EGG-SSRE-9581

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TECHNICAL REPORT

TRIAL APPLICATION OF PRATOOL:
PERFORMANCE OF SENSITIVITY STUDIES
ON SERVICE WATER SYSTEMS

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March 1991

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ABSTRACT

PRATOOL is a computer program developed to supplement the IRRAS probabilistic risk assessment (PRA) computer program. It is intended to be a tool for performing sensitivity analysis on a PRA. This will allow a PRA's results to be easily reevaluated to show its sensitivity to changing parameter values (i.e., failure rates). This report documents a trial application of PRATOOL. It evaluates the sensitivity of core damage frequency to service water system availability at several nuclear power plants.

FIN No. L1660

SUMMARY

PRATOOL is a computer program developed to supplement the Integrated Reliability and Risk Analysis System (IRRAS) probabilistic risk assessment (PRA) computer program. It is intended to be a tool for performing PRA sensitivity analyses. This will allow a PRA's results to be easily reevaluated to show its sensitivity to changing parameter (system, component type, basic event, etc.) values (i.e., failure rates). This report documents a trial application of PRATOOL. It evaluates the sensitivity of core damage frequency to service water system availability at several nuclear power plants.

For the purpose of this trial application of PRATOOL, service water system sensitivity studies were performed using the results of several NUREG-1150 PRAs. These plants were chosen because their PRAs were already loaded into the IRRAS data base. Therefore, they are readily available for this type of study.

PRATOOL contains a small subset of the functions provided by IRRAS. The user can select sets of parameters that will act as the bases for sensitivity analyses. Depending on the PRA used, the parameters selected can include: systems, component types, trains, locations, failure modes, and basic events. It will also perform an AND-ing operation on selected parameters. This allows the user to define any number of possible combinations of parameters.

The results of the four sensitivity studies would tend to indicate that the SWS availability is important for BWRs but unimportant for PWRs. Both BWRs showed significant increases in CDF if their SWS failure rates are allowed to increase. From the results of the four sensitivity studies, it is interesting to note that no improvements made to any of the SWSs' failure rates would result in a significant decrease on CDF.

PRATOOL appears to be a helpful tool to use for obtaining sensitivity analyses for a PRA's CDF. It is easy to learn and easy to use. However, it is limited both by the accuracy of the PRA model being analyzed and the degree of importance of the parameter being analyzed.

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TRIAL APPLICATION OF PRATOOL: PERFORMANCE OF SENSITIVITY STUDIES ON SERVICE WATER SYSTEMS

INTRODUCTION

PRATOOL is a computer program developed to supplement the Integrated Reliability and Risk Analysis System (IRRAS) computer program. It allows the user to perform sensitivity analysis on probabilistic risk assessment (PRA) results. A PRA's results can be easily reevaluated to show the PRA's sensitivity to changes in parameter failure rates. This report documents a trial application of PRATOOL. It evaluates the sensitivity of core melt frequency to service water system (SWS) failure rates at several nuclear power plants.

For the purpose of this trial application of PRATOOL, service water system sensitivity studies were performed using the results of several NUREG-1150 PRAs. These plants were chosen because their PRAs were already loaded into the IRRAS data base. The plants examined include: Surry, Peach Bottom, Grand Gulf, and Sequoyah.

The following section contains a brief description of PRATOOL, including its functions, capabilities, and limitations. A more detailed description, including the operating instructions, is contained in the PRA Applications User's Manual.

PRATOOL DESCRIPTION

PRATOOL contains a small subset of the functions provided by IRRAS. While executing PRATOOL, the user selects a set of parameters that will act as the basis for a sensitivity analysis. Depending on the PRA used, the parameters selected can include: systems, component types, trains, locations, failure modes, and basic events. The system will also perform an AND-ing operation on selected parameters. This allows the user to define any number of possible combinations of parameters, such as selecting a particular system, a component type within that system, and a particular failure mode for that component type.

Once a set of parameters is defined, the program performs a sensitivity analysis. This is done by recalculating core damage frequency (CDF) for a number of discrete sample points over the range .01 to 100 times the defined parameters' basic-event point-estimates. The user can then display the sensitivity analysis results using any of several different types of plots or reports.

