A Formal Integration of the Level 1 and Level 2 PSA Models for Risk-informed Applications

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1. Introduction

The Risk-informed Application (RIA) [1] whose essential part is based on the result of a Probabilistic Safety Assessment (PSA) employs two surrogate measures for the plant risk: one is a Core Damage Frequency (CDF) that is given as a result of the Level 1 PSA and the other is the Large Early Release Frequency (LERF) that is obtained from the Level 2 PSA. The main purpose of this paper is to provide a formal approach for integrating two PSA models that are developed sequentially and different in nature (i.e., PSA Level and Level 2) into a single model with which the foregoing two risk measures can be simultaneously evaluated through a single computation; the importance of the Level 1 basic events to the Level 2 risk measure can be effectively evaluated; and the change of the Level 1 events can be directly propagated through the Level 2 risk model. The applicability of the present approach is assessed through an example application to the UCN 3&4 PSA models.

2. Methods and Results

A principal step in the performance of a conventional Level 2 PSA is the development of Plant Damage States (PDSs) that are used to establish an interface between plant systems and containment analyses. Then the use of PDS must assure that all the input information required by the containment models is contained in the definition of the PDS and there is a complete transition without any loss of information between these two parts of a PSA that are sequential and different in nature. When the Level 2 quantification is decoupled from the Level 1 model by the PDS, the only information transferred from the Level 1 model to the Level 2 model is the information in these PDSs. The aforementioned fact informs us that a fine treatment of the PDS plays a key role in integrating the two successive levels of a PSA into a single model. More specifically, such a type of integration is not possible without an explicit and fine treatment of the Level 1 event tree (ET) sequences grouped into each PDS into the Level 2 Containment Event Tree (CET) model. Of course, a similar type of integration can be made through a direct link of the ET and the CET models, thereby alleviating the need for the Level 1 to Level 2 interface. In that case, the Level 1 accident sequences are carried all the way through a single model from initiating event (IE) to containment response. However, the foregoing which are main contributors to LERF. The functional forms for the PDSs and the STCs given explicitly in Table approach often results in a single model that may be quite complex and huge, and therefore cause a significant loss of transparence to review. For the reason, the main concern of this paper is limited to the formal integration of a conventional ET-PDS-CET framework into a single model in which the PDS is employed for an interface between the ET and the CET models. The concept of the foregoing approach is to utilize both a functional relationship between each PDS and the ET sequences belonging to the PDS and a functional relationship between each PDS and the corresponding CET accident pathways. Then, the Level 2 risk measure can be expressed as a Boolean equation for the Level 1 core damage sequences and the Level 2 CET sequences. Since the Level 1 core damage sequences can be expressed with the corresponding Minimal Cut Sets (MCSs), the Level 2 risk measure can be given as a functional form whose elements contain (a) Level 1 core damage sequences (or the corresponding MCSs), (b) PDSs, and (c) Level 2 CET accident pathways. Figure 1 shows a process for integrating the Level 1 and Level 2 PSA models into a single PSA model by using a matrix formulation of a plant risk [2]. Since the foregoing approach deals with the existing Level 1 and Level 2 PSA models developed sequentially without an essential modification, the integration process is simple and easy to manipulate. In addition, it is possible to perform a variety of analyses for the risk-informed applications as well as for the conventional PSA through the formulated model (such as a simultaneous computation of the CDF and LERF through a single run, importance of the Level 1 basic events to LERF, consistent propagation of the Level 1 uncertainties to LERF, and a direct propagation of the change of the Level 1 events through the Level 2 model).

Table 1 shows the function forms for the Level 2 Source Term Category (STC) that were obtained through an example application of the present approach to the UCN 3&4 [3] Level 1 ET and Level 2 PSA CET models. While in Table 1 PDS_5 and PDS_6 were expressed as functions of the Level 1 core damage sequences, STC_3 and STC_4 were given as functions of the PDSs and the frequencies for the CET accident pathways. Both STC_3 and STC_4 correspond to the two failure modes of the containment (i.e., 'early leak' and 'early rupture' types, respectively), 1 were obtained through an implementation of the Level 2 PSA code 'CONPAS' [4], which can be evaluated through the Level 1 PSA codes such as 'KIRAP' [5].

