A Rule-based Transformation of a Detailed Level 2 Model to a Simplified LERF Model and Its Uncertainty Bound

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1. Introduction

The current Risk-informed Regulation (RIR) framework [1] employs two risk metrics in making regulatory decisions for the plant risk: one is a Level 1 Core Damage Frequency (CDF) and the other is the Large Early Release Frequency (LERF) that is obtained from the Level 2 PSA. In those cases where only the Level 1 PSA analysis is available, however, the current RIR allows for the simplified LERF model [2] as an alternative means. The main purpose of this paper is (a) to provide the result of a rule-based transformation from the UCN 3&4 detailed Level 2 PSA model into the simplified LERF event tree (ET) model and (b) to assess its uncertainty bound through a type of sensitivity analyses (especially caused from a different grouping of various LOCA sequences in the LERF model).

2. Methods and Results

Although the simplified LERF model provides an effective means for estimating approximately the LERF in those cases where only the Level 1 PSA analysis is available, a detailed Level 2 PSA model should be utilized to obtain a more accurate estimate of the LERF when it is available. For the latter case, the LERF can be estimated by either the direct utilization of the detailed Level 2 results or the transformation of the Level 2 model into a simplified LERF model. A similar approach [3] was previously performed for the UCN 3&4 Level 2 PSA model [4]. However, the approach heavily relied on a hand-calculation by which the same manner has to be repeated to obtain the corresponding LERF whenever the Level 1 information is changed. Moreover, the hand-calculation might cause some loss of the Level 2 information during its implementation process. The aforementioned problem could be completely resolved by employing a rule-based transformation approach.

The present rule-based approach is fundamentally based on (a) construction of the simplified LERF model, (b) development of the event classification rules by which the detailed Level 2 sequences are systematically grouped into the corresponding LERF sequences, and (c) quantification of the LERF model with a Level 2 computational tool. Its implementation process is subsequently described.

Development of the Simplified LERF Model

The simplified LERF ET model is structured to include only questions related with severe accident pathways dealing with the likelihood of an early containment failure (ECF) or bypass. The former part of the model is structured so that the Level 1 accident sequences are allocated to a risk category based on the status of the plant. The latter part of the model contains questions directly related to the structural failure of the containment due to key severe accident phenomena. The formulated UCN 3&4 LERF model (see Fig.1) is very similar to that proposed by Pratt et al. [2], except for an additional consideration of the third branch 'CFAILBCM' of the top event 'CONISOLAT'. The branch 'CFAILBCM' (i.e., containment failure before a severe core damage) has been added to completely interface the UCN 3&4 PDS with the corresponding LERF model although it is no a LERF contributor.

Establishment of Event Classification Rules

The UCN 3&4 Level 2 approach is fundamentally the same as that of the conventional Level 2 PSA except that it employs a small CET whose quantification is treated with the corresponding DETs (Decomposition Event Trees) in more detail. Consequently, all the CET branch probabilities are assigned conditionally on each PDS sequence. Once the PDS and CET/DET are established, they can be grouped into the corresponding LERF events with the user-specified LERF event classification rules. The LERF model is not quantified by itself; but instead it is only used as a logical tool for grouping systematically the CET and PDS sequences to the corresponding LERF events. This is similar to that used to determine the source term release categories (STCs) in the UCN 3&4 Level 2 PSA. For the present LERF model, the LERF event classification rules have been formulated so that the containment bypass-related events of the UCN 3&4 PDS (i.e., SGTR, Interfacing system LOCA, and Containment isolation failure) are matched with the 'NOT ISOLATED' branch of the LERF event 'CONISOLAT', the induced SGTR of the UCN 3&4 CET is matched with the branch 'ISGTR YES' of the LERF event 'IND-SGTR', and the ECF-related events (i.e., Early leak, Early rupture, and Alpha mode failure) are matched with the branch 'ECF YES' of the LERF event 'CF-EARLY'. All the LOCA

branch 'DPRES-YES' of the 'RCSDPRES' event and the remaining PDS sequences to the branch 'DPRES-NO'.