It should be noted, PRATOOL performs its CDF recalculations using only the dominant sequence cutsets identified by the PRA. Therefore, it does not requantify the entire PRA logic model.

SERVICE WATER SYSTEM SENSITIVITY ANALYSES

This section contains a discussion of the four SWS sensitivity studies performed in this trial application of PRATOOL. In those cases where the SWS did not significantly impact core damage frequency (CDF), only the system sensitivity results are presented. However, in those cases where the SWS had a large impact on CDF, more detailed results are presented.

Pressurized Water Reactors

The SWSs of two pressurized water reactors (PWR) were evaluated using PRATOOL. The two PWRs, Surry and Sequoyah, are both Westinghouse plants. Surry has an ice condenser containment and Sequoyah has a large dry containment.

Figure 1 shows the Sequoyah PRA's sensitivity to the entire SWS (at Sequoyah, the SWS is called the essential raw cooling water system). This includes all the PRA's basic events with an SWS designation. As can be seen, the SWS has very little impact on CDF. Improving the availability of all the SWS components by a factor of 100 would result in only a minimal decrease in CDF. Conversely, decreasing the availability of all the SWS components by a factor of 100 would increase CDF by about only $4.0E-6$ /RY. Sensitivity studies were also performed on the essential service water and high pressure service water portions of the SWS, and they had no impact on CDF.

Likewise, Figure 2 shows the Surry PRA's sensitivity to the entire SWS. As can be seen, the Surry SWS has no impact on CDF. Because of the limited impact the SWS has on core melt for these two plants, no further sensitivity studies were performed.

Boiling Water Reactors

As can be seen in the following discussion, the SWSs at the boiling water reactors (BWR) evaluated for this report were more important to CDF than was the case for the PWRs. The two BWRs evaluated using PRATOOL were Peach Bottom and Grand Gulf. At Peach Bottom the portion of the SWS designated as essential service water (ESW) plays an important role in CDF mitigation. And at Grand Gulf, the standby service water (SSW) portion of the SWS is important for CDF mitigation. Sensitivity studies performed on the other portions of the SWSs (high pressure service water and normal service water at Peach Bottom, and plant service water at Grand Gulf) indicated they had little impact on CDF.

Figure 3 shows the Peach Bottom PRA's sensitivity to the entire ESW system. As can be seen, the Peach Bottom ESW can have a significant impact on CDF. Although improving ESW component

availabilities by a factor of 100 results in only a modest ($1.0E-6$) decrease in CDF, decreasing ESW availabilities by a factor of 100 increases CDF by about a factor of 500. Because of this large increase in CDF, more extensive sensitivity studies were performed for Peach Bottom.

Sensitivity studies were performed for each of the component types represented in the ESW basic events. These studies measured the change in CDF that could be obtained by varying the basic event probabilities for a particular component-type within the ESW system. Figures 4 and 5 show the results for the component-types that have the greatest effects on CDF. Motor-driven pumps (MDP), check valves (CKV), and air-operated valves (AOV) have the greatest individual impact on CDF increase. It is interesting to note that human error (XHE) probability increases do not result in any significant increase in CDF. However, it does represent the majority of the decrease in CDF that is obtainable through ESW improvement.

Because the dominant single contributing component-type (MDPs) was a factor of ten less than the total system sensitivity, a series of sensitivity studies were performed that evaluated pairs of dominant component-types. Figure 6 shows the results of the dominant multiple-component-type studies. As can be seen in Figure 6, the combination of MDP and CKV availabilities has the greatest potential for increasing CDF.

Figure 7 shows the Grand Gulf PRA's sensitivity to the entire SSW system. As can be seen, the Grand Gulf SSW can have a significant impact on CDF. Although improving SSW component availabilities by a factor of 100 results in only a slight ($7.0E-7$ /RY) decrease in CDF, decreasing SSW availabilities by a factor of 100 increases CDF by about a factor of 300. Therefore, more extensive sensitivity studies were performed for Grand Gulf.

