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SRESA *Newsletter*

Jul. – Sep.-2023 Issue-3

A quarterly publication of Society for Reliability and Safety [Reg. No. 3141/2010/G.B.B.S.D.], Mumbai

SRESA Mission & Programmes

SRESA has outreach program as one of the important components to support mutual exchange, education, and learning. In this direction we our flag bearer event – ICRESH-2024.

SRESA has started working on development of Engineering Code, Standard and Guides in Risk and Reliability. Our First Standard on PRA is in the final stages of review.

One of the ambitious projects of SRESA is establishing IIRR – Indian Institute of Risk and Reliability – The second article provides an overview of the project.

From the President's Desk ....

There were three long pending items with SRESA managing committee, viz., looking for a new SRESA office address, upgradation of SRESA website, publication of SRESA Probabilistic Risk Assessment (PRA) Standard, along with few relatively small issues.

I am happy bring to your kind notice that on all the three fronts, there is considerable progress. SRESA web-site upgradation was pending for couple of years, nevertheless, we could identify a web-site developer in Faridabad, who is developing SRESA website with new software, tools, and protocols. I would prefer the word 'modernizing' the website as apart from old features it will have new modules and protocols that makes this website more effective for the visitors. Second and very important we are also the issue of SRESA's new address. Before that I will sincerely thank Shri S.J. Raut, who happily volunteered his address for SRESA office. Third and most important SRESA's first standard, entitled the PRA Standard for Nuclear Plants, was communicated to Bureau of Indian Standard (BIS) further discussions are on with BIS and AERB, as to what should be the publication possibilities and protocols.

Finally, I am glad that preparations for ICRESH-2024 is going exceedingly well and we all hope that ICRESH-2024, proposed to be held in Mumbai, during 21 – 24 February 2024, like all past ICRESH events will be a grand success.

Prabhakar V Varde

In this issue ....

An Overview of Dynamic Probabilistic Safety Assessment Methodologies and Tools

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Abstract

Regulatory requirement needs Probabilistic Safety Assessment (PSA) (internal and external) to be carried out for Nuclear Power Plants (NPP). Current PSA models are based on the Event-Tree/Fault-Tree (ET/FT) methodology which are static and cannot capture dynamism that is impact of process, hardware, software and human interactions on the stochastic system behavior. To overcome the limitations of the traditional approach to PSA, several dynamic PSA (DPSA) methodologies are being developed. The present article highlights the limitations of the current PSA models, various dynamic effects possible in the plant, challenges in implementing the dynamic effects in the current PSA models, various methodologies available for implementing the dynamism, advantages and limitations of DPSA studies, various dynamic PSA tools available globally and developmental aspects of DPSA tool in India.

1. Introduction

Probabilistic Safety Assessment (PSA) is an analytical technique used extensively for assessing the risk of complex engineering systems like Nuclear Power Plants (NPP), chemical, process plants, etc. The current risk models in PSA use traditional Event-Tree/Fault-Tree (ET/FT) analysis, these are static in nature and are based on Boolean logic approaches. Many static PSA tools are available commercially, such as Isograph, Risk Spectrum, SAPHIRE, IRRAS etc. In the present-day static PSA models the short time dynamic effects such as impact of process, hardware, software, human interactions etc. on the stochastic system behaviour is not adequately captured. In view of this, there is an effort to develop dynamic PSA methodologies that can account for various short time dynamic effects in the existing static PSA models. Here the dynamic effects refer to the consideration of effect of time (time dependency) in the input parameters of PSA model.

1.1 Dynamic Effects

As described in K.-S. Hsueh and A. Mosleh [1] the dynamic effects can be divided into short time and longtime effects as shown in Fig. 1 [2]. By the name, short time effects refer to those effects that occur in a short period of time and in general once the initiating event starts these effects will come into effect. Whereas, the longtime effects occur in a long period of time and they can be effective at any point of time of plant operation and these effect can be easily implemented into the existing static PSA models.

