Survey on the Technology Readiness Level of R&D projects for a Technical Risk Management

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1. Introduction

The purpose of applying the Technology Readiness Level/Design Readiness Level (TRL/DRL) in technical risk management is to make technology assessments, and improve communication among researchers with a consistent, systematic technology readiness

Technical risk management[1] for the Nuclear Hydrogen Production project was adopted of experience assessed with Delphi Method from the Next Generation Nuclear Plant(NGNP)of the DOE to improve the poor contactor management of the major projects which experienced cost increases and/or schedule delays in long-term[2].

In the current phase that is doing key technology research and development projects, the technology readiness level was reviewed and applied to the Nuclear Hydrogen Production project to prepare an input for the next design phases.

Based on the previous works, pre-conceptional design and key R&D works for the Nuclear Hydrogen Design and Development(NHDD)projects and the results of key research and development projects, the TRL was applied to assess the levels and compared with the advanced design stages of Westinghouse Electric Co[3].

With this process, several issues were identified to apply the design and technology level to the familiar steps of design process and research and development projects. In order to resolve these issues, it is needed to systematically adjust and modify the current process with TRLs .

2. Technical Risk Management Steps

To ensure both known and unknown risks for the Nuclear Plant project, technical risk management was adopted experience from Department of Defense, NASA, and other systems engineering projects from industries. The steps for the risk management [1] are:

- System performance requirements defined as part of the technical and functional requirements (T&FRs), and performance goals with performance criteria.
- Expected performance of the systems defined based on published data or specific submittals provided by technology providers or subject matter experts.
- The relative maturity of the input based on either a Technology Readiness Level (TRL) for technology development related input, or a Design Readiness (DRL) scale for design basis related input.
- Risk identification tools cataloged the known risks with the performance of the alternatives.
- The performance and uncertainty data combined an overall performance score range for each alternative.
- The performance score ranges, if there is, in the presence of uncertainty, a risk-informed decision
- Using the results of the decision analysis, risk reduction plans with the known risks
- The specific risk reducing and technology / design maturing events mapped to the risk reduction plan, and the extent to which each risk / maturation accomplished by the given task is quantified.
- Expected risk reduction combined with the expected performance measure to evaluate the future risk-informed decisions.

3. Key Development Risks of Nuclear Hydrogen Production Project

During the progress of previous feasibility and pre-conceptual design stages in KAERI, the technical and functional requirements, and performance goals with performance criteria were identified of several risks to implement the nuclear hydrogen system, for examples, materials for high temperature etc.

After identifying the issues of nuclear hydrogen production system, several key development risks were selected as key development technologies to reduce and eliminate the known and unknown technical risks for future design projects. An identified risks to R&D projects[4,5] listed below;

- Qualification of technology
  . Fabrication of Coated Particle Fuel
  . Reactor core ceramics with graphite
  . Materials in the high-temperature regions(Rx, IHX)
- Verification and validation of analysis methods
  . KEPIC and ASME code acceptance required
  . Testing and Materials standards acceptance
  . Licensing
  . Code developments: core analysis code,
- Availability and development of instrumentation
  . Small He gas loop system
- Development of the hydrogen production processes
  . IS process, HTES

4. Technology Readiness Level for the key R&D projects of Nuclear Hydrogen Project

Technical and design maturity are used to estimate the level of unknown risk associated with the performance of a given sub-system or component from the previous design works. However, KAERI did not start the design of the nuclear hydrogen production

system after deciding the schedule delay. We are just focusing to reduce the technical risks with key R&D projects and preparing the inputs of design phases and making environment for the nuclear hydrogen system, adopting the technology readiness level to evaluate the doing projects at this point.

