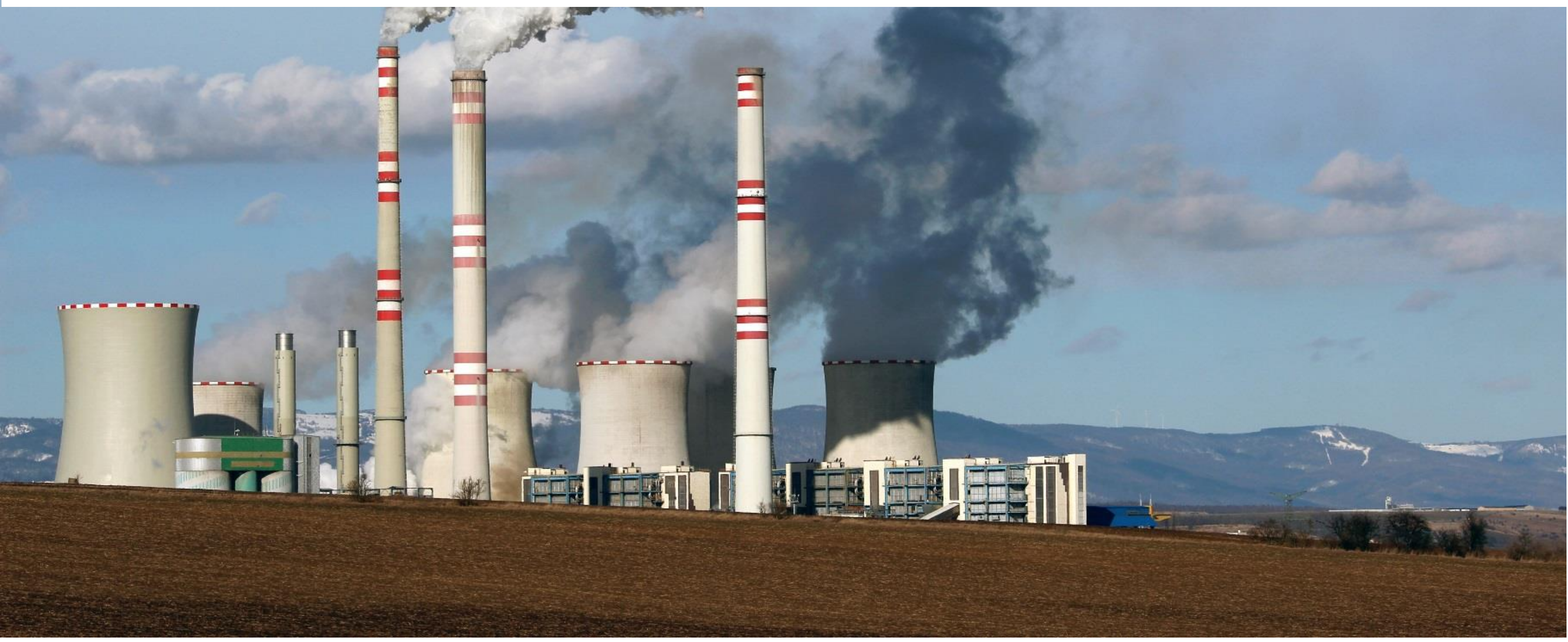
NARSIS

New Approach to Reactor Safety ImprovementS

Newsletter # 4



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Welcome!

Evelyne** Foerster NARSIS **project coordinator

Dear reader
A warm welcome to the this issue of NARSIS Newsletter!

NARSIS coordinates the research efforts of eighteen partners encompassing leading universities, research institutes, technical support organizations (TSO), nuclear power producers and suppliers, reactor designers and operators from ten countries. The project aims at making significant scientific updates of some elements required for the Probabilistic Safety Assessment (PSA), focusing on external natural events such as earthquake, tsunami, flooding, high-speed winds etc.

Among the objectives of the NARSIS project, the dissemination of research results to the academic sphere has a special place. The production of knowledge and education are two sides of the same coin. That means that research and access to research are essential in the training of young people to ensure the safe use of the nuclear energy of the today and tomorrow.

