



Optimized Algorithm Using Heuristics

One of the possibilities to run analyses of Probabilistic Safety Assessment (PSA) models faster is given by the structural properties of typical models. The RiskSpectrum team recently released a new version of the calculation engine RSAT where new heuristics have been utilized for common structures of large fault tree and event tree models.

The size of Probabilistic Safety Assessment (PSA) models in the nuclear industry grew continuously from the seventies with the WASH-1400 study with the scope limited to some 1000 sequences to contemporary models with hundreds of thousands of sequences only for the basic Level 1 consequences.

It is not only the extended set of scenarios including seismic, fire and flooding analyses, but also the detail of safety system modeling, the amount and quality of reliability data and the refined coverage of dependencies that drives the PSA model growth. Extension of these large PSA Level 1 models into PSA Level 2, where the same level of detail is applied can generate many millions of sequences to be solved.

These advances in realistic modeling were enabled by software support and the growing power of computational resources. Yet, the model size presents challenges for the infrastructure in which PSA is developed, maintained, and used.

The Model Size Challenge

The first obvious challenge is the calculation complexity, especially for 'summary' consequences such as Core Damage or Large Early Release. The combinatorial nature of Boolean models defined by event trees and fault trees require either harder approximations or new heuristics exploiting specific properties of calculations.

Approximations are Needed

Approximations necessarily imply a loss of precision. If we use them with care and understanding of their effects, we might arrive at results that could not be achieved in a precise calculation and where simplifications in reliability models and uncertainties in reliability data dominate over the imprecision caused by approximations. Application of cutoff belongs definitely to the most prominent approximations, together with a conservative quantification of the minimal cut set list.

Splitting the Problem, Combing the Solutions



Fault tree analysis belongs to algorithmically difficult problems that do not have a general efficient solution. But there might be one for certain instances of this problem that share some properties. This idea influences implementation of fault tree solving algorithms so that the efficiency on typical models exceeds a naïve approach of, say, the basic MOCUS algorithm.

One of the possibilities to make analyses more efficient is given by the structural properties of typical PSA models. Some heuristics can utilize common structuring of large analysis cases.

In some cases, often present in large analysis cases, it is possible to perform parts of the analysis more locally. Such an optimized 'divide and conquer' implementation can make a big difference, because the algorithm avoids additional steps that guide the search for minimal cut sets by splitting the problem into smaller parts and combining the solution. Also, this approach supports optimized use of modern hardware, where data locality plays an increasingly important role.



After updating to RiskWatcher Web 1.8 with RSAT 4.0.0, combined with the new MCS merging feature, we have experienced a significant increase in calculation speed. Our risk monitoring PSA model including PSA Level 1 and 2, internal events, and detailed modeling of I&C systems, that was typically solved in 45 min (with cutoff at $1E-13$) now are solved in 3.5 min. This is a reduction of calculation time by 92%! The faster calculation allows the risk monitor system to provide better support in the operating and planning Configuration Risk Management activities.

Mrs. WANG Zhenqi from Sanmen NPP (CNNC Group)



Speed Up Your Calculations Using the Latest Release

Two optimizations of this kind are implemented in the latest version of the calculation engine RSAT for RiskSpectrum PSA 1.6.0 and RiskWatcher 1.8. A typical speed-up for a large analysis case goes up to a factor of 10, where even higher values are achieved for special cases. The decrease of the calculation time on a complete PSA model with all analysis cases (including a potentially large number of small analysis cases) is summarized in the table below with the expected decrease factor up to three.

RSAT version	3.5.0	4.0.0	Factor
Model 1	60.000s	35.000s	1.7
Model 2	6.200s	6.000s	(3%)
Model 3	43.000s	27.000s	1.6
Model 4	2.900s	1.000s	2.9
Model 5	11.600s	8.400s	1.4



We have experienced a dramatic increase in calculation speed using RSAT 4.0.0. with RiskWatcher. Our most complicated RiskWatcher model, which is for internal events level 2 PSA, took over 10 hours to solve, but is now solved within approximately 30 minutes reducing the calculation time by 1/20.

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