3. Concluding Remarks

A formal approach for integrating the two successive levels of a PSA that are developed sequentially and different in nature (i.e., Level 1 PSA and Level 2 PSA) into a single PSA model has been presented in this paper. The applicability of the present approach has been assessed through an example application to the UCN 3&4 Level 1 and Level 2 PSA models. Finally, a few distinctive functional forms of the integrated PSA model have been given for the case of the UCN 3&4 PSA models. The formulation of the integrated PSA model has been automatically made through an implementation of the Level 2 PSA code and the resultant model can be evaluated through the Level 1 PSA codes.

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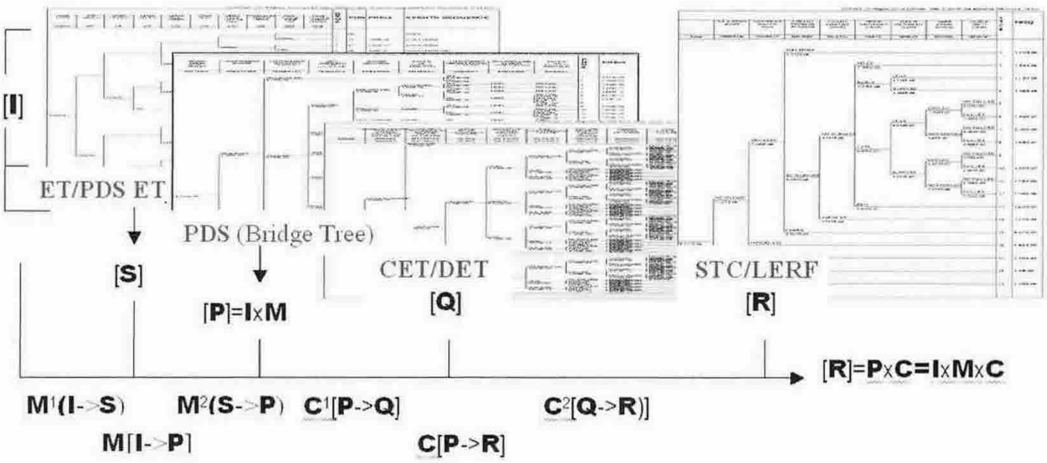

Fig. 1 An Integration Process of the Level 1 -2 PSA Models through a Formulation of a Plant Risk Matrix

Table 1 Typical Example of the Integrated PSA Mod el formulated for UCN 3&4

PDS/STC	Functional Forms of the Integrated PSA Model
PDS= *f* (PDSET_s)	... **PDS_5** = SBOPDS_S35 + SBOPDS_S37 + SBOPDS_S80 + SBOPDS_S82 + SBOPDS_S93 + SBOPDS_S95. **PDS_6** = SBOPDS_S36 + SBOPDS_S38 + SBOPDS_S81 + SB OPDS_S83 + SBOPDS_S94 + SBOPDS_S96. ...
R= *f* (PDS_s, CET_s) **R=** *f* **(MCS)**	**STC_3** = 1.00959E-04 * PDS_3 + 4.37332E-04 * PDS_4 + 9.08626E-04 * PDS_5 + 3.93599E-03 * PDS_6 + 9.50711E-03 * PDS_7 + 9.50711E-03 * PDS_8 + 2.19489E-03 * PDS_9 + 9.50711E-03 * PDS_10 + 9.50711E-03 * PDS_11 + 9.50711E-03 * PDS_12 + 9.50711E-03 * PDS_13 + 2.19489E-03 * PDS_14 + 9.50711E-03 * PDS_15 + 9.50711E-03 * PDS_16 + 9.50711E-03 * PDS_17 + 9.50711E-03 * PDS_18 + 9.08626E-04 * PDS_19 + 3.93599E-03 * PDS_20 + 9.50711E-03 * PDS_21 + 9.50711E-03 * PDS_22 + 9.08626E-04 * PDS_23 + 3.93599E-03 * PDS_24 + 9.50711E-03 * PDS_25 + 9.50711E-03 * PDS_26 + 1.75278E-05 * PDS_33 + 7.59399E-05 * PDS_34 + 3.15500E-04 * PDS_35 + 1.36692E-03 * PDS_36 + 1.52700E-03 * PDS_37 + 1.52700E-03 * PDS_38 + 3.15500E-04 * PDS_39 + 1.36692E-03 * PDS_40 + 1.52700E-03 * PDS_41 + 1.52700E-03 * PDS_42. **STC_4** = 4.97032E-04 * PDS_3 + 5.59535E-04 * PDS_4 + 4.47329E-03 * PDS_5 + 5.03582E-03 * PDS_6 + ...