1.2 Concerns with Existing PSA Models

As discussed above the existing PSA models use ET/FT methodology and these models do not adequately account for the impact of process, hardware, software, human interactions on the stochastic system behaviour. From a historical perspective, the first challenge identified with the ET/FT methodology was modelling of logic loops. If one carefully examines the existing PSA models, the long-time dynamic effects can be easily accommodated by modifying basic events probabilities to account for the components ageing, periodic updating of the PSA models and new logic model development for new plant configurations. In contrast, only a limited, implicit treatment of short time dynamic effects is possible with conventional PSA methodologies.

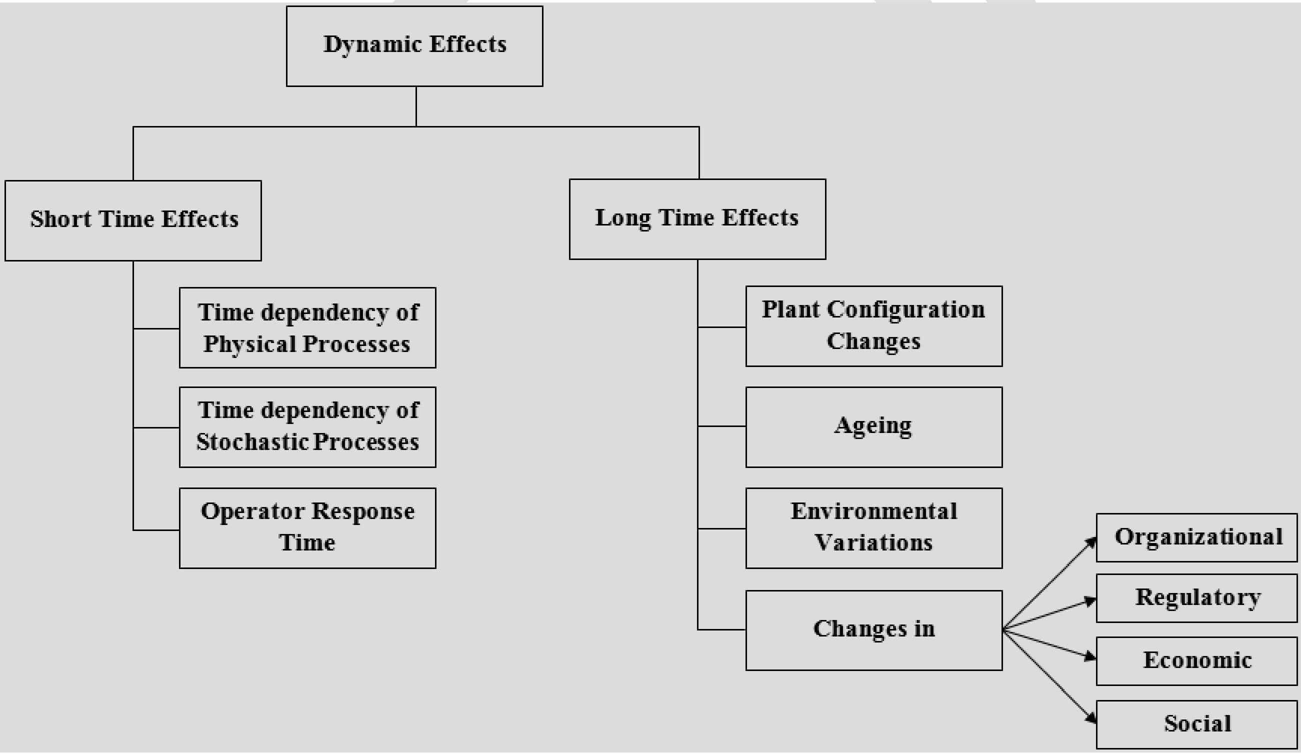

Fig. 1 : Different types of dynamic effects [2]

1.3 Need for Dynamic PSA Tools

Incorporating dynamic (time dependent) interactions into the PSA models is difficult. Such challenges can arise due to digital control systems, human interactions, and passive components etc. Several dynamic PSA methodologies are proposed to overcome the limitations of the traditional approach to PSA but they are highly computation intensive. They can produce large amounts of data that are difficult to analyze without the use of post processing tools. It should be noted that dynamic PSA methodologies should not be regarded as alternative to the traditional PSA but rather complementary for the improved modeling of the systems with significant process, hardware, software and human interactions.