Rule-based Quantification of the LERF Model

Fig.1 shows all the branch frequencies of the simplified LERF ET whose rule-based quantification has been made with the Level 2 PSA code 'CONPAS' [5]. A summation of all the LERF contributors (i.e., 'LERF YES' branches) has resulted in a LERF value of 1.240E-6/ry. This LERF value is exactly the same as that of the corresponding UCN 3&4 detailed Level 2 PSA. Here, it should be noted that while the estimation of the release frequencies requires a Level 3 offsite consequence calculations, the present LERF model does not contain any risk information.

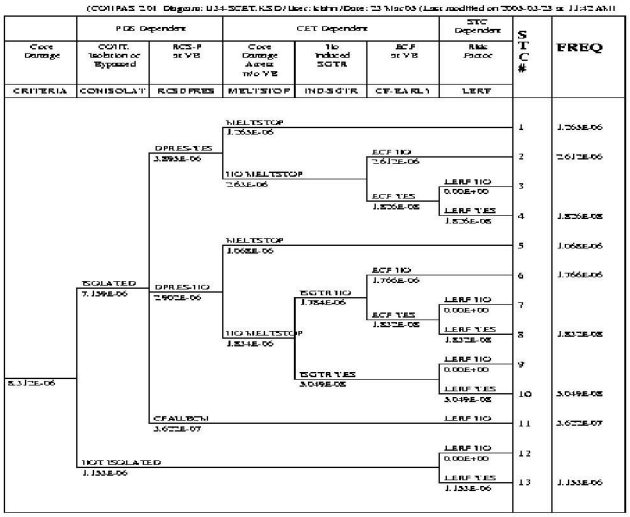

Fig.1 The Quantified LERF Model for the UCN 3&4

Uncertainty Bound of the LERF Model

The simplified LERF model employs two states for the RCS pressure at a vessel breach (VB): High-pressure state (i.e., 'DPRES-NO') and Depressurized state (i.e., 'DPRES-YES'). According to that proposed by Pratt et al. [2], transients and small break LOCAs where the RCS is not depressurized by an operator are categorized into the 'DPRES-YES' branch while the 'DPRES-NO' branch contains intermediate and large break LOCAs that are expected to result in a RCS below 200psia. In the case of the UCN 3&4 PDS, both of the medium (200~600psia) and small (600~2000psia) LOCAs are categorized into a single 'MEDIUM' sequence whose pressure ranges from 200 to 2000psia while the large LOCA is categorized into a 'LOW' sequence whose pressure is below 200 psia. This difference between the UCN 3&4 PDS model and the simplified LERF model in assigning the LOCA sequences causes a type of uncertainty for the simplified LERF model. For this case, a result of the sensitivity analysis (see Table 1) shows that the uncertainty bound of the simplified LERF model is subjected to between 1.240E-6/ry.and 1.248E-6/ry (3.5% higher than the base case).

Table 1 Results of the LOCA Group Sensitivity Analysis

Cases	UCN 3&4 PDS		Present simplified LERF model	
	SLOCA Pressure	MLOCA Pressure	RCSDPRES Branch assignment	LERFs (/ry)
Base	MEDIUM	MEDIUM	SLOCA: DPRES-NO MLOCA: DPRES-NO	1.240E-6
Case 1	HIGH	MEDIUM	SLOCA: DPRES-NO MLOCA: DPRES-NO	1.284E-6
Case 2	HIGH	MEDIUM	SLOCA: DPRES-NO MLOCA: DPRES-YES	1.284E-6
Case 3	MEDIUM	MEDIUM	SLOCA: DPRES-NO MLOCA: DPRES-YES	1.240E-6
Case 4	HIGH	LOW	Not feasible	-
Case 5	MEDIUM	LOW	Not feasible	-

3. Concluding Remarks

In this paper, it has been shown that the present rule-based transformation approach could exactly match all the LERF contributors addressed in a detailed Level 2 model with those of the corresponding simplified LERF model. Subsequently, a type of model sensitivity analyses for the different groupings of LOCA sequences has been made to assess an uncertainty of the transformed LERF model. The result has shown that even for such case there is no essential impact on the resultant LERF estimate. An additional finding obtained through this study is that the simplified LERF model itself couldn't provide the LERF estimate exactly responding to the change of the Level 1 information unless it is interfaced at the level of Level 1 ET or PDS sequences.

ACKNOWLEDGEMENTS

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