

## AIMS-PSA: A Software for Integrated PSA

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This article presents key features of an integrated probabilistic safety assessment (PSA) software, called AIMS-PSA, to support the management and quantification of various types of PSAs such as internal full power PSA, fire/flooding PSA, seismic PSA and shutdown PSA.

Main modules of the AIMS-PSA are fault tree module, event tree module and cut set browser module that are typical modules for event tree and fault tree analysis. The special features introduced in the AIMS-PSA are the project explorer and the integration module.

The AIMS-PSA is designed to follow the work flow; preparation of a model, integration of the model, quantification and presentation of the quantification results. The project explorer of the AIMS-PSA manages the works related to PSA models and helps us to perform the PSA analysis based on the work flow.

The integration module is an engine to integrate and modify the fault tree and event tree models using a kind of script. The use of script engine provides a means to integrate event trees and fault trees for Level-1 PSA, to generate the PSA model for fire/flood/seismic from the internal event PSA model, to handle equipment outage for the shutdown PSA, and to perform a large amount of sensitivity analyses.

The AIMS-PSA also has useful features to support the review of PSA models such as search function using filter, abstraction of failed logic, cut set comparison module, and so on.

## I. INTRODUCTION

KAERI (Korea Atomic Energy Research Institute) has been developing Level-1 PSA softwares such as the KIRAP (Ref. 1) in 1987 which runs on DOS operating system, the KIRAP-Win (Ref. 2) in 1995 which runs on Windows, the integrated PSA software AIMS-PSA Release 1 (Ref. 3) in 2005. Those PSA softwares have been used successfully for PSAs of domestic nuclear power plants. Even though AIMS-PSA Release 1 has useful features for the event tree and fault tree analysis, the design is not intuitive, it is difficult to perform a large amount of sensitivity study, it is not easy to use by non-experienced PSA persons, and it is based on the outdated Visual Basic 6.

KAERI started to develop a new AIMS-PSA Release 2 (AIMS-PSA in this paper) to solve the problems discovered in the previous AIMS-PSA Release 1. Those are;

- Intuitive design
- Integration and automation
- Fast quantification using the cut set generator FTREX (Ref. 4)
- Review of PSA models
- Sensitivity analysis and interface with external events PSA

Basic modules of the AIMS-PSA are event tree module, fault tree module and cut set browser module. New additional modules are developed: One is the project explore for model management, and the other is script interpreter, called SIMA (Script Interface for Mapping Algorithm), for integration and sensitivity analysis.

This article describes the main features of the AIMS-PSA; the basic design in the section 2, the PSA model integration of event trees and fault trees in the section 3, features to help the review of a PSA model in the section 4, and finally the features for sensitivity analysis and interface with external PSAs in the section 5.

## II. BASIC DESIGN and PROJECT EXPLORER

The new AIMS-PSA is developed using the Visual Basic .Net. It introduces a docking window which provides a means to divide and resize windows as shown in Fig. 1.