Studies show however that the process leading to the transfer of knowledge is complex in this field. Consensus emerges that the efforts generally made to make scientific knowledge available represent a necessary but not sufficient condition for real implementation. A double movement marks the context of the relations between nuclear science and society. On the one hand, the need to develop and improve knowledge through research is well understood, on the other, the current feeling of a divorce between nuclear science and the citizen exists. Under the impetus of these movements, the imperative of knowledge transfer acquires a powerful social and political dimension, which questions the responsibility of researchers, the social acceptability of scientific progress and the practical dissemination of knowledge through educational programs.

In this frame, NARSIS has two priority goals and perhaps a third one, which links the first two. The first objective is the development of research, constantly challenged with societal issues, so as to raise the potential level of safety in Europe. The second objective is to increase the attractiveness of nuclear sciences in the broad sense and raise confidence of young people in the possibility of integrating professional market in this field. Between the two, the objective is naturally the capacity to disseminate the research results and make the border between students and researchers much more permeable than they used to be.

We share these objectives with The European Nuclear Education Network (ENEN) through their European project ENEN+ whose aim is to attract, retain and develop new nuclear talents beyond academic curricula and which facilitates student mobility. Thus, the collaboration between the two projects was established naturally, allowing more than twenty Masters' students to benefit from ENEN grant and attend the first NARSIS workshop, which was held in Warsaw. During this event, each workpackage of the NARSIS project prepared two lectures related to the subject of the task. We present in this newsletter the summary of these lectures. The full text can be found in the workshop proceedings, which is a deliverable of the project.

With this newsletter, we would like to broaden the circle and share the outcomes of our project with larger audience. Our objective is to attract wide support from and involvement of any stakeholder interested in cooperative development of the nuclear safety. This newsletter aims to function as an information tool for disseminating results and outcomes of our project but also to become a forum for discussion, reflection and dialogue. Our conceptual strategy is anticipative, reflecting our wish to involve more researchers, professionals and interested groups in the debate including through our web site www.narsis.eu

We will be happy to receive your comments and suggestions. Please feel free to communicate your feedback to Prof. Behrooz Bazargan Sabet (b.bazargan-sabet@brgm.fr) for inclusion in our forthcoming issues. We would also like you to help us disseminate this second newsletter to your network.

We look forward to hearing from you!

EVENT

NARSIS Workshop
TRAINING ON PROBABILISTIC SAFETY ASSESSMENT FOR NUCLEAR FACILITIES

2 Sept -5 Sept 2019

Institute of Heat Engineering, Warsaw University of Technology, Warsaw, Poland

http://nuclear.itc.pw.edu.pl/narsis-workshop/

WP summaries

WP1: Characterization of potential physical threats due to different external hazards and scenarios

James Daniell
KIT

This WP is devoted to the development of methods to characterize some external hazards of interests, as identified as priorities by the PSA End-Users community in the EU ASAMPSA_E project. We update individual hazard characterization and secondary effects by introducing new approaches derived from latest researches and develop framework for combined hazards (multi-hazards) and screening analysis to select relevant scenarios for safety assessment.

Lecture #1: Introduction to External Hazard Events: Background, Parameters and Interactions

James DANIELL, Andreas SCHAEFER, Hugo WINTER, Vito BACCHI, Lucie PHEULPIN

This paper sets the outline to the workshop topic by providing a background and investigation into the following questions:-

1) What type of events can hit NPPs?
2) What type of events can occur in Europe?
3) How do we model hazards and their interactions?

The different external hazard events which can impact nuclear power plants are complex and numerous. ASAMPSA_E project identified 81 external hazard event types which can impact a plant. These types of interactions can occur as single events or combinations can occur as cascades or coinciding events. The influence of natural hazard types upon one another can be presented in various interactions:-

1) Directly via inducing the second hazard
2) Common-root cause and some have little correlation with the others
3) Mutually exclusive (e.g. high water level and low water level).
4) Coincidental hazards (events that occur simultaneously but are independent)

For these four types of multi-hazard relationships, different temporal and spatial settings should be investigated.