Level	*Specific Definition of TRL*	Definition of NHDD Fuel's TRL
1	*Basic principles observed and reported*	TRISO fuel concept identified
2	*Technology concept and or application formulated*	Materials and fabrication processesmfor 20-30g/batch identified at conceptual level
3	*Analytical and experimental critical function and/or characteristic proof of concept: Lab level for pieces of components*	20-30g/batch fabrication of kernels, coatings and fuel elements developed for specifications and procedures
4	*Lab-scale component validation in lab environment: Demonstrate technical feasibility and functionality. Beginning of integration of some interfacing components into sub-assemblies*	20-30g/batch Fabrication processes for kernels, coatings and fuel elements developed and proved in lab environment
5	*Lab-scale component or sub-assembly validation in relevant environment. Beginning of integration of sub-assemblies into sub-systems*	Large scale(2-3Kg/batch) gelation, coater and fuel element fabrication equipment prepared and tested on non-enriched fuel
6	*Subsystem model or prototypical scale demonstration in relevant environment*	Large scale batches of fuel elements produced with enriched uranium and subjected to irradiation and PIE. Beginning proof of integrity- fission product release.
7	*Subsystem prototype demonstration in an operational environment. Beginning integration of subsystems into complete system*	Production process developed and qualified using non-enriched uranium
8	*Total system completed, tested and fully demonstrated and validated*	using "production" equipment produced, irradiated and subjected to PIE to qualify process and fuel.
9	*Total system used successfully in project operations*	Fuel elements used to power NGNP and after full cycle of irradiated subjected to full range of PIE.
10	*Total system used successfully in commercial opertions*	Commercial application

Table 1.the detail TRL definition of NHDD's Fuel fabrication system

As an example to scale the 10 levels of TRL, Table 1 shows the specific generic definition of TRL in the left and detailed definition of the fuel fabrication system scaled with 10 levels in the right.

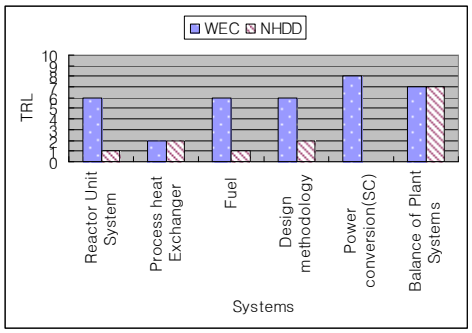

Figure 1.the comparison of technical maturity between WEC and NHDD under TRL scales

After applying the TRL to NHDD's R&D projects, NHDD technical maturity was identified in Figure 1. Figure 1 shows the two unique patterns, one is the same level technical maturity that both WEC and NHDD are studying the Hydrogen production in an unproven stage and the Balance of plant systems from the proven technology of the PWRs. The other has a big difference gap related to technologies of the high temperature gas-cooled reactor that KAERI has not experience before.

Figure 2 displays the TRL of Fuel fabrication area with the risk that is scored of the weighting in a classification of technical maturity[2].

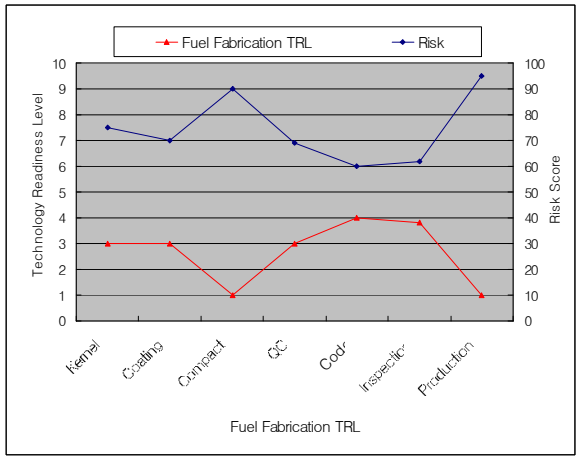

Figure 2.the Fuel Fabrication area TRL

3. Conclusions

The results of the TRL scaling analyzed in the current R&D project, are basically identified of technical maturity and the risk score at this point with sample TRL rating. A TRL should be increased and balanced to achieve the realization of VHTR.

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