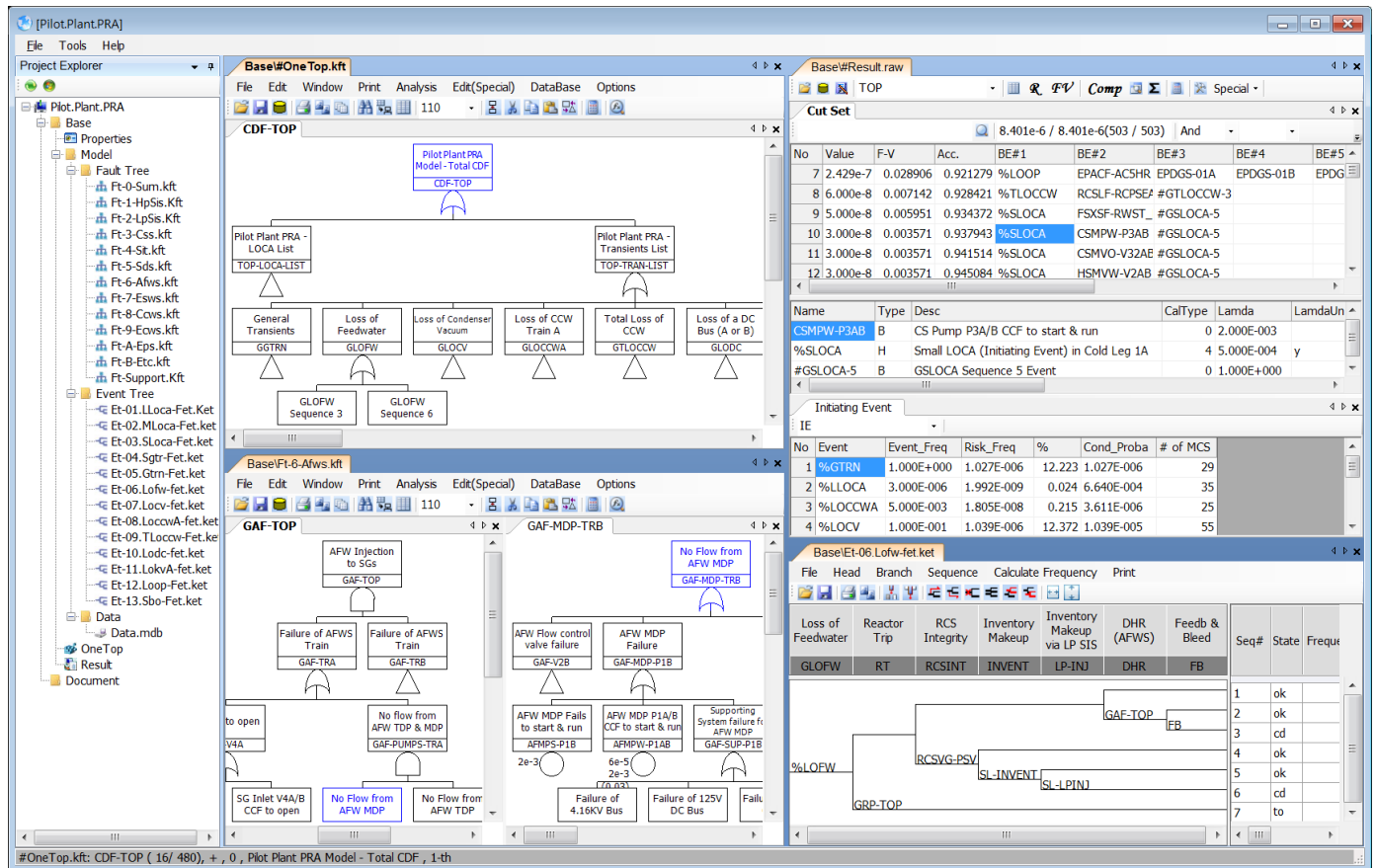


Fig. 1. Basic Screen Design of AIMS-PSA that utilizes a docking window

One of key functions of the AIMS-PSA is the project explorer that provides a means to perform necessary analyses intuitively. The AIMS-PSA uses the concept of project. A project can have several folders and a folder is corresponding to a PSA model.

The project explorer is designed to follow the work flow; preparation of a model, integration of the model, quantification and presentation of the results. A folder in the project explorer has 4 items based on the work flow;

- Properties : designate the top event or truncation value
- Model : prepare and modify a PSA model such as event trees, fault trees and data file
- OneTop : integrate the files given in Model and build a big one fault tree, called One Top fault tree in AIMS-PSA
- Result : generate cut sets for One Top fault tree

The Model menu manages event trees and fault trees. Once the PSA model is prepared, we can simply integrate the PSA model by clicking a button in OneTop menu and quantify (generate cut sets) the PSA model by clicking a button in Result menu.

The AIMS-PSA utilizes the right mouse button as far as possible. If we select an object (an object can be anyone; an item in the project explorer, an event in the fault tree module or a cut set in the cut set browser) and click right mouse button, the AIMS-PSA display menus related to the selected object.

### III. MODEL INTEGRATION

The AIMS-PSA combines event trees and fault trees in the PSA model to build One Top fault tree and generate minimal cut sets for the One Top fault tree. The One Top fault tree is similar to the risk monitor model. The AIMS-PSA combines a top logic corresponding to the sum of event trees, fault trees representing event tree logic, system fault trees for branches of event trees.

When an event tree is converted into a fault tree, the top gate name representing the event tree becomes the head ID of the event tree. A sequence in the event tree is represented as multiplication of initiating event and branches. To distinguish the sequence number, a dummy event, whose value is 1, representing a sequence number is added to the sequence. For example as shown in Fig. 2, GLLOCA is a gate representing an event tree for GLLOCA, and GLLOCA-2 is a gate representing the 2<sup>nd</sup> sequence that includes a dummy event #GLLOCA-2 whose value is 1.