2. Dynamic PSA methodologies

As per NUREG/CR-6901 [3] [4], the various dynamic PSA methodologies can be divided into following three categories:

i) Continuous-time methods

a. Continuous Event Tree (CET) approach
b. Continuous Cell to Cell Mapping (CCCM)

ii) Discrete-time methods

a. Dynamic Logical Analytical Methodology (DYLAM)
   - Dynamic Event Tree Analysis Method (DETAM)
   - Dynamic Discrete Event Tree (DDET)
   - Accident Dynamic Simulator (ADS)

b. Monte-Carlo (MC) Simulation Approach
c. DDET/MC Hybrid Simulation
d. Cell-to-Cell Mapping Technique (CCMT)

iii) Methods with visual interfaces

a. Petri Nets
b. Dynamic Flowgraphs
c. Dynamic Fault Trees
d. Event Sequence Diagram Approach
e. GO-FLOW Methodology

The inputs for all dynamic methodologies are:

- A time-dependent system model (such as RELAP5 or MELCOR codes),
- Possible normal and abnormal system configurations which may need to be determined using a Failure Mode and Effect Analysis (FMEA), and
- Transition probabilities (or rates) among these configurations.
- Operational rules (including triggers that cause a state change) to determine how the system should function during the dynamic analysis.
- Common cause failures can be modelled as a separate system configuration or using other standard techniques (e.g., beta factor method) depending on data availability.

3. Dynamic PSA Tools

A list of existing DPSA tools in various countries is provided in Table 1 [1] [3] [4] [5].

Table 1: Various DPSA tools existing in different countries

S. No.	Tool	Description	Country
1	MSAS	Monte Carlo Simulation for Accident Sequences	JRC, Ispra, Italy
2	DYLAM	Dynamic Logical Analytical Methodology	JRC, Ispra, Italy
3	DETAM	Dynamic Event Tree Analysis Method	MIT, USA
4	ADS	Accident Dynamic Simulator	University of Maryland, USA
6	MCDET	Monte Carlo Dynamic Event Tree	GRS, Germany
7	ADAPT	Analysis of Dynamic Accident Progression Trees	SNL, USA
8	SCAIS	Simulation Code System for Integrated Safety Assessment	CSN, Spain
9	RAVEN	Reactor Analysis and Virtual control ENvironment	INL, USA
10	BARC-DPSAT	BARC Dynamic PSA Tool	BARC, INDIA

It can be said that while dynamic PSA methodologies overcome the limitations of the traditional approach to PSA, but they are highly computation intensive. These challenges are being addressed by using massively parallel computing and developing methodologies for scenario clustering, respectively. One such tool being developed by Reactor Safety Division, BARC is BARC-Dynamic Probabilistic Safety Assessment Tool (BARC-DPSAT). It is an indigenous tool being developed, which is useful to study the impact on plant risk due to multiple events and useful in obtaining realistic probabilistic safety margins with reduced uncertainty. The various developmental aspects of the tool and the methodology adopted in developing various modules are explained in the following section.

