class 1E Equipment for Nuclear Power Generating Stations," 1975/1987.
2. ANSI/IEEE C37.98, "IEEE Standard Seismic Testing of Relays," 1987.
3. EPRI NP-7147-SL, V2, "Seismic Ruggedness of Relays," 1995.