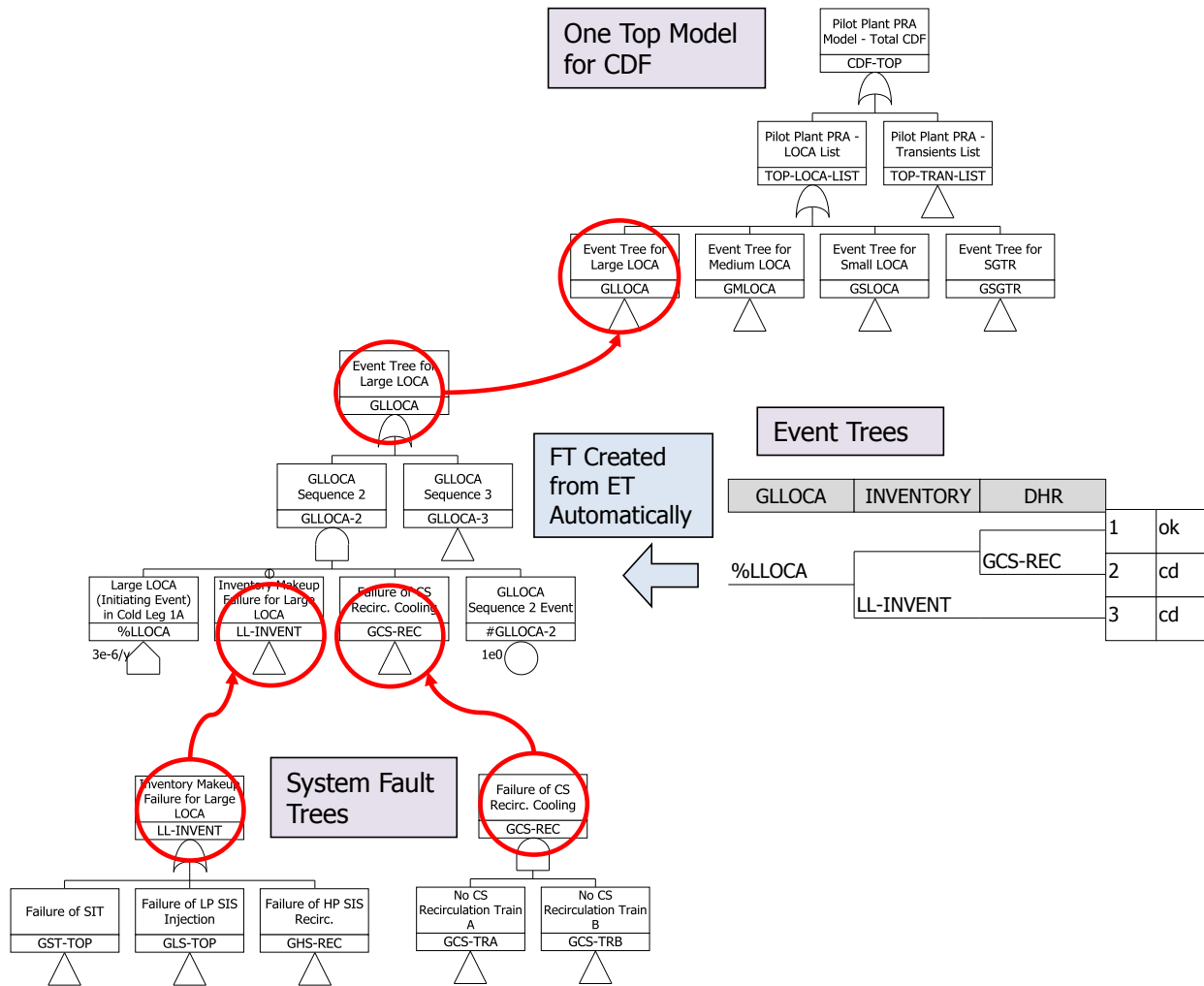


Fig. 2. Integration of event trees & fault trees in the AIMS-PSA

The AIMS-PSA generates minimal cut sets for One Top fault tree instead of generating minimal cut sets for sequence by sequence. The use of dummy event representing a sequence number enables to extract minimal cut sets for the sequence from the whole minimal cut sets for a PSA model. Thus, one time calculation is enough for quantification of a PSA model. It takes about 3 ~ 60 seconds to generate minimal cut sets for a full power - internal event - Level-1 PSA model. It is about 10 to 100 times faster than typical method to quantify sequence by sequence.

#### IV. REVIEW OF PSA MODEL

The AIMS-PSA has several features to help the review of a PSA model. The followings are features for the review of the PSA model;

- Trace the relation between event tree, fault tree and cut sets
- Fault tree module
  - Find event/gate using a filter
  - Compare two fault trees
- Cut set browser module
  - View cut sets & find cut sets including the given event
  - CDF for each initiating event, CDF for each sequence
  - Importance analysis (basic event, component)
  - Compare two cut sets

A feature to trace the relation between event tree, fault tree and cut sets makes easy to review the PSA model and result. We can jump to the fault tree corresponding to a branch or a sequence of an event tree, or jump to the cut set corresponding to a sequence of an event tree. It can be done by executing a menu by clicking a mouse button. Propagating a cut set thru the one top fault tree helps to review the fault tree logic how the cut set is generated.

