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Development of Regulatory Technology for the SMART Research Reactor

J. C. Jo, Y. G. Yune, W. S. Kim, C. Y. Yang, I. G. Kim, M. J. Jhung, H. J. Kim, and S. O. Yu
Safety Issue Research Department, Korea Institute of Nuclear Safety, Yuseong-gu, Daejeon, jcjo@kins.re.kr

1. Introduction

The basic design of System-integrated Modular Advanced Reactor (SMART), a small-to-medium sized integral type pressurized water reactor (PWR) with the capacity of 330MWth, was developed in Korea recently. The reactor can be utilized for multi-purposes such as electricity production, sea water desalination, ship propulsion, and/or district heating. Presently, for the research and development purpose of demonstrating the safety and performance of the Integral type PWR design, "Project for Development of SMART Research Reactor (SMART-P) with the capacity of 65MWth" has been performed since July of 2002.

In the Atomic Energy Act of Korea, two distinct licensing processes for each of the research reactor and power reactor are properly set out. However, one for the reactor which is utilized for the research and development of commercial power reactors is not specifically prescribed in the AEA. Thus it is necessary to establish an appropriate regulatory process for the SMART-P licensing.

In addition, the design features of SMART-P including the integral reactor design concept, the passive safety systems and the new components such as metallic nuclear fuel, helical tube steam generator, desalination equipment, etc. are those of new technologies which have not yet been incorporated into the PWR design in Korea. In this respect, to identify and resolve safety issues, to develop regulatory technical requirements/guides related to the new technologies, and to establish safety evaluation and confirmation methods and codes are required as requisites for the forthcoming licensing review of SMART-P.

In accordance with those necessities, the project "Development of Regulatory Technology for the SMART-P" [1] has been performed in the Korea Institute of Nuclear Safety since August of 2002.

2. Scope of the Study

The domestic and foreign regulatory systems for nuclear reactor licensing are surveyed and analyzed to get essential information needed for the establishment of a licensing process of SMART-P.

Since the integral reactor design concept, the passive safety systems and the new components are adopted in the SMART-P design, a set of regulatory technical requirements has to be developed in preparation for the licensing review. A plan to develop the additionally needed regulatory technical requirements, if any, is established on the basis of the results of evaluation for the applicability of the current requirements to the SMART-P. According to the development plan, some regulatory technical requirements/guides are either developed newly or modified appropriately for the licensing SMART-P review.

In addition, the safety issues identified in the licensing reviews of foreign integral reactors and passive reactors are surveyed and the draft of SMART-P design is reviewed to identify potential issues.

Applicability of the existing safety evaluation and confirmation technologies developed for the commercial PWRs either under construction or in operation in Korea as well as the test/verification programs for foreign integral/passive reactors to the SMART-P design are evaluated to find out what technical items should be improved for the safety review of SMART-P. According to the improvement and development plan which is to be established on the basis of the evaluation results, both improvements and developments in the safety evaluation and confirmation technologies are performed for the application to the SMART-P regulation.

3. Results and Discussion

The research results can be summarized as follows:

(1) Through the expert review of the candidate models of licensing process for the SMART-P, an optimized model has been selected and the implementation plan including its draft legalization has been established. The implementation plan consists of a short term plan for the SMART-P and a long term plan for the other development reactors to be built in the future [2].

(2) A total of 28 safety issues have been identified through the survey study of the SMART safety issues, the investigation of the foreign countries' experiences in licensing of the advanced reactors, and the preliminary review of the SMART-P design. Possible resolutions for the 14 issues of them have been proposed. For the remaining unresolved 14 safety issues, the background, status of design, relevant existing requirements, and expected directions for possible resolutions have been provided [1].

(3) The applicability of existing regulatory technical requirements to the SMART-P has been evaluated. The 4 items of them, including those related to the use of proven technology, safety of non-safety related systems, metallic fuel, and desalination equipment which need to be developed newly or to be modified, have been identified, and their backgrounds, status, and draft requirements or expected directions for possible requirements have been provided.

Finally the regulatory technical requirements related to the use of proven technology, safety of non-safety related systems, metallic fuel, and desalination equipment have been established in terms of draft rules and safety review guides [3].