Sensitivity studies were performed for each of the component types represented in the SSW system's basic events. These studies measured the change in CDF that could be obtained by varying the basic event probabilities for a particular component-type within the SSW system. Figures 8 and 9 show the results for the component-types that have the greatest effects on CDF. Motor-driven pumps (MDP), motor-operated valves (MOV), and human errors (XHE) have the greatest individual impact on CDF increase.

Because the dominant single contributing component-type (MDPs) was a factor of six less than the total system sensitivity, a series of sensitivity studies were performed that evaluated pairs of dominant component-types. Figure 10 shows the results of the dominant multiple-component-type studies. As can be seen in Figure 10, the combination of MDP and MOV nearly matches the sensitivity of the entire system.

1991/03/04

SEQUOYAH

09:14:07

Sensitivity Analysis

EG&G Idaho, Inc. (INEL)

Figure 1 Sequoyah SWS Sensitivity

1991/03/04

SURRY

09:16:26

Sensitivity Analysis

EG&G Idaho, Inc. (INEL)

Figure 2 Surry SWS Sensitivity

1991/03/04

PEACHBOT

17:15:16

Sensitivity Analysis

EG&G Idaho, Inc. (INEL)

Figure 3 Peach Bottom Sensitivity

1991/03/04

PEACHBOT

17:17:18

Sensitivity Analysis

EG&G Idaho, Inc. (INEL)

Figure 4 PB Component Sensitivities

1991/03/04

PEACHBOT

17:19:37

Sensitivity Analysis

EG&G Idaho, Inc. (INEL)

Figure 5 PB Misc. Sensitivities

1991/03/04

PEACHBOT

17:22:09

Sensitivity Analysis

EG&G Idaho, Inc. (INEL)

Figure 6 PB Multiple Sensitivities

1991/03/04

GRANDGF

16:40:14

Sensitivity Analysis

Figure 7 Grand Gulf Sensitivity

1991/03/04

GRANDGF

16:42:32

Sensitivity Analysis

EG&G Idaho, Inc. (INEL)

Figure 8 GG Component Sensitivities

Figure 9 GG Misc. Sensitivities

1991/03/04

GRANDGF

16:47:48

Sensitivity Analysis

EG&G Idaho, Inc. (NEL)

Figure 10 GG Multiple Sensitivities

RESULTS AND OBSERVATIONS

The results of these limited sensitivity studies would tend to indicate that the SWS availability is important for BWRs but unimportant for PWRs. Both BWRs showed significant increases in CDF if their SWS failure rates are allowed to increase. It is interesting to note that no improvements made to any of the four SWSs' availability would result in a significant decrease on CDF. This is, in part, due to the fact that the SWS does not drive CDF in any of the PRAs evaluated. However, before making any judgements on the importance of the SWS based on these analyses, the following comments should be considered.

A PRA is an integrated model of how a plant responds to off-normal conditions. The results of the PRA are only as good as the models used to obtain them. If a system is poorly modeled by a PRA, the results will not accurately reflect its importance to CDF. Therefore, any subsequent sensitivity study could also be inaccurate.

PRATOOL, in its present form, only analyzes the dominant cutsets obtained from a PRA. It does not requantify the entire PRA using different probability values. Therefore, the possibility exist that some cutsets that could be significant for an increased basic event value will be overlooked in a sensitivity study.

The sensitivity studies performed using PRATOOL are limited to the effects that changing parameter values have on CDF. They do not address the potentially more significant issue of what effects changing parameter values would have on offsite-dose consequences.

There are several features that could be added to PRATOOL to make it more flexible, to improve its range of accuracy, or to aid the user in judging the accuracy of results. A selective listing of sequence cutsets (e.g., list all sequence cutsets containing a SWS failure) would aid the user in determining whether or not a particular parameter of interest would be considered by a sensitivity study.

Another feature that might prove useful would be the ability to lower the cutoff value for sequence cutsets for any given accident sequence. This would allow the user to evaluate the sensitivity of those components whose failure rates are so low that the sequence cutsets they appear in are truncated.