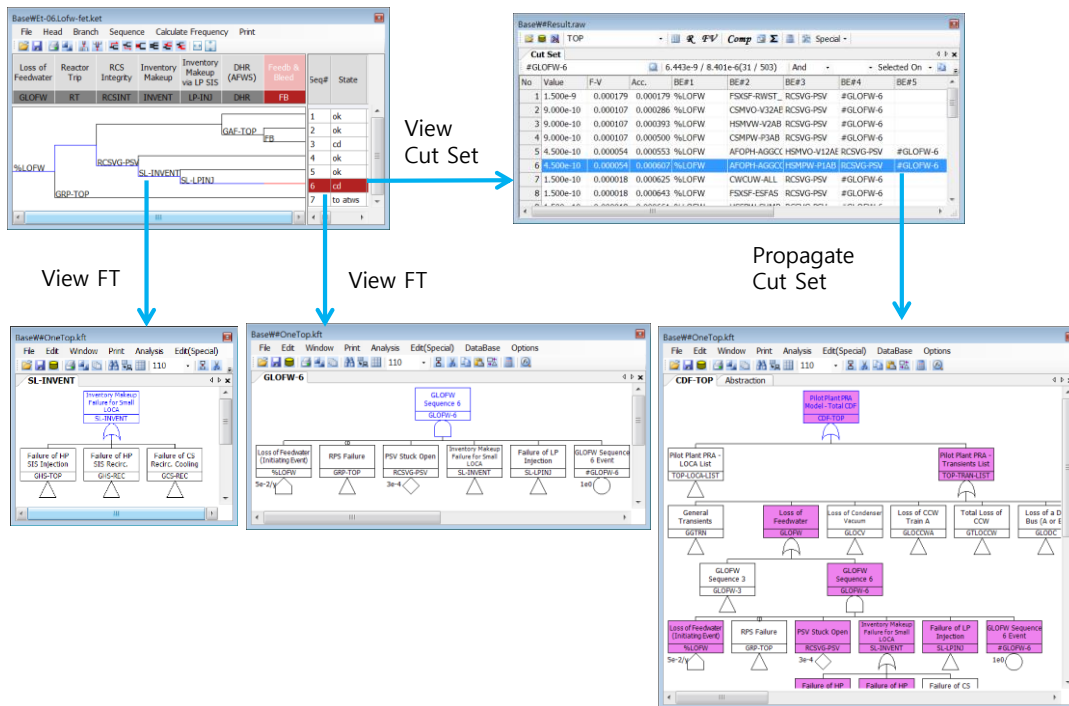


Fig. 3. Trace the relation between models

The find function in the fault tree module helps find gates or events. The left window displays the list of events whose name matches the filter, and the list of parent gates for the selected event. We can open a window for the selected event. The left side of Fig. 4 shows an example to find basic events for AFW motor pumps and to display fault trees for parent gates.

The right side of Fig.4 shows an example to compare two fault trees where different logics between fault trees are displayed in violet color and a remark to describe the differences is displayed in violet color.