There are many methods for external hazards characterisation and much data and work exists in the field including standards for each hazard type for Europe. Uncertainties are found throughout every step of the hazard modelling chain and are important to characterise as part of PSA. Deterministic and probabilistic methods both have their place and can both be employed for each hazard type. Extreme value statistics and real-life examples are key to understanding NPP external hazard modelling

Lecture #2: Modelling External Floodings – The quantification of the Extreme Sea Level according to the French flooding guide recommendations

Vito Bacchi, Claire-Marie Duluc, Lise Bardet

This lecture aims to illustrate how the flooding hazard induced by an "Extreme Sea Water Level" situation must be evaluated according to French regulations recommendations adopted in the demonstration of nuclear safety of basic nuclear installations (BNI).

With this aim, we first introduce the French flooding guide published by the French Authority for Nuclear Safety (ASN) in 2013, which proposes a list of recommendations concerning the external flooding hazard assessment. Then, we will focus on the main scientific challenges related to extreme storm surge assessment, namely (i) the statistical models employed for the analysis of the *outlier* storm surge and (ii) the use of historical information in the statistical modelling. In conclusion, we will present the mentioned concepts with a practical evaluation of extreme storm surges at "La Rochelle" harbor.

WP summaries

WP2: Fragility assessment of main NPPs critical elements

Pierre Gehl

BRGM

This WP defines the theoretical framework for considering combined aggressions. New methods are introduced to define improved functions for physical and functional fragility assessment of main critical NPPs' SSC. Indeed, a considerable source of epistemic uncertainty is present in the construction of fragility curves, due to usual consideration of estimated damages caused by single IM parameters. Recent works have shown that the use of more than one IM leads to a better prediction of the damage states with significant reduction in the uncertainty. We improve fragility models by accounting for cumulative effects, soil-structure interactions and ageing mechanisms. Regarding these latter, structural degradations due to plants' ageing is expected to be among key factors to be assessed in order to obtain a realistic evaluation of the reactor safety, especially when extreme environmental demands, such as large earthquakes or tsunamis are considered.

**Lecture #3: Identification of Critical Elements within NPPs
Screening and Ranking Methods**

Andrej Prošek, Andrija Volkanovski

This lecture presents deterministic and risk informed methodologies for classifying all equipment into one of the safety classes according to its importance to nuclear safety. Before deterministic method is presented, some fundamentals are given: what is nuclear safety, which are fundamental safety functions, how safety functions are protected from hazards, and nuclear design criteria. The deterministic classification system provides for a rational basis of determining relative stringency of design requirements applicable to equipment. Then some probabilistic safety assessment (PSA) description is given. Namely, risk-informed process for categorizing structures, systems and components (SSCs) according to their safety significance is as an alternative to deterministic classification. Important to safety SSCs are those safety-related and non-safety related SSCs whose function is to protect the health and safety of the public, while safety-related SSCs are those important to safety SSCs that perform important safety functions during and following design basis.

Lecture #4: Methods for the Derivation of Fragility Functions

Pierre Gehl, Jeremy Rohmer, Karol Kowal, Sławomir Potempski, Marine Marcilhac-Fradin, Yves Guigueno, Irmela Zentner, Marie-Cécile Robin-Boudaoud, Manuel Pellissetti

This lecture proposes a critical appraisal of current approaches for the derivation of fragility functions for structures, systems and components related to nuclear power plants. Fragility functions express the conditional probability of reaching or exceeding a limit state, given the level of the external hazard loading(s), represented by intensity measures. The dispersion in the fragility function may be caused by a wide range of uncertainty sources, such as the variability in the modelling parameters, the variability in the hazard loading or the quality of the statistical estimation of the fragility parameters. Therefore, this paper demonstrates some of these issues, while applying several fragility methods to an equipment component subjected to earthquake loadings. More specifically, a quantitative analysis of the most suitable intensity measures is detailed: it consists in the identification of the ground-motion parameters that are representative of the ground motions and that are well correlated with the response of the component. Finally, the case of two intensity measures, used as predictors in a vector-based fragility function, is introduced in order to reduce the inherent dispersion in the fragility function (i.e., aleatory uncertainty).