(4) The applicability of the existing safety evaluation and confirmation technologies in the fields of reactor core, design-basis accidents, and structural integrity to the SMART-P design have been evaluated, and some technologies which need to be either improved or developed newly have been identified on the basis of the evaluation results. According to the plan to improve or develop the safety evaluations and confirmation technologies, the necessary computer code models, computation methodology, and procedures have been

developed and then the integrated regulatory audit calculation system has been established.

In addition, the integrated or separate effects thermal hydraulic tests have been reviewed. The final results achieved in this area can be summarized as,

- COREDAX code has been developed for the regulatory audit in the nuclear design and neutron kinetics of the SMART-P core. The current version 1.0 of the COREDAX code is useful to the basic regulatory audits of core design and power transients for a given core configuration [4].

- Audit calculation system of SMART accident analysis composed of the analysis code, input deck, and analysis methodology has been established. To develop such system, the PIRTs (Phenomena Identification and Ranking Tables) for various accident scenarios for SMART-P have been developed and important phenomena have been identified. Essential thermal hydraulic models have been developed and the RELAP5-SMART code for accident analysis of SMART-P has been established based on RELAP5/MOD3.3 code.

To validate the predictability of RELAP5-SMART code systematically, a code assessment matrix has been developed. A geometric input deck of RELAP5-SMART code has been developed under the quality assurance program. Finally, preliminary analyses for the important accidents of SMART-P including a SBLOCA have been performed to demonstrate the proper implementation of the audit calculation system for accident analysis of SMART-P [5].

- Regulatory audit calculation systems to confirm the mechanical integrity of the reactor components have been developed and the applicability of the existing safety evaluation has been exampled. Also, current issues for the pressure-temperature limit curve have been investigated and guidelines for the stress categorization using the elastic finite element analysis have been reviewed and applied to the central cover of the pressurizer.

Finally the thermal hydraulics, fluidelastic instability and fretting wear characteristics of steam generator helical tubes and metal fuels have been investigated [6].

4. Lessons-Learned

The lessons learned from this study are as follows.

(1) If a new licensing system is required to be established for any future advanced reactor, the regulatory technology development schedule (milestone) should be planned considering the time taken for the legislation of the new licensing system.

(2) To resolve the safety issues and to identify the licensability of the future advanced reactor design early enough, it is necessary to identify the safety issues at the beginning stage of the development program with the cooperation between regulators and designers.

(3) The possible items of regulatory requirements and guides (technical standards) needed to be developed for future advanced reactors can be found out by evaluating applicability of the existing technical standards to the future reactors, and it will be desirable to develop them, if any, in a technology-neutral and performance-based way, to avoid the prescriptive regulations and to reflect the recent global standards for nuclear safety regulation.

The current reactor regulations with technical standards in Korea have been developed for pressurized water reactors. Therefore, those should be amended to be applicable to the forthcoming advanced reactors or it is necessary to establish the individual sets of regulatory technical standards for each of them additionally.

(4) Also the level of detail of regulatory requirements should be determined deliberately to be amendable, if necessary, during the licensing review.

(5) The items of regulatory confirmation technologies needed to be developed for future reactors can be identified by checking applicability of the existing ones to the future reactors. The test data for the validation and verification of design codes should be shared with regulators and it will be desirable that the test program of the designers should be reviewed by the regulators in advance.

5. Concluding Remarks

The licensing process, regulatory technical requirements, resolutions of safety issues, and safety evaluation and confirmation technologies for the SMART-P developed in this study can be applied directly to the licensing and safety review of the SMART-P. Furthermore, the application of them can be extended to the licensing review of SMART design. Especially, the licensing process established can be also applied to the licensing of other future development (demonstration) reactors utilized for the purpose of research and development of future advanced reactors such as GEN-IV.

If the passive safety systems are adopted into commercial PWRs in the future, the resolutions of related safety issues as well as the regulatory confirmation technologies can be utilized for the regulations of such PWRs.

The SMART-P regulatory technology developed in this study will contribute to securing the international competitiveness of the Korean small-to-medium sized integral type reactor SMART, since it is possible to export the regulatory technology including regulatory technical standards with the SMART reactor design together.

REFERENCES

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