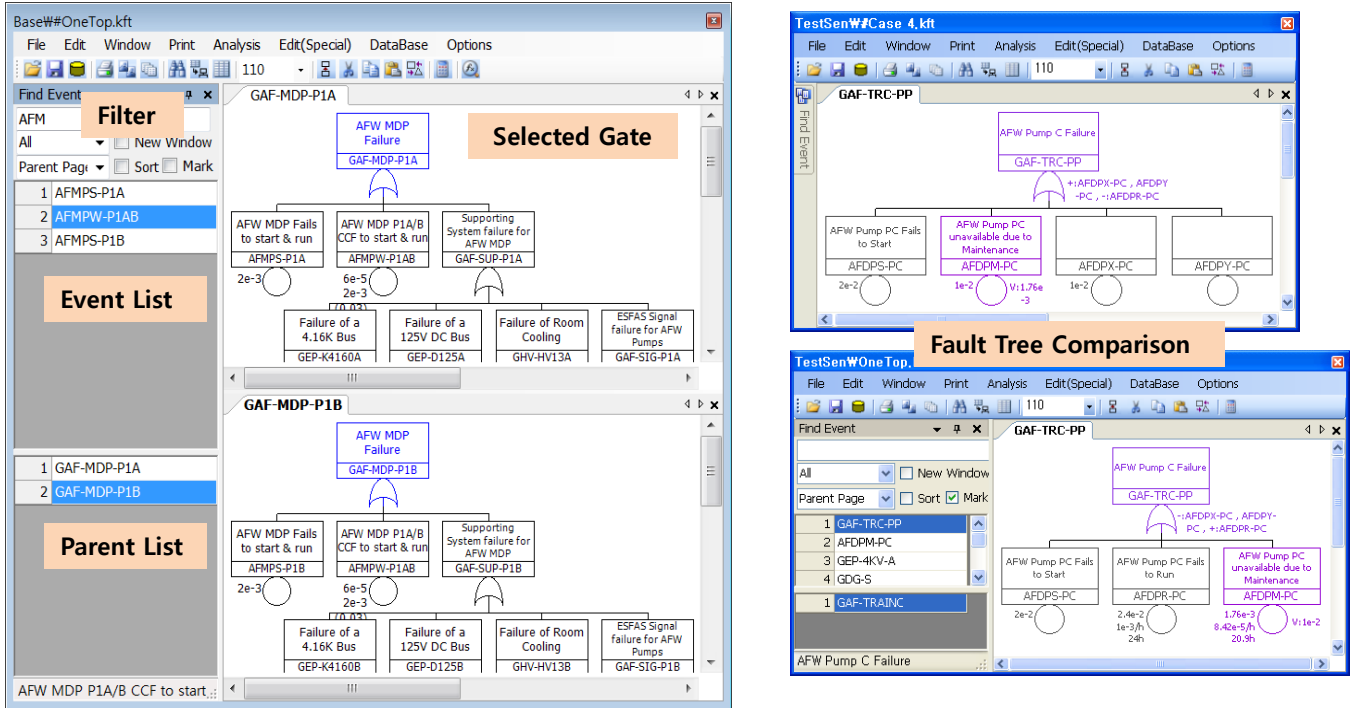


Fig. 4. Find event/gate using a filter and Compare two fault trees

The basic function of the cut set browser module shows minimal cut sets. Using the minimal cut sets, the AIMS-PSA can calculate CDF (Core Damage Frequency) for each initiating event, CDF for each sequence of event trees. It can also calculate importance of each basic event and importance of each component if the relation table is given for a component and basic events/CCF events.

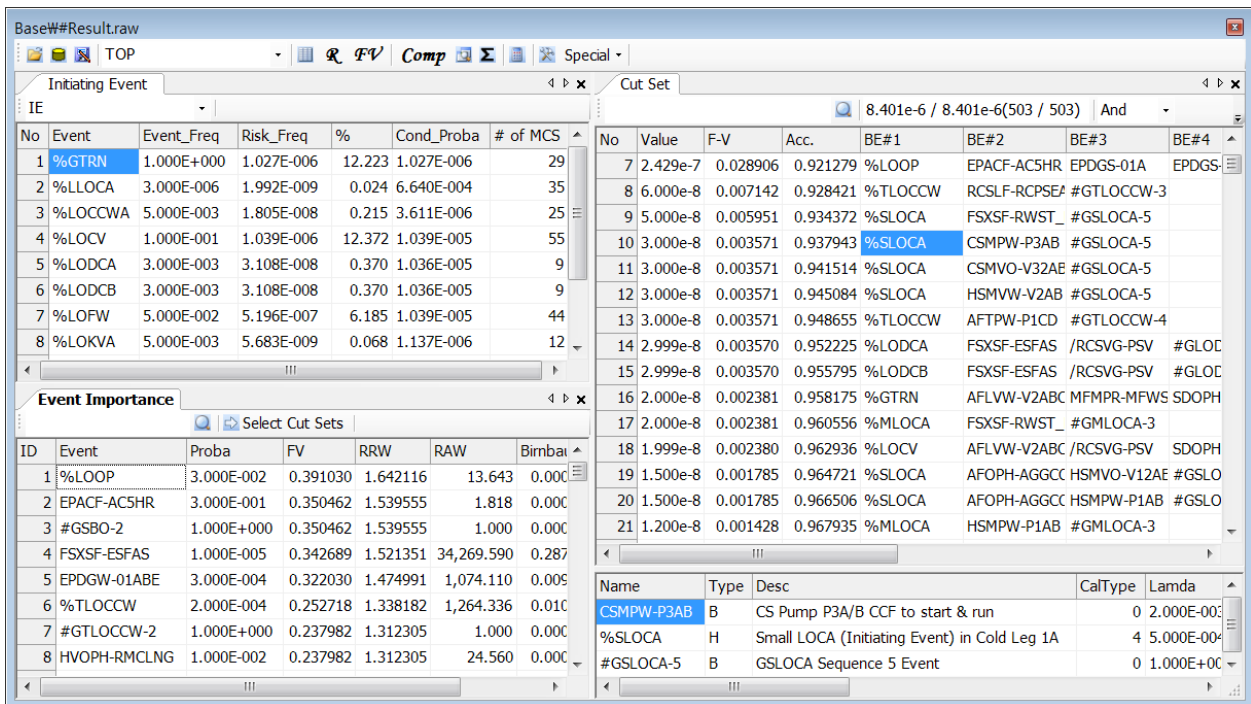


Fig. 5. Functions of Cut Set Browser

The AIMS-PSA provides a feature to compare two minimal cut set files. It distinguishes cut sets into 4 categories; the same (gray), no relation (white), absorbed by another one (cyan), and absorbing another one (yellow). Fig. 6 shows an example of cut set comparison where the 222-th cut set of the left side is absorbed by the 59-th cut set of the right side, and gray colored cut sets (218-th, 219-th, and so on) in the left side are the same as in the right side.