It should also be considered whether or not it would be desirable to have the ability to perform a sensitivity study that requantify the entire PRA model. Although this would be much more time consuming than the present PRATOOL method for obtaining sensitivity results, in some cases it could prove useful.

It would also appear that in many cases, the graphs obtained using PRATOOL could be used to calculate approximate values for several importance measures such as Fussell-Vesely importance and risk-reduction importance.

CONCLUSIONS

PRATOOL appears to be a helpful tool to use for obtaining sensitivity analyses for a PRA's CDF. It is easy to learn and easy to use. However, it is limited both by the accuracy of the PRA model being analyzed (as would any tool used to perform an analysis on an existing PRA) and the degree of importance of the parameter being analyzed. In other words, if the analyst is using a well-modeled PRA and looking at parameters that are among the dominant contributors to CDF, then the results of the sensitivity study will be accurate.

In most cases, it will be beyond the scope and ability of a PRATOOL user to assess the accuracy of the PRA model. However, by reviewing the dominant sequence cutsets of a PRA, the user should be able to make some qualitative estimates as to the accuracy and applicability of the results obtained using PRATOOL.

Adding some or all of the modifications discussed in the previous section would increase the flexibility of PRATOOL. They would also aid the user in determining the accuracy and applicability of results obtained. If the results obtained were judged to be inadequate, the means would be available to pursue more detailed studies.

APPENDIX A

SENSITIVITY ANALYSES
TEXT FILES

Figure 1. Sequoyah SWS Sensitivity

1991/03/04

SEQUOYAH

09:14:07

Sensitivity Setup

EG&G Idaho, Inc.

(INEL)

Plot Legend - BASE

Attributes Included

NONE

Attributes Excluded

NONE

Events Included

NONE

Events Excluded

NONE

Plot Legend - SWS

Attributes Included

System - SWS

Attributes Excluded

NONE

Events Included

NONE

Events Excluded

NONE

Figure 2. Surry SWS Sensitivity

1991/03/04

SURRY

09:16:26

Sensitivity Setup

EG&G Idaho, Inc.

(INEL)

Plot Legend - BASE

Attributes Included

NONE

Attributes Excluded

NONE

Events Included

NONE

Events Excluded

NONE

Plot Legend - SWS

Attributes Included

System - SWS

Attributes Excluded

NONE

Events Included

NONE

Events Excluded

NONE

Figure 3. Peach Bottom ESW Sensitivity

1991/03/04

PEACHBOT

17:15:16

Sensitivity Setup

EG&G Idaho, Inc.

(INEL)

Plot Legend - CBASE

Attributes Included

NONE

Attributes Excluded

NONE

Events Included

NONE

Events Excluded

NONE

Plot Legend - ESW

Attributes Included

System - ESW

Attributes Excluded

NONE

Events Included

NONE

Events Excluded

NONE

Figure 4. PB Single Sensitivities

1991/03/04

PEACHBOT

17:17:18

Sensitivity Setup

EG&G Idaho, Inc.

(INEL)

Plot Legend - AOV

Attributes Included

Component Type - AOV

System - ESW

Attributes Excluded

NONE

Events Included

NONE

Events Excluded

NONE

Plot Legend - CKV

Attributes Included

Component Type - CKV

System - ESW

Attributes Excluded

NONE

Events Included

NONE

Events Excluded

NONE

Plot Legend - ESW

Attributes Included

System - ESW

Attributes Excluded

NONE

Events Included

NONE

Events Excluded

NONE

Plot Legend - MDP

Attributes Included

Component Type - MDP

System - ESW

Attributes Excluded

NONE

Events Included

NONE

Events Excluded

NONE

Figure 5. PB Misc. Sensitivities

1991/03/04

PEACHBOT

17:19:37

Sensitivity Setup

EG&G Idaho, Inc.

