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SEISMICALLY INDUCED RELAY CHATTER RISK ANALYSIS FOR THE ADVANCED TEST REACTOR[a]

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ABSTRACT

A seismic probabilistic risk assessment (PRA) was performed as part of the Level 1 PRA for the Department of Energy (DOE) Advanced Test Reactor (ATR) located at the Idaho National Engineering Laboratory (INEL). This seismic PRA included a comprehensive and efficient seismically-induced relay chatter risk analysis. The key elements to this comprehensive and efficient seismically-induced relay chatter analysis included (1) screening procedures to identify the critical relays to be evaluated, (2) streamlined seismic fragility evaluation, and (3) comprehensive seismic risk evaluation using detailed event trees and fault trees. These key elements were performed to provide a core fuel damage frequency evaluation due to seismically-induced relay chatter. A sensitivity analysis was performed to evaluate the impact of including seismically-induced relay chatter events in the seismic PRA. The systems analysis was performed by EG&G Idaho, Inc. and the fragilities for the relays were developed by EQE Engineering Consultants.

INTRODUCTION

EG&G Idaho has been performing the Advanced Test Reactor (ATR) probabilistic risk assessment (PRA).[1] The seismic analysis is an integral part of the external event and spatially dependent accident analysis included in the ATR Level 1 PRA. Previous seismic analysis (Reference 1) for the ATR PRA have included the integration of seismically-induced internal flood and internal fire, and the modeling human error rates as a function of the earthquake magnitude.[2] An update of seismic analysis (to be included in Revision 2 of the ATR PRA) includes the integration of seismically-induced relay chatter. This paper describes the integration of a comprehensive and efficient seismically-induced relay chatter analysis as part of the ATR PRA.

Seismically-induced relay chatter is a potential risk concern because temporarily opening or closing (chatter) of some relays could cause normally-operating equipment to stop, remotely-actuated valves to change positions, or other deleterious events to result. Evaluation of relay chatter is a necessary step in a comprehensive seismic risk analysis. Consideration of such events is required by the Nuclear Regulatory Commission for Individual Plant Examinations of External Events (IPEEEs) for severe accident vulnerabilities.[3]

The procedures for addressing relay chatter effects in IPEEEs depend upon the approach taken for the seismic evaluation. The seismic evaluation could be either a deterministic or probabilistic approach. The deterministic approach is a seismic margin review of the plant, whereas a probabilistic approach is a seismic PRA. Previous relay chatter studies (e.g., Seismic Margin Assessment of the Hatch Nuclear Plant - Unit 1[4]) have used the seismic margin review of the plant approach and did not evaluate the impact of relay chatter on the core fuel damage frequency.

For the ATR PRA, a probabilistic approach has been performed to evaluate the impact of seismically-induced relay chatter on the ATR core fuel damage frequency. Several steps were taken to provide a comprehensive and efficient relay chatter risk analysis. These steps included (1) a screening procedure to identify the critical relays to evaluate, (2) a streamlined seismic fragility evaluation, and (3) a detailed event tree and fault tree evaluation with the relay chatter events included in the fault tree models. These steps, the core fuel damage results

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obtained from the analysis, and the sensitivity analysis results are presented. The sensitivity analysis results show the impact of including seismically-induced relay chatter events in the seismic PRA.

DESCRIPTION OF THE PLANT

The ATR is a 250-MW(t) test facility located at the INEL. The ATR, which began operation in 1968, has a smaller core, higher power density, lower primary coolant system (PCS) pressure and temperature (350 psig and 170°F), and greater ratio of coolant weight to power, than typical commercial pressurized water reactors (PWRs).

Designed to study the effects of intense irradiation on samples of reactor materials, the unique cloverleaf shape of ATR's 1.2-m high core provides positions for nine in-pile tubes (flux trap positions), and numerous smaller irradiation locations. The lobes of the cloverleaf core allow various power levels to be established at different lobe positions. Separate loop systems for each in-pile tube provide coolant at the experiment's designated temperature, pressure, and flow rate. A comparison of the ATR to a typical commercial PWR is presented in Table 1.

The top of the ATR reactor vessel is located at ground level, and two floors below house PCS pumps and heat exchangers, switchgear, loop systems, and other equipment. Framed with structural steel, the confinement structure above the reactor is designed as a barrier to radionuclide release into the atmosphere.

The ATR original design was to 1960 Uniform Building Code (UBC) Zone 2 provisions. Some of the structures and components were later evaluated for a safe shutdown earthquake (SSE) of 0.24g. It is planned that the ATR will remain in operation through the first decade of the next century, so an assessment of the additional risk posed by earthquakes is in order. The seismic accident sequence analysis performed for the ATR includes a unique fault tree based treatment of seismically induced-relay chatter.