Fig. 6. Cut Set Comparison

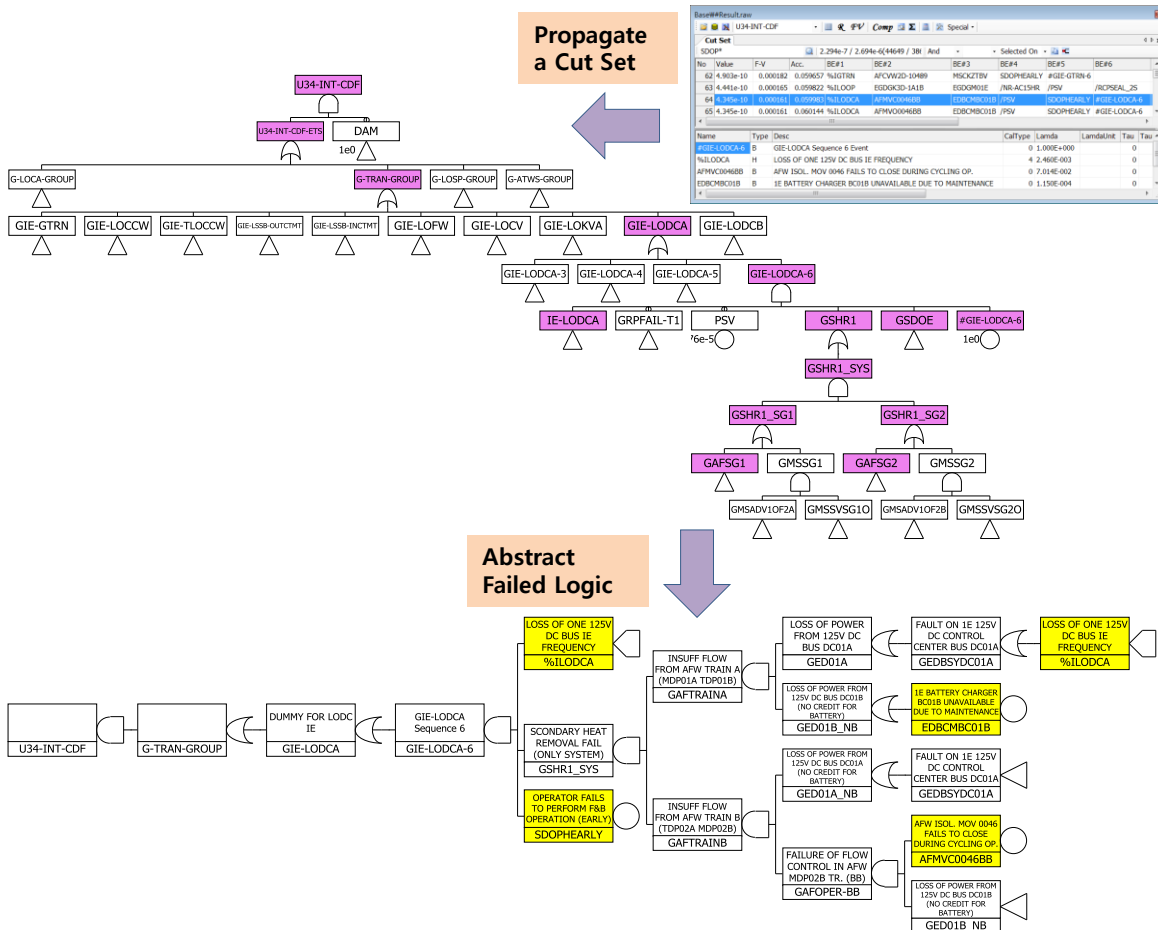


Fig. 7. Propagate a Cut Set & Abstract Failed Logic



Most PSA software provides a feature to propagate a cut set in fault tree. But, it is very difficult to trace the logic for the cut set in a large fault tree. The unique feature of the AIMS-PSA is to find an abstraction of the failed logic. Fig. 7 shows an example for the cut set propagation and the abstraction. We can find that it is not easy to trace whole logic for the cut set. The bottom side of the Fig. 7 is the abstracted logic for the cut set. It extracts the logic closely related to the cut set. Thus, it helps to trace the whole logic of the cut set.

**V. SIMA : INTERFACE for MODEL INTEGRATION & SENSITIVITY ANALYSIS**

The script interpreter called SIMA (Script Interface for Mapping Algorithm) plays an important role in the AIMS-PSA. The SIMA is used in many areas such as;

- Integration of PSA model in the project explorer
- Sensitivity analysis
- Interface with external PSAs

The SIMA is a kind of script in the text format. It is used to read files to build a PSA model, to modify the PSA model, to generate cut sets for the PSA model. The key features of the SIMA are to read files (such as event trees and fault trees) and to modify the logic. The example scripts used in the SIMA are shows in Table 1.

Table 1. Examples of SIMA Script Commands

Category	Script	Examples	Description
Project	ProjectFolder	ProjectFolder D:\U34-PSA	the project folder
	Page	Page Case1	the working folder
Reference Model	ReferencePage	ReferencePage Base	reference folder when using a reference model
File	File	File Ft-Sis.kft File Et-Loop.ket	Input files to be read (fault tree, event tree, data)
Cut Set Generation	TopEvent	TopEvent U34I-CDF	Top event name to be analyzed
	CutOff	Cutoff 1e-14	Truncation value
Modify Model	Value	Value A 1e-3	the event value
	Set	Set A B Set C True Set D False	Replace an event with another event Replace A with B Set C to be True, Set D to be False
	Gate	Gate G1 + G2 G3	Add a logic a gate (G1 is an OR gate whose inputs are G2 and G3)
	Add+	Add+ A B	Add B to A (useful for an external PSA)

In this section, it will be described how the sensitivity analysis is done in the AIMS-PSA.