WP summaries

WP3: Integration and safety analysis

Phil Vardon
TU Delft

WP3 treats one of the major pillars of the NARSIS project that is the development and use of an approach relying on the Bayesian Belief Networks (BBN). Another part of the WP is dedicated to developing an "Extended Best Estimate plus Uncertainty" (E-BEPU) analysis, which enables to combine insights from probabilistic and deterministic safety analysis, in order to provide adequate safety margins and to avoid cliff-edge effects. Improvements of flexible approaches and procedures relying on expert-based information, as well as the identification and prioritization of the most influential sources of uncertainty are considered. This will help constraining their impact on modelling results before integration within the BBN. The proposed treatment of uncertainty and particularly the quantitative approach help to reduce conservatism in favor of evidence-based approaches.

Lecture #5: Latent Weaknesses and Root Causes In The Feedback Of Operating Experience Programmes

Milorad Dusic

The lecture introduces the concept of latent weaknesses that can exist in a system for longer time periods and if undetected can result with a triggering event in incidents or even accidents. The concept is demonstrated on the case of Davis Besse NPP near miss where primary coolant boundary was due to corrosion reduced to stainless steel lining within the reactor pressure vessel. The operating organization's feedback of operating experience programme should be able to deal with the existing latent weaknesses by thorough investigation of all incidents. The paper describes three main methods that are being used; classical root cause analysis, probabilistic precursor analysis and deterministic transient analysis. The first of these three methods is used to identify the underlying causes that if corrected would prevent similar events from happening in the future, the precursor analysis is the only method that can quantify the safety significance of the event and transient analysis is used to identify physical phenomena in fast developing reactor transients.The lecture describes various root cause methodologies that are being used today, their brief description and their strengths and limitations. Further, it describes the procedure for applying precursor analysis using the plant specific probabilistic safety assessment and the use of deterministic safety analysis for determination of eroded/still available safety margins during the event being analysed.

Lecture #6: Uncertainties and Risk Integration

Jeremy Rohmer, Varenya Duvvuru Mohan, Philip J. Vardon, Pierre Gehl, Pieter van Gelder, Eric Chojnacki

The present communication addresses the problem of uncertainty quantification (UQ) within risk assessment frameworks used for nuclear power plants (NPPs). We first clarify the notion of uncertainty by analysing its link with risk and decision-making. Due to the difficulty in giving a single "fit-to-all" definition, we preferably adopt a less ambitious (but more practical) approach, and define uncertainty through a classification. We highlight the necessity for separating two facets, namely aleatory uncertainties (inherent to the variability/randomness of the system under study) and epistemic uncertainties (inherent to incomplete/imprecise nature of available information). By focusing on the problem of quantifiable and quantification of uncertainty for any models supporting risk analysis of NPPs (whatever their type, analytical, expert-based, numerical), we further describe the main steps of a generic framework for UQ. In this study, Bayesian network (BN) is proposed as an integrative tool at each step of this framework, i.e. for uncertainty propagation, sensitivity analysis, what-if scenario study and probability updating. A simplified, toy BN representing flooding related station blackout event at the NPP, is used to show how BNs allow incorporation of all evidence in the probabilistic risk assessment and quantification of both aleatory and epistemic uncertainties.