SCREENING

The first step of the relay chatter risk analysis involved a screening procedure to identify the critical relays to be included in the seismic event tree and fault tree models. The following ground rule was established for the relay screening process:

> The relays of concern are those that cause a piece of running equipment to shut down (or otherwise behave inappropriately) if they are subjected to seismically induced chatter. Those relays which might prevent a piece of equipment from starting if they are subjected to seismically induced chatter during an attempt to start are not to be considered. The window of opportunity for such effective relay chatter is sufficiently narrow to provide much less risk to the ATR than that provided by the relays that will be examined.

The relay screening procedure involved several tasks. The first task entailed an examination of the ATR PRA models to identify those components and systems that are essential following the occurrence of a seismic event. The one-line electrical drawings of these identified components and systems were then reviewed to distinguish the relays associated with these components and systems. This screening task reduced the number of potential relays from thousands to hundreds.

The next task involved further examination of the one-line electrical drawings of the identified components and systems. This additional review was performed to identify only those relays that are essential to the successful operation of the required components and systems. This second task screened out all the nonessential relays and reduced the number of potential relays down to approximately 80.

The third task of the screening procedure involved discussions with ATR Electrical Engineering (ATR-EE) personnel to verify the specific type and location of the identified essential relays. From these discussions, solid state relays were identified and screened out.

With the location of the remaining relays known, the final task of the screening procedure was performed. The final task consisted of a plant walkdown with ATR-EE and EQE Engineering Consultants (EQE) analysts. This walkdown was performed to verify the exact location and to screen out those relays that were considered to be seismically robust based upon type and location. This final screening procedure task identified a total of 17 relays that were considered to be susceptible to vibration-induced chatter and potentially important to seismic risk. These relays were incorporated into the PRA seismic event models.

FRAGILITY EVALUATION

The second step of the relay chatter risk analysis involved a streamlined seismic fragility evaluation. The streamlined seismic fragility evaluation was achieved by two means. First, EQE analysts provided input during the walkdown phase of the screening process. The input was based on previous fragility evaluations performed by EQE analysts. Second, by noting the type and location of the identified relays during the plant walkdown, EQE analysts applied their knowledge and judgement to the fragility evaluation for the identified relays.

DETAILED RISK ASSESSMENT

The third step of the relay chatter risk analysis was a detailed risk assessment. The detailed risk assessment entailed modifying the existing system fault tree models and requantifying the seismic accident sequences. The system fault tree models from the ATR PRA were modified to include the identified critical relays as basic events. These modified system fault tree models were then linked with the seismic event tree from the ATR PRA. The accident sequence Boolean equations were produced and the seismic accident sequences were then quantified.

RESULTS

The seismic event quantification produced three accident sequences that have a core fuel damage frequency greater than 1.0E-7/yr. The core fuel damage frequency for the three accident sequences vary from 9.4E-7 to 1.3E-5/yr with a total mean core fuel damage frequency of 2.1E-5/yr.

When all the non-seismic failures were removed from the Boolean equations, the total mean core fuel damage frequency was reduced to 1.5E-5/yr. Therefore, the seismic failures contribute over 70% to the total core fuel damage frequency.

SENSITIVITY ANALYSIS

A sensitivity analysis to evaluate the impact of including seismically-induced relay chatter events on the ATR core fuel damage frequency was achieved by the examining the results from a previous ATR seismic event analysis that did not include seismically-induced relay chatter events (Reference 1). The results from the previous study contained the same three accident sequences and their core fuel damage frequency varied from 1.1E-7 to 1.3E-5/yr with a total mean core fuel damage frequency of 1.9E-5/yr.

When all the non-seismic failures were removed from the Boolean equations of the previous seismic analysis, the total mean core fuel damage frequency was reduced to 1.5E-5/yr. Thus, the seismically-induced relay chatter events have negligible impact on the ATR core fuel damage frequency.

CONCLUSIONS

The results from the seismically-induced relay chatter risk analysis for ATR show that seismically-induced relay chatter events have negligible effects on the core fuel damage frequency. The primary reason that seismically-induced relay chatter events have negligible effects is because station blackout is expected slightly above the SSE value.

REFERENCES

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3. U.S. Nuclear Regulatory Commission, "Individual Plant Examination of External Events (IPEEE) for severe accident vulnerabilities," Generic Letter No. 88-20, Supplement 4.

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Table 1. Comparison of ATR and PWR characteristics

Reactor Operating Conditions	ATR	PWR
Power MW(t)	250	2,000-4,000
Core power density (MW/l)	1	0.1
Operation pressure (psig)	355	2,250
Inlet temperature (°F)	125	550
Outlet temperature (°F)	170	600
Primary coolant flow rate (gpm)	<48,000	300,000
Primary coolant weight (lb)	600,000	450,000
Primary coolant weight/thermal power (lb/MW)	2,400	170
Decay Heat (MW at 10 s)	13	135
(MW at 1 d)	1.3	19
Fuel		
Total Uranium weight (lb)	89	180,000
Enrichment (% U-235)	93	2-4
Configuration	48 in. long Al plates attached to side plates	Zirc rods containing stacked pellets
Matrix	UAl_x	UO_2
Fuel temperature (°F)	430	2,000-3,000
Fission product inventory	60-d operation at 250 MW	10 times ATR

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