**V.A. Sensitivity Analysis**

As shown in the left side of Fig. 8, the project explorer includes the list of files for a PSA model where it has 13 fault trees and 13 event trees. The project explorer reads input files to build the One Top fault tree and generates minimal cut set for the One Top fault tree where the project explore uses the SIMA to read files (for event trees and fault trees), to designate the top event name and the truncation limit, and to designate the project folder and the working folder.

The project explorer manages a project that can have several folders (a folder is corresponding to a PSA model). A typical folder has all input files for a PSA model. The AIMS-PSA provides a special feature for the sensitivity analysis; it includes models different with a certain folder and designates the reference folder. Then, the project explorer combines the One Top fault tree given in reference folder and models given in the folder itself. The right side of Fig. 8 shows an example

for the sensitivity folder. The sensitivity folder has a Ft-HpSis-Case1.kft file that has different model with the base folder. The project explorer combines the One Top fault tree of the base folder and the Ft-HpSis-Case1.kft to produce the sensitivity model. This feature of the AIMS-PSA provides convenient means for the sensitivity analysis.

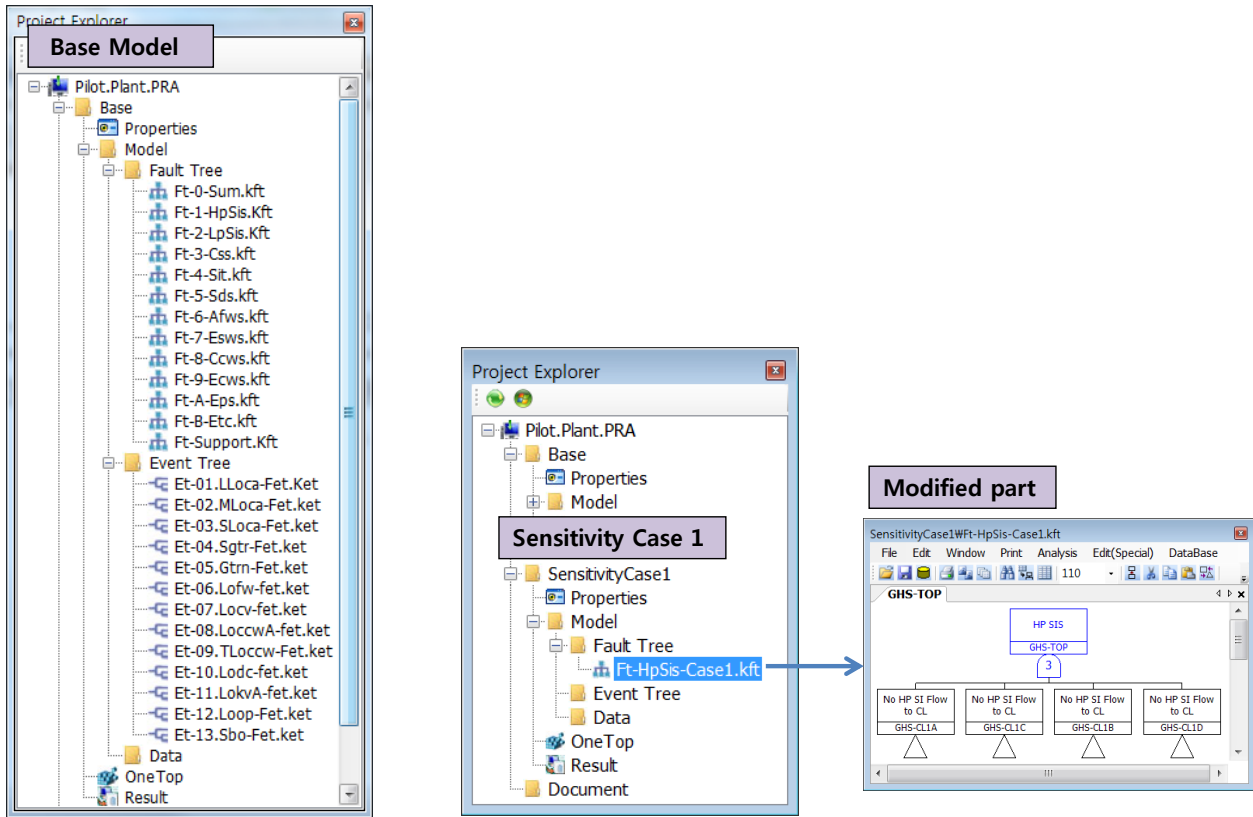


Fig. 8. Folder for Base Case and Sensitivity Analysis

We can perform one sensitivity analysis using one sensitivity folder. The AIMS-PSA provides a sensitivity table for cases that a lot of sensitivity analyses are required. Fig. 9 shows an example of sensitivity table. One row in the sensitivity table is corresponding to a sensitivity folder. The second row of the table represents a case that the reference model is Base, the values for 3 basic events are changed as shown SIMA field, and the top event CDF-TOP is quantified with cutoff value of 1e-11.

