Post-doctoral subject on:

Processing of aleatory and epistemic uncertainties in nuclear safety applications

ISSUES

Nuclear safety analyses are partly based on statistical computations giving in particular confidence intervals on safety margins, probabilities of exceeding safety criteria or the importance of the input uncertain parameters through sensitivity analyzes. The input uncertainties involved in these studies can be classified into two broad categories: the aleatory uncertainties, which represent the intrinsic randomness of a phenomenon, irreducible in nature and the epistemic uncertainties, which are reducible uncertainties resulting from a lack of knowledge.

Hitherto, in these safety studies, the two types of uncertainties are usually not distinguished, and they are all processed within the same probabilistic framework involving their modeling by probability density functions and their propagation by random sampling techniques. However, if the choice of probabilistic framework is justified for aleatory uncertainties for which sufficient data enable their modeling by probability density functions, it can be questioned for epistemic uncertainties, for which their characterization is only based on the expert opinion. For these epistemic variables, a more suitable framework, corresponding to the non-probabilistic concepts, should be investigated.

WORK CONTENT

The objective of the work will be to implement extra-probabilistic methods such as, interval analysis, p-boxes modeling, possibility theory or Dempster-Shafer theory of evidence, for processing epistemic uncertainty in the context of nuclear safety numerical models. It will consist, in the one hand to define a satisfactory modeling for these epistemic uncertainties, and in another hand to develop an effective methodology to propagate both these epistemic uncertainties and the aleatory uncertainties. Two major difficulties are present and justify a post-doctoral work:

- The high cpu-time cost of the numerical model, that makes the sampling step difficult (only several hundreds of model evaluations are possible),
- The large number of the epistemic uncertain variables (several tens).

The final objective will be to obtain a relevant characterization of the quantities of interest (typically a 95%-quantile) for decision-making in nuclear safety analyzes.

The main application case will concern a loss-of-coolant accident (LOCA) in a pressurized water nuclear reactor. Other possible applications may concern severe accident situations analyzes and Probabilistic Safety Assessment of new fast sodium cooled reactors.

REFERENCES

Aven T., Zio E. Some considerations on the treatment of uncertainties in risk assessment for practical decision making. *Reliability Engineering and System Safety,* pp. 64-74, vol. 96, 2011.

Baudrit C. *Représentation et propagation de connaissances imprécises et incertaines : Application à l'évaluation des risques liés aux sites et sols pollués*, Thèse de l'Université Paul Sabatier – Toulouse III, 2005.

Dubois D. et Guyonnet D. Risk-informed decision making in the presence of epistemic uncertainty. *International Journal of General Systems* 40 (2011), 145–167.

Fallet-Fidry G. *Contribution à la modélisation et au traitement de l'incertain dans les analyses de risques multidisciplinaires de systèmes industriels. Application à la Source Froide d'une unité de production d'énergie.* Thèse de l'Université de Lorraine, 2012.

Helton J.C and Johnson J.D. Quantification of margins and uncertainties: Alternative representations of epsitemic uncertainty, *Reliability Engineering and System Safety,* 96 :1034-1052, 2011

Le Duy T.D. *Traitement des incertitudes dans les applications des Études Probabilistes de Sûreté Nucléaire.* Thèse de Docteur de l'Université Technologique de Troyes, 2011.

Marquès M. *Propagation of aleatory and epistemic uncertainties in quantification of systems failure probabilities or safety margins*, Conférence ESREL 2014, Wroclaw, Pologne

Schöbi R. and Sudret B. *Propagation of uncertainties modelled by parametric p-boxes using sparse polynomial chaos expansions.* ICASP12, Va,ncouver, Canada, July 12-15, 2015.

Smets P. Decision making in the TBM : the necessity of the pignistic transformation. *International Journal of Approximate Reasoning* 38 (2005), 133–147.

SUPERVISORS

Michel MARQUES

CEA/Nuclear Energy Division/Reactor Studies Department/Innovative Systems Section
Centre de Cadarache
13108 Saint-Paul-Lez-Durance, France
michel.marques@cea.fr- Tel. +33 (0)4 42 25 71 31

Bertrand IOOSS

Département de Management des Risques Industriels, EDF R&D
EDF R&D - Département MRI
6 Quai Watier - 78401 Chatou, France
bertrand.iooss@edf.fr - Tel : +33 (0)1 30 87 79 69

WORK LOCATION

CEA (Commissariat à l'Énergie Atomique et aux Énergies Alternatives)

Centre de Cadarache | DEN/CAD/DER/SESI/LEMS | Bâtiment 1222

13108 Saint-Paul-Lez-Durance, France