4. BARC-DPSA Tool

BARC-DPSAT [6] is developed based on the DET concept. The tool is being developed to account for both internal as well as external events. The various modules that are implemented in the software tool are Dynamic Event Tree (DET) Module, Thermal Hydraulic Interface Module and Uncertainty Analysis Module. The basic flow diagram of the tool is shown in Fig. 2 and is explained in the following steps:

1. By using the DET module, the user can construct the dynamic event trees, which represent the dynamic accident scenarios for a given initiating event (IE). As shown in Figure 2, there are 5 possible end states.
2. Now, the user can select any of the accident sequences to check its end state (in the present case 4th sequence is considered). For this purpose, the user needs to have a thermal-hydraulic (TH) model (which is RELAP5 model in the present case) and all the required input data. This can be run using the Thermal Hydraulic Interface Module.
3. If there are no variations in the input parameters of the input data, the user can run the analysis for once and can obtain the end state of the accident sequence. However, if there are any variations in the input parameters (in the present case 3 parameters are chosen), then user can choose Uncertainty Analysis module to capture all the variations in the input parameters and run the TH analysis depending on the number of samples prescribed by the user in the Uncertainty Analysis module.
4. Depending on the number of samples generated, those many numbers of end states will be obtained. This information can be used to obtain the end state probability and can be fed to DET module to show the status of the accident sequence and its probability of occurrence.

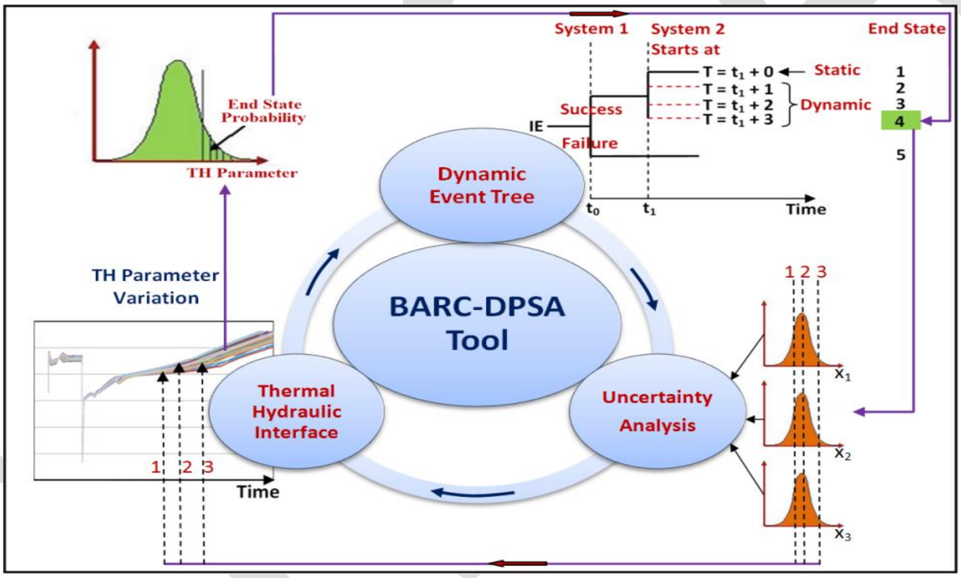

Fig. 2: Flow diagram of BARC-DPSA Software Tool

5. DPSA Advantages and Challenges

Some of the advantages of DPSA are as follows:

- It provides realistic risk quantification, estimation of realistic probabilistic safety margins and reduce uncertainty in the calculations.
- Supports risk informed decision making by robust PSA results with information on uncertainties.
- Assists regulatory decision making, e.g. review of Plant PSA, EOPs.
- It provides framework for comprehensively considering uncertainties.

Apart from the advantages, DPSA also has some limitations. Some of the challenges in DPSA are:

- Computational issues for doing simulations.
- They can produce large amounts of data that are difficult to analyse.
- Increases the scope of DET tools including the risk quantification.