ProjectCase	ReferencePage	File	Sima	TopEvent	CutOff	Result	Remark
1 Case-Base	Base			CDF-TOP	1e-11	CDF-TOP = 8.392e-6	Base Case
2 Case-AFW_TDP_2	Base		Value AFTPS-P1C 0.01 Value AFTPS-P1D 0.01 Value AFTPW-P1CD 3e-4	CDF-TOP	1e-11	CDF-TOP = 8.402e-6	2 x AFW TDP
3 Case-CSS_CV_10	Base		Value CSCVO-V31A 0.001 Value CSCVO-V31B 0.001 Value CSCVW-V31AB 3e-5	CDF-TOP	1e-11	CDF-TOP = 8.397e-6	10 x CS CV

Fig. 9. Sensitivity Table for Large Amount of Sensitivity Analyses

## V.B. Interface for External PSA

The SIMA script regarding to “Modify Model” in Table 1 is needed to modify a PSA model. This category of SIMA script is used to build an interface for an external PSA. Typical external PSA uses the internal PSA model as basis and adds models to describe the affected components due to an external event. As shown in Fig.10, we can prepare a DB for fire event



analysis and produce a list of SIMA scripts in a text file. The project explorer of the AIMS-PSA takes the SIMA scripts as Data file and combines it with an internal PSA model to produce a fire PSA model.

The use of SIMA script in a text file provides a means for interface between the AIMS-PSA and the other software that can be developed by ourselves or third parties. In a simple case, we can use Microsoft Excel to prepare the list of SIMA scripts. IPRO-ZONE (Ref. 5) and PRASSE (Ref. 6) are softwares for the fire/flood PSA and the seismic PSA, respectively, used together with the AIMS-PSA.

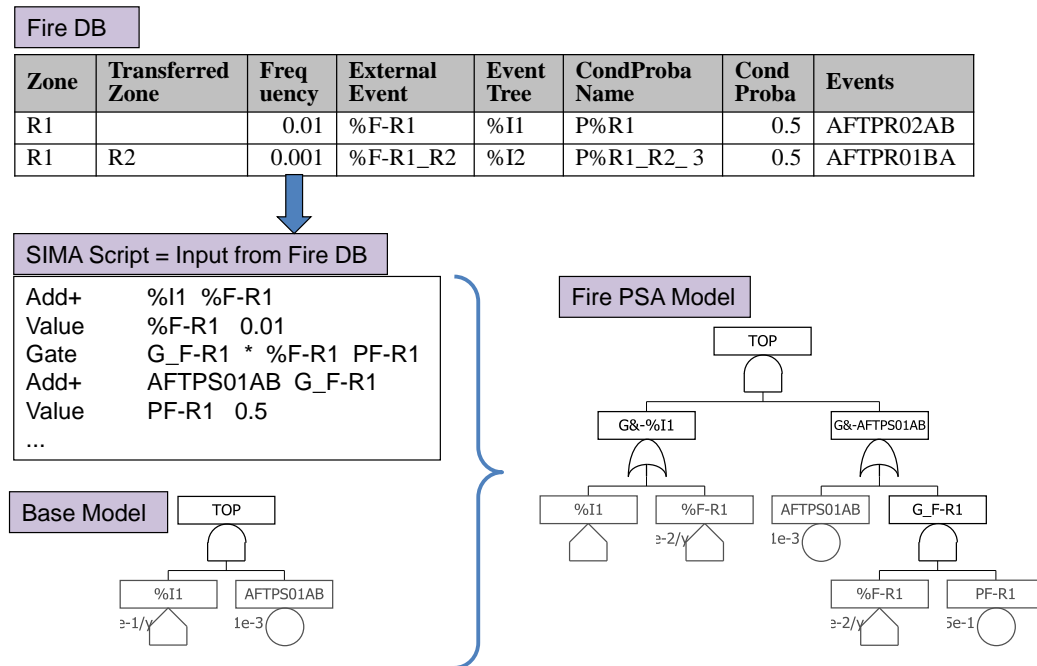


Fig. 10. Example of SIMA Script for External PSA

## VI. CONCLUSIONS and FURTHER WORKS

KAERI has been developing software package OCEANS (Ref. 7) for PSA from the Level-1 PSA to Level-3 PSA. The AIMS-PSA presented in this article plays a key role in the OCEANS, which takes charge of the event tree and fault tree analysis. The new AIMS-PSA Release 2 has been being developed to solve the problems found in previous PSA tools and has been successfully used for many PSAs;

Recently, KAERI is developing a PSA model that includes the Level-1 and Level-2 PSA, internal and external event PSA, full power and low power/shutdown PSA, and multi-unit PSA. The PSA requires large amount of works and technologies. Thus, further works are required to enhance and develop PSA software to handle the multi-unit issue, integration of Level-1 and Level-2 PSA model, and so on.

## ACKNOWLEDGMENTS

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