PLS and RNA applied to the prediction of critical variables for a LBLOCA using R modeling

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The adoption by regulators of the risk-informed decision-making philosophy opened up the debate on the role of the deterministic and probabilistic approaches to support regulatory matters of concern to Nuclear Power Plants safety. RG 1.174 [1] is a key document in this framework, which provides guidance in support of licensee request for changes to a plant`s license basis, such as a power uprate. This regulatory guide presents five principles of risk-informed decision making to be used for making decisions regarding plant-specific changes to the licensing basis. The third principle states that the proposed change has to maintain sufficient safety margins [2, 3] and is the one we are concerned with in this paper. Development of methods for the assessment of safety margins within this framework has attracted attention only in recent years with an aim at using probabilistic safety analysis results into requirements and assumptions in deterministic analysis, and vice versa, to provide a more comprehensive and realistic measure of reactor safety [4-6].

In this context, it is proposed an approach based on the order statistics [7-10] to estimate the safety margins using "Best Estimate" codes [11] using information provided by the Probabilistic Risk Assessment (PRA) level 1 and considering uncertainties associated with deterministic and eventuality probabilistic codes [12-15]. However, one of the problems arising from the use of thermal-hydraulic codes is the high computational cost in the simulation of plant behavior for a particular accident scenario. The application of predictive methods such as Partial Least Squares (PLS) [16] and Artificial Neural Networks (ANN) [17], which can obtain the values of critical thermohydraulic variables for determine safety margins (Peaking Clad Temperature (PCT)), can help to reduce such a cost.

This work represents the application of the PLS and ANN on the statistical analysis of the results obtained from the simulation of transients using "Best Estimate" thermohydraulic codes and statistic of order. The objective is focused on measuring the importance on the PCT of the uncertainty associated with different thermohydraulic variables of interest [18-23]. The values of the PCT are used as a starting point for the PLS and ANN to perform predictions of the expected behavior of PCT in a new transient. The methodology proposed gives the suitable balance between precision of the results obtained to predict the PCT behavior and the computational effort needed. This methodology is applied to a Large Break Loss of Coolant Accident (LBLOCA) in the hot leg of a Pressurized Water Reactor. This paper apply the PLS and ANN in the modeling language R.

REFERENCES

1. USNRC. An approach for using probabilistic risk assessment in risk-informed decisions on plant-specific changes to the licensing basis. Regulatory Guide 1.174. November (2002).
2. J. Hortal, R. Mendizábal, F. Pelayo "What does "safety margin" really mean?". Safety, Reliability and Risk Analysis: Theory, Methods and Applications – Martorell et al (eds). Taylor &Francis Group, London (2009).
3. R. Mendizàbal, "Probabilistic safety margins: definition and calculation" Safety, Reliability and Risk Analysis: Theory, Methods and Applications – Martorell et al (eds) Taylor &Francis Group, London (2009).
4. Pagani, L., On the Quantification of Safety Margins. PhD Thesis. Massachusetts Institute of Technology (2004).
5. Gavrilas, M., Meyer, J., Youngblood, B., Prelewicz, D., Beaton, R., "A Generalized Framework for Assessment of Safety Margins in Nuclear Power Plants", Proceedings to BE 2004: International Meeting on Updates in Best Estimate Methods in Nuclear Installations Safety Analysis, Washington, DC, November 14-18, (2004).
6. IAEA. Safety margins of operating reactors: Analysis of uncertainties and implications for decision-making. IAEA-TECDOC-1332, Vienna (2003).
7. Wilks, S.S., 1967. Collected papers: Contributions to mathematical statistics, ed. John Wiley, New York, EE.UU, (1967).
8. S. Martorell, Y. Nebot, J.F. Villanueva, S. Carlos, V. Serradell, F. Pelayo and R. Mendizábal. "An approach to integrate thermal-hydraulic and probabilistic analyses in addressing safety margins estimation accounting for uncertainties". ESREL'08 September (2008).
9. Martin, R.P., O'Dell, L.D, "AREVA's realistic large break LOCA analysis methodology". Nuclear Engineering and Design. 235, pp 1713-1725 (2005).
10. USNRC, 1989, Quantifying Safety Margins: Application of Code Scaling, Applicability, and Uncertainty Evaluation Methodology to a Large -Break Loss-of-Coolant Accident, NUREG/CR-5249, EGG-2659, 1989, see also Nuclear Engineering and Design, 119, (1990).
11. Wallis, G.B.,. "Uncertainties and probabilities in nuclear reactor regulation." Proceedings of the 11th International Topical Meeting on Nuclear Reactor Thermal-Hydraulics. Avignon, France, October 2-6, (2005).
12. IAEA. Implications of power uprates on safety margins of nuclear power plants. IAEA-TECDOC-1332, Vienna (2004).
13. IAEA. Technical Meeting on the Use of Best Estimate Approach in Licensing with Evaluation of Uncertainties, September 10-14, Pisa, Italy (2005).
14. IAEA. Technical Meeting on Effective Combination of Deterministic and Probabilistic Safety Analysis in Plant Safety Management, September 4-8, Barcelona, Spain (2006).
15. Martorell, S., Nebot Y., Villanueva, J.F., Carlos, S., Serradell, V., Pelayo, F., Mendizábal, R., 2006. "Safety margins estimation method considering uncertainties within the risk-informed decision-making framework". Proceedings of the PHYSOR 2006 Conference, Vancouver, (Canada), September 10-14, (2006).
16. P. Geladi, B.R. Kowalski, Partial Least Squares Regression. Analytica Chimica Acta, Elsevier Science Publishers B.V.185, 1-17, (1986).
17. J.J. Hopfield. Neural networks and physical systems with emergent collective computational abilities. Proceedings of the National Academy of Sciences, 79:2554-2558, (1982).
18. Wulff W., Boyack B.E., Catton I., Duffey R.B., Griffith P., Katsma K.R., Lellouche G.S., Levy S., Rohatgi U.S., Wilson G.E., Zuber N., "Quantifying reactor safety margins. Part 3: Assessment and ranging parameters". Nuclear Engineering and Design, 119, pp 33-65, (1990).
19. J.F. Villanueva, S Carlos, S. Martorell, V. Serradell. Análisis del impacto de Márgenes de seguridad de un LOCA en un PWR considerando incertidumbres en variables termohidráulicas y probabilistas. XXXV Reunión Anual SNE, (2009).
20. M.Y. Young, S.M. Bajorek, M.E. Nissley, L.E. Hochreiter . "Aplication of code scaling applicability and uncertainty methodology to the large break loss of coolant". CSAU. Nucl. Eng. Des. 186 pp. 39–52, (1998).
21. S.M. BAJOREK, et al., "Small break loss of coolant accident phenomena identification and ranking table (PIRT) for Westinghouse pressurized water reactors" (Proc. 9th Int. Mtg on Nuclear Reactor Thermal-hydraulics: NURETH-9 (KIM, J.H., PETERSON, P., Eds), Elsevier Science,
22. Lee SY and Ban CH (2004), "Code-Accuracy Based Uncertainty Estimation (CABUE) Methodology for large-Break Loss-of-Coolant Accidents", Nuclear Technology 148, 335-347, (2004).
23. Frepoli, C., An Overview of Westinghouse Realistic Large Break LOCA Evaluation Model, Science and Technology of Nuclear Installations, Volume 2008, Article ID 498737, 15 pages, (2008).