WP summaries

WP4: Applying and comparing various safety assessment approaches on a virtual reactor

Giuseppe Rastiello
CEA

In this WP model reduction strategies are implemented in order to improve modelling and simulation capabilities for NPPs, when assessing the impact and related interactions of external threats on NPPs from a probabilistic perspective. The applicability of such strategies within the solutions proposed for integration and reactor safety analysis is tested on a simplified virtual NPP case representative of the European fleet, considering the external threats scenarios. Finally, from the related reactor safety analyses, the pros and cons of BBN and E-BEPU solutions with respect to existing approaches, are discussed, as well as the possible improvements to be integrated into the current PSA methodologies

Lecture #7: Metamodels for Reducing Computational Costs in Probabilistic Safety Analyses

Jeremy Rohmer

Probabilistic safety analyses for nuclear power plant require running a large number of times the numerical simulator (typically thousands of times). This may be incompatible with the computation time cost of a single simulation run, which can typically reach several hours. A first solution can rely on large computing clusters. Yet, this is not achievable by all companies / research institutes and in the present communication, we explore an alternative solution of statistical nature, namely meta-modelling. This corresponds to a function constructed using a few computer experiments (i.e. a limited number of time consuming numerical simulations). It aims at reproducing the behavior of the "true" numerical model in the domain of model input parameters and at predicting the model responses with a negligible computation time. We describe the key elements for implementing such a technique and provide an application where the objective is to identify all uncertain parameters that lead to the failure of considered system.

Lecture #8: Severe Accident Assessment with Uncertainty and Sensitivity Analysis

Piotr Darnowski and Piotr Mazgaj

The lecture introduces the concept of sensitivity and uncertainty analysis (S&UA) for severe accidents. Studies of an accident progression with the assessment of uncertainties is a standard approach in Deterministic Safety Analysis and especially for modern design basis studies. Uncertainty analyses are also common in the case of severe accident investigations. Plant scale severe accident simulations are performed in the framework of the Probabilistic Safety Analysis (Level 2) but also as a part of other safety-related studies. Proper knowledge about the uncertainty of results is an important issue due to complex phenomenology and simulation models. The sensitivity analysis allows getting a broader understanding of the studied accident and gaining knowledge which and how different phenomena or circumstances impact the results. In this lecture, the methodology is demonstrated with a simple example of hydrogen production in the Phébus FPT-1 integral experiment. The popular Wilks' based non-parametric approach is described.

WP summaries

WP5: Supporting Tool for Severe Accident Management

Luka Štrubelj
Gen Energija

T*his WP develops a tool to support decision-making (DM) in the severe accident management at NPP and emergency plan implementation procedures, relying on the PSA techniques, hence extending the results, insights and conclusions in the form of structured logic models of progression of hazard-induced accident sequences. Induced hazard damage states are postulated as initial conditions (in a similar fashion as for the stress testing purposes). The assessment of the induced hazard damage states considers the type and intensity of the hazard or combinations of hazards resulting in a given plant damage state. The PSA application then focuses on estimating the conditional probabilities for (further) accident progression and, ultimately, conditional probabilities ranges of release categories / source terms.*

Lecture #9: Severe Accident Phenomenology and Management

Luka Štrubelj

During severe accident in NPP, the priority of personnel is to assure fundamental safety functions: control of reactivity, removal of heat from fuel and confinement of radioactive material. Especially challenging are last two. At the beginning of severe accident the NPP operators are responsible for actions, later the technical support center takes over the responsibility. The severe accident management starts, when the core exit thermos-couples are greater than 650 ºC. The decisions of technical support center are made based on timely and accurate information. The effectiveness of strategy is monitored, and the plant status is checked. During the severe accident the mitigation of the challenges is constantly monitored. Main strategies during the severe accident are:

- injection of water into the steam generator in order to remove heat,
- depressurization of reactor coolant system in order to be able to inject water,
- injection of water into reactor coolant system, to flood fuel,
- injection of water into containment,
- reduction of fission product releases,
- control of containment conditions,
- flooding the containment and
- refilling the spent fuel pool.

However all of these actions have negative impacts, which can be mitigated with appropriate mitigation actions.

Lecture #10: Principles Of Severe Accident Risk Analysis

Ivica Bašić, Ivan Vrbanić, Marko Bohanec

The lecture first presents the generic principles of Severe Accident Risk Analysis and then continues with discussing how the general principles were used and customized as Supporting Tool for Severe Accident Management including Definition of Hazard-Induced Damage States and Development of State-Specific APETs for Demonstration Purposes.

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