6. Conclusion

Current PSA models are based on the ET/FT methodology and are static in nature. These static models cannot adequately capture short time dynamic effects. To overcome these limitations, several dynamic PSA methodologies are being developed. DPSA provides realistic risk quantification and helpful in estimation of realistic probabilistic safety margins with reduced uncertainty. However, they are highly computationally intensive. They can produce large amounts of data that are difficult to analyze without the use of post processing tools. To overcome the challenges of DPSA, the current research is towards reducing the computationally intensive by developing Reduced Order Models or surrogate models and adopting parallel processing to reduce the computational time.

References

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Dr. Gopika Vinod joined with Reactor Safety Division of Bhabha atomic Research Centre as a Scientific Officer from 37th batch of Training school after completing her graduation in Computer engineering. She received her doctoral degree in Reliability Engineering from Indian Institute of Technology, Bombay and also been post doctoral fellow at Steinbies Advanced Risk Technologies, Germany. She is a recipient of DAE Young Engineer Award 2007, DAE Group Achievement award (2015, 2019). Currently she is heading the Probabilistic Safety Section of Reactor Safety Division of BARC. She also holds faculty position as Professor with Homi Bhabha National Institute.

She has been actively involved in Reliability, Safety and Risk analysis of emerging technologies such as. digital systems, passive systems, Integrated Multi Unit Probabilistic Safety Assessment Model for nuclear reactor site risk assessment, etc. She has worked on the development of Reliability-based Operator Support Systems such as Risk Monitor, Symptom based Diagnostic System, for Indian Nuclear Power Plants. Her other areas of research activities include risk-informed in-service inspection, reliability of computer-based systems, dynamic reliability analysis, human reliability analysis, etc.

Dr. M. Hari Prasad, is a Scientific Officer at Bhabha Atomic Research Centre, Trombay, Mumbai, India. Since year 2000, he has been working in the areas of Probabilistic Safety Assessment (PSA) of Nuclear Power Plants, Seismic PSA, Risk Based Inspection of Power Plants, Dynamic PSA, Dynamic reliability-based risk analysis of passive safety systems, Risk Monitor and advanced PSA tool development. Has got a credit of two books and several research publications. Guided several M. Tech. thesis. Collaborated several projects at national and international level. He Received Post Doctoral Fellowship from Steinbeis Advanced Risk Technologies, Stuttgart, Germany from 2014 to 2016. Recipient of "Technical excellence award" for contributions towards "Dynamic reliability-based risk analysis of passive safety systems" by Society of Reliability Engineering, Quality and Operations Management, 2012. Recipient of "DAE Young Engineer Award 2011". Recipient of "DAE Scientific and Technical Excellence Group Achievement Award 2008" for design and developing 32 m DSN antenna for Chandrayan-I Mission.

He holds B.Tech in Mechanical Engineering from Sri Venkateswara University College of Engineering (India), M.Tech and Ph.D. in Reliability Engineering from IIT Bombay (India).

Point to ponder about ….

"As for human actions that lead to safety & security concerns, have two major categories, the more relevent to 'Safety' called random or inadvertant human error; the other relevant to 'Security' referred as intended human malacious actions to cause harm. The experience suggests that the third category is, 'non-action(s) /delayed-actions(s), for which, if a systematic root cause analysis is performed the root(s) may be found in organizational or institutional negligence". It can be argued that the third category cause more harm to safety as well as security".
(An article will be published on the subjet in one of the coming issues of this Newsletter)

Information about important Risk and Reliability and related Conferences

ICMIAM-2023, 6 – 8 Dec. 2023; Federal University, Australia, (https://icmiam.com/)

ICSRS-2023 22-24 Nov. 2023, Italy

An Invitation from SRESA Newsletter

Articles are invited from Academics, Researchers, Engineers, and Industry practitioners, and Young Scientists on their work for wider publicity for publishing in SRESA Newsletter. SRESA Newsletter is a platform for sharing, and learning. We all know that publishing an article requires lots of effort and time. In SRESA Newsletter you can request review on the core theme of the article, with little efforts. If you were awarded a Ph.D. Degree, then SRESA Newsletter is the right platform for wider publicity of your work.

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