Transactions of the Korean Nuclear Society Autumn Meeting
Gyeongju, Korea, November 2-3, 2006

Application of Requirements Engineering to Nuclear Power Plant Design

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1. Introduction

A nuclear power plant (NPP) represents complex and multidisciplinary characteristics of the modern system. Its design starts with identification of top level requirements of the stakeholder and licensing body followed by development of comprising systems design requirements. Detailed design of systems and components is performed based on the systems design requirements and the plant is verified in the upward direction [Figure 1].

The requirements engineering [1] enables this whole process to streamline requirements to give comprehensive understanding and structured management of the NPP development. Highly developed computer and data management technology can support realization of such complex systems based on the requirements. The requirements engineering helps to identify the top level functional and performance requirements to detailed requirements of design, operation, etc. It also links all the requirements by giving them traceability which makes impact and coverage analyses easier.

KOPEC has tried to improve design practices to increase efficiency and understanding of design as well as to support effective and intelligent management of the NPP. In this study, KOPEC's efforts are reported for NSSS system design and power uprate evaluation where the requirements engineering is applied to.

2. Application of Requirements Engineering

2.1 NSSS System Design

The design requirements for the major NSSS systems – the chemical and volume control system, the plant protection system, etc - were identified and traced by reviewing the UCN 5&6 design documents such as system design requirements, interface requirements and design specifications documents. The licensing documents including codes and standards were also reviewed.

Development and operation of NPPs requires most of the modern engineering disciplines to define various kinds of design requirements. The requirements in the design documents were listed, reviewed and classified according to the characteristics of the requirements. In order to manage requirements in a comprehensive and integrated way, they were grouped into eight categories: functional, performance, physical, interface, quality, environmental, constraints and test requirements. Each design requirement was assigned to one of the requirement categories.

The requirements were traced from top level contract or licensing documents to the design specifications or operation procedures [Figure 2]. The derived design requirements for each system were interlinked according to the design flow to give traceability. The requirements were also connected to the test or operation procedures to confirm the validation process. Missed links of requirements and irrelevant requirements could be found through this process. Some requirements were found to come from downstream activities.

Standard skeletons of design documents were proposed based on this activity. They have a standard document structure with categorized requirements which can help to trace a requirement only by reviewing the document structure.

2.2 Power Uprate

The thermal power of Kori units 3&4 and Yongkwang units 1&2 has increased by 4.5% of the rated power, which is the primary requirement. Design and licensing requirements are to be identified and derived subsequently by reviewing the related documents to establish a requirements management system. The review process just follows the flow of the power uprate procedure from the licensing requirements to the detailed design and operation requirements. Figure 3 shows an example of such process – capacity requirements of pressurizer spray valves due to the power uprate.

The developed system can be used to evaluate effectiveness and completeness of the power uprate program and also as a guideline for other following power uprate programs. In addition, it also helps to enhance the understanding of the power uprate program.

3. Conclusion

Establishing a requirement management system with requirements of adequate levels of depth takes lots of efforts. However, the system can provide a useful tool for impact analyses, cost and progress analyses in design, operation and maintenance of NPPs. It is also

found that it is an effective way of enhancing the design capability and completeness.

Currently, the nuclear industry is showing an increasing interest in implementation of the configuration management as an efficient and effective way of managing the NPP intelligently [2]. The requirements management system will be a basis for the configuration management.

REFERENCES

[1] Elizabeth Hull, Ken Jackson and Jeremy Dick, Requirements Engineering, Springer, USA, 2005.

[2] Configuration Management in Nuclear Power Plants, IAEA-TECDOC-1335, IAEA, Vienna, Austria, 2003.01.

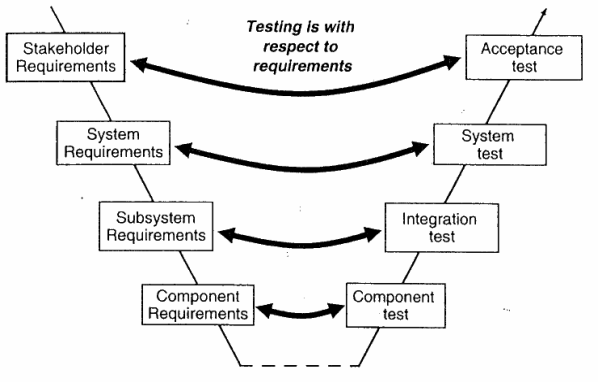
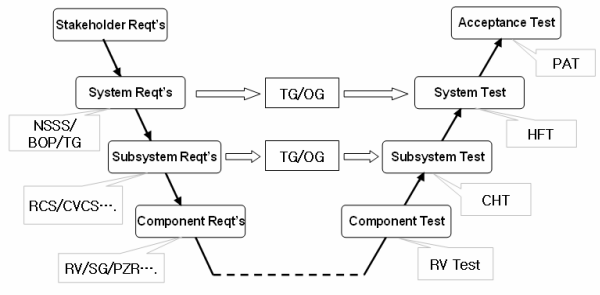


Figure 1 Requirements Development and Validation [1]



TG/OG : Test/Operation Guideline
PAT : Power Ascension Test
HFT : Hot Functional Test
CHT : Cold Hydrostatic Test
RV : Reactor Vessel

Figure 2 NPP System Design Diagram

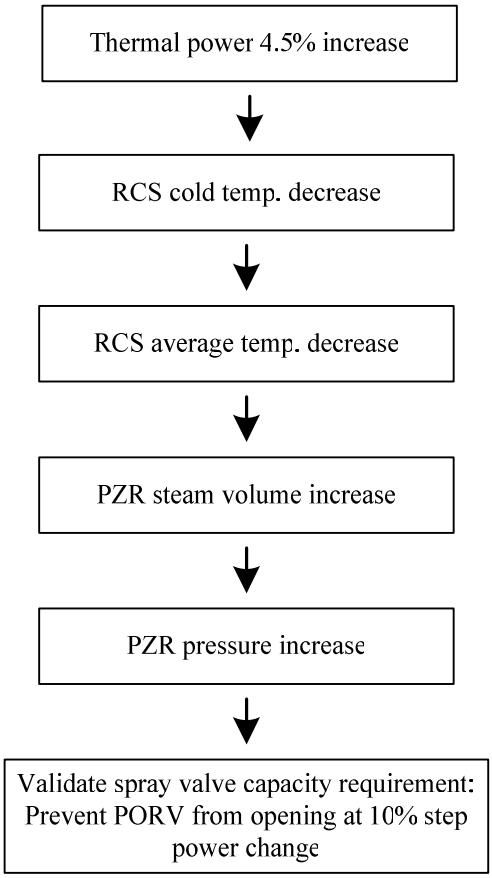


Figure 3 Impact of Power Uprate to Pressurizer Spray Valve Capacity Requirement