(INEL)

Plot Legend - ESW

Attributes Included

System - ESW

Attributes Excluded

NONE

Events Included

NONE

Events Excluded

NONE

Plot Legend - PTF

Attributes Included

Component Type - PTF

System - ESW

Attributes Excluded

NONE

Events Included

NONE

Events Excluded

NONE

Plot Legend - XHE

Attributes Included

Component Type - XHE

System - ESW

Attributes Excluded

NONE

Events Included

NONE

Events Excluded

NONE

Plot Legend - XVM

Attributes Included

Component Type - XVM

System - ESW

Attributes Excluded

NONE

Events Included

NONE

Events Excluded

NONE

Figure 6. PB Multiple Sensitivities

1991/03/04

PLACHBOT

17:22:09

Sensitivity Setup

EG&G Idaho, Inc.

(INEL)

Plot Legend - CKV+AOV

Attributes Included

Component Type - AOV CKV

System - ESW

Attributes Excluded

NONE

Events Included

NONE

Events Excluded

NONE

Plot Legend - ESW

Attributes Included

System - ESW

Attributes Excluded

NONE

Events Included

NONE

Events Excluded

NONE

Plot Legend - MDP+AOV

Attributes Included

Component Type - AOV MDP

System - ESW

Attributes Excluded

NONE

Events Included

NONE

Events Excluded

NONE

Plot Legend - MDP+CKV

Attributes Included

Component Type - CKV MDP

System - ESW

Attributes Excluded

NONE

Events Included

NONE

Events Excluded

NONE

Figure 7. Grand Gulf SSW Sensitivity

1991/03/04

GRANDGF

16:40:14

Sensitivity Setup

EG&G Idaho, Inc.

(INEL)

Plot Legend - BASE

Attributes Included

NONE

Attributes Excluded

NONE

Events Included

NONE

Events Excluded

NONE

Plot Legend - ssw

Attributes Included

System - SSW

Attributes Excluded

NONE

Events Included

NONE

Events Excluded

NONE

Figure 8. GG Single Sensitivities

1991/03/04

GRANDGF

16:42:32

Sensitivity Setup

EG&G Idaho, Inc.

(INEL)

Plot Legend - MDP

Attributes Included

Component Type - MDP

System - SSW

Attributes Excluded

NONE

Events Included

NONE

Events Excluded

NONE

Plot Legend - ssw

Attributes Included

System - SSW

Attributes Excluded

NONE

Events Included

NONE

Events Excluded

NONE

Plot Legend - CKV

Attributes Included

Component Type - CKV

System - SSW

Attributes Excluded

NONE

Events Included

NONE

Events Excluded

NONE

Plot Legend - MOV

Attributes Included

Component Type - MOV

System - SSW

Attributes Excluded

NONE

Events Included

NONE

Events Excluded

NONE

Figure 9. GG Misc. Sensitivities

1991/03/04

16:45:19

GRANDGF

Sensitivity Setup

EG&G Idaho, Inc.

(INEL)

Plot Legend - HTX

Attributes Included

Component Type - HTX

System - SSW

Attributes Excluded

NONE

Events Included

NONE

Events Excluded

NONE

Plot Legend - ssw

Attributes Included

System - SSW

Attributes Excluded

NONE

Events Included

NONE

Events Excluded

NONE

Plot Legend - XHE

Attributes Included

Component Type - XHE

System - SSW

Attributes Excluded

NONE

Events Included

NONE

Events Excluded

NONE

Plot Legend - XVM

Attributes Included

Component Type - XVM

System - SSW

Attributes Excluded

NONE

Events Included

NONE

Events Excluded

NONE

Figure 10. GG Multiple Sensitivities

1991/03/04

GRANDGF

16:47:48

Sensitivity Setup

EG&G Idaho, Inc.

(INEL)

Plot Legend - MDP+XHE

Attributes Included

Component Type - MDP XHE

System - SSW

Attributes Excluded

NONE

Events Included

NONE

Events Excluded

NONE

Plot Legend - MOV+MDP

Attributes Included

Component Type - MDP MOV

System - SSW

Attributes Excluded

NONE

Events Included

NONE

Events Excluded

NONE

Plot Legend - MOV+XHE

Attributes Included

Component Type - MOV XHE

System - SSW

Attributes Excluded

NONE

Events Included

NONE

Events Excluded

NONE

Plot Legend - ssw

Attributes Included

System - SSW

Attributes Excluded

NONE

Events Included

NONE

Events Excluded

NONE

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