

Variance Decomposition Sensitivity Analysis of a Passive Residual Heat Removal System Model

Y. Yu, Tao Liu, Jiejuan Tong, Jun Zhao, Francesco Di Maio, Enrico Zio, Aling Zhang

► **To cite this version:**

Y. Yu, Tao Liu, Jiejuan Tong, Jun Zhao, Francesco Di Maio, et al.. Variance Decomposition Sensitivity Analysis of a Passive Residual Heat Removal System Model. Sixth International Conference on Sensitivity Analysis of Model Output, SAMO2010, 2010, pp.7772 - 7773. <hal-00721059>

HAL Id: hal-00721059

<https://hal.archives-ouvertes.fr/hal-00721059>

Submitted on 26 Jul 2012

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

Variance Decomposition Sensitivity Analysis of a Passive Residual Heat Removal System Model

YU Yu^a *, LIU Tao^a, TONG Jiejuan^a, ZHAO Jun^a, DI MAIO Francesco^b,
ZIO Enrico^b and ZHANG Aling^a

^a*Institute of Nuclear and New Energy technology, Tsinghua University, Beijing, China*

^b*Department of Energy, Polytechnic of Milan, Via Ponzio 34/3, 20133 Milan, Italy*

Abstract

Passive systems are central in the safety design of new generation nuclear power plants (NPPs). In this paper, the variance decomposition method is adopted to identify key parameters which influence the uncertain behavior of the passive Residual Heat Removal system (RHRs) in the High Temperature Gas-Cooled Reactor (HTGR).

Keywords: Uncertainty and Sensitivity Analysis; Variance Decomposition; Passive Safety System; Residual Heat Removal system (RHRs); High Temperature Gas-Cooled Reactor – Pebble Bed Modular (HTR-PM).

1. Introduction

Generation IV nuclear reactor systems (e.g., High Temperature Gas Cooled Reactors (HTGR)) are involving innovative design solutions for improved reliability and safety. Sensitivity analysis can provide relevant insights on the response of the innovative system implemented to different inputs [Saltelli et al. (2000)]. In this paper, we adopt the variance decomposition method [McKay (1996)] for performing sensitivity analysis of Thermal-Hydraulic (T-H) model of a natural circulation passive systems designed for providing the decay heat removal function in a HTGR.

The operation of such passive systems relies on natural convection, with no need of support by external power sources as is the case for the active safety heat removal systems employed in the current and evolutionary reactor designs. Because of this, the magnitude of the driving force is relatively small, as compared to those driving the active systems, and is influenced by the operating state of the system [Zio et al. (2003), Pagani et al. (2005)]. Considerable uncertainties affect the parameters and factors (e.g. heat transfer coefficients and pressure losses) which determine the driving force for natural circulation of passive systems and there is a strong dependence on the physical conditions and plant configuration existing at the time of action request. All these aspects significantly influence the performance of a passive heat removal system and render the problem of assessing its reliability (or dually, its probability of failure) quite a difficult one [Pagani et al. (2005), Mackay et al. (2008)]. In this view, it is important to identify those key parameters which mostly affect the passive system safety function, and then have detailed investigations on their effects [Zio et al. (2003)]. In this work, the variance decomposition method of sensitivity analysis is applied to study the effects of the uncertainties in input to a numerical model for computing the maximum outlet water temperature $T_{w,out}$ reached during a set of accident scenarios in the Residual Heat Removal system (RHRs) of the High Temperature Reactor-Pebble Modular (HTR-PM) [Zhengy et al. (2008)].

2. Results and conclusions

The variance decomposition-based sensitivity analysis has allowed identifying 3 out of 37 individual input parameters as the most important contributors to the variance of the output safety parameter $T_{w,out}$ of the passive RHR system of the HTR-PM (the power W , the inlet temperature of air in the air-cooled tower $T_{a,in}$ and the water pressure in the pipes P_w). This confirms previous results obtained by the application of the Analytical Hierarchical Process with expert judgment [Yu et al. (2010)]. Furthermore, the analysis of groups of parameters has shown a clear preponderance of plant configuration parameters (i.e., power W , the number of pipes in the air cooler N_a , number of water cooling pipes for each loop N_w , etc.) with respect to the effects on uncertainties in the maximum

outlet water temperature reached during the considered set of accidental scenarios in the RHRs of the HTR-PM.

In conclusion, the approach has been demonstrated coherent in comparison to other techniques (e.g., AHP), computationally fast (i.e., for each input parameter, the importance index is evaluated in few minutes on a Intel[®] Atom™ 330 Dual Core) and the results of the group sensitivity analyses allow underlining important physical and modelling aspects related to the system behaviour, that may turn useful when applied in the successive safety assessment analyses of the plant.

3. Acknowledgements

This work was supported by the Science & Technology Fellowship Programme in China financed by the European Commission (Reference: EuropeA-id/127024/L/ACT/CN) and by Chinese National S&T Major Project (Grant No. ZX06902).

4. References

Mackay, F. J., Apostolakis, G. E. and Hejzlar, P., 2008: "Incorporating reliability analysis into the design of passive cooling systems with an application to a gas-cooled reactor", *Nuclear Engineering and Design*, 238(1), pp.217-228.

McKay, M. D., 1996: "Variance-Based Methods for Assessing Uncertainty Importance in NUREG-1150 Analyses", LA-UR-96-2695, Los Alamos National Laboratory, pp. 7-11

Pagani, L.P, Apostolakis, G. E. and Heizlar, P., 2005: "The Impact of Uncertainties on the Performance of Passive Systems", *Reactor Safety*, 149(2), pp.129-140.

Saltelli, A., Chan, K., Scott. M., "Sensitivity Analysis", John Wiley & Sons, 2000.

Yu , Y., Liu, T., Tong, J., Zhao, J., Di Maio, F., and Zio, E., "The Analytic Hierarchy Process for the Sensitivity Analysis of Passive Safety System", *The 10th Conference on Probabilistic Safety Assessment and Management (PSAM10)*, Seattle, 7-11 June 2010.

Zheng Y. and Shi L., 2008: "Characteristics of the 250MW Pebble-Bed Modular High Temperature Gas-Cooled Reactor in Depressurized Loss of Coolant Accidents", *Proceedings of the 4th International Topical Meeting on High Temperature Reactor Technology, HTR2008*, Washington, DC USA.

Zio, E., Cantarella, M. and Cammi, A., 2003: "The analytic hierarchy process as a systematic approach to the identification of important parameters for the reliability assessment of passive systems", *Nuclear Engineering and Design* ,226(3), pp. 311-336.