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Reactor Technology Comparison Method using Modeling and Decision Making Technique

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1. Introduction

To make wise choices about the future of nuclear power, we need improved knowledge of the safety, safeguards, and security features of both existing and new nuclear energy plants. Understanding the potential advantages and disadvantages of nuclear energy is critical for those stakeholders and decision-makers facing Korea's energy challenges. This report provides an overview of the evolution of nuclear reactor technology and discusses development and deployment of reactor technology in future Korea.

Following reactor technology options will be considered within this report:

1) Active Reactor (GEN Ⅱ : OPR-1000)
2) Advanced Reactor (GEN Ⅲ : APR-1400)
3) Passive Reactor (GEN Ⅲ+ : AP-1000)
4) Small Modular Reactor (GEN Ⅳ)

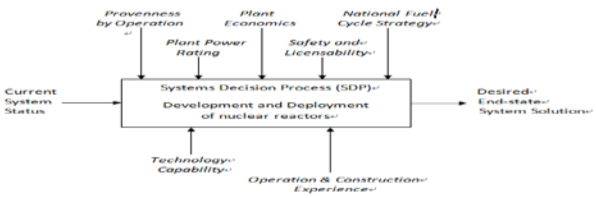
2. Problem Definition

2.1 Selection Criteria

Many factors influence the development and deployment of nuclear reactors. I assume that development and deployment of nuclear reactors as systems decision process (SDP) and find criteria by analyzing influencing factors on the systems.

In this paper, I identify IDEF0 (Integration Definition for Function Modeling) model, a formal method of describing systems, processes, and their activities. An IDEF0 model is capable of representing the functions, decisions, processes, and activities of a system.

< IDEF0 model of deployment of nuclear reactors >



From the upper diagram, I identify five of controls components : Provenness by Operation, Plant Power Rating, Plant Economics, Safety and Licensability, and National Fuel Cycle Strategy. And also, identify two mechanisms : Technology Transfer, Operation & Construction Experience.

➢ *Provenness by Operation*

This criterion is a prudent criterion in selecting reactor type and design for the countries with no previous experience of nuclear power plant construction. So, operability, performance and safety of the plant to be warranted through operation in vender countries or other importing countries.

➢ *Plant Power Rating*

Generally, largest possible unit sizing favored by the economy of scale of nuclear power plant. Due consideration to be given to grid reinforcement needed to maintain the desired quality and performance (grid stability) from the integration of the large nuclear power plant unit

➢ *Plant Economics*

Plant capital cost and operation cost of one design to be compared to the others favoring the lowest price.

➢ *Safety and Licensability*

Reactor design with previous accident histories and not meeting international safety standards to be excluded. Licensing criteria to be affected reflecting the current state-of-the-art technology and operating experience.

➢ *National Fuel Cycle Strategy*

The details of reactor's fuel cycle are critical elements in determining risk levels for nuclear safety, security. With both the front and back ends of the fuel cycle, intrinsic properties of reactor design.

➢ Technology Capability

➢ Operation & Construction Experience

2.2 Evaluation of selection criteria

In this section, we will evaluate 5 selection criteria that is formerly introduced for the swing weight matrix method. The basic concept of this method in determining weights is relatively straightforward. A measured that is very important to the decision problem should be weighted higher than a measure that is less important.

Then, swing weights are assigned to each of the criteria. These will distinguish the different alternatives for the decision making. Here, the swing weighting is used to calculate the global weights assigned to each value measure. These swing weights are based on importance values. The following table shows the swing weight matrix for comparison of 4 reactor technologies.

< Swing weight matrix of the Criteria >

		Level of importance of the value measure		
		Very important	Important	Less important
Variation in measure ranges	High	Safety & Licensability 100	Plant Power Rating 60	Technology Capability 50
	Medium	Provenness by Operation 80	Operation & Construction Experience 50	
	Low	Plant Economics 60	National Fuel Cycle Strategy 40	

From the upper swing weight matrix, measured swing weights are converted into global weight by this equation:

$$w_i = \frac{f_i}{\sum_{i=1}^{n} f_i}$$

Where, $\mathbf{f_i}$ is the non-normalized swing weight assigned to the i^{th} value measure.

i= 1 to n for the number of value measures.

$\mathbf{w_i}$ are the corresponding measure weights.

The measure, or global, weights for value measures are then calculated from the data in the swing weight matrix. The result is shown in the following table:

< Global weight matrix of the Criteria >

Criteria	Swing weight	Measure global weight
Provenness by Operation	80	0.182
Plant Power Rating	60	0.136
Plant Economics	60	0.136
Safety and Licensability	100	0.227
National Fuel Cycle Strategy	40	0.091
Technology Capability	50	0.114
Operation & Construction Experience	50	0.114
Total	440	1.000

2.3 Comparison of each reactor technology

In this section, we will discuss and compare 3 reactor technologies against selection criteria that is evaluated previous section. In the Value matrix, the dimensionless values are scored from 0 to 10.

< Value matrix of Reactor Technology>

Criteria	Available Reactor Technology			
	Active Reactor (GEN Ⅱ :OPR-1000)	Advanced Reactor (GEN Ⅲ:APR-1400)	Passive Reactor (GEN Ⅲ+:AP-1000)	Small Modular Reactor (GEN Ⅳ)
Provenness by Operation	10	9	8	7
Plant Power Rating	9	10	9	8
Plant Economics	8	9	10	10
Safety and Licensability	7	8	10	10
National Fuel Cycle Strategy	9	10	9	9
Technology Capability	10	10	8	7
Operation & Construction Experience	10	10	8	8

And then, the candidate value is calculated by the following equation:

$$v(x) = \sum_{i=1}^{n} w_i \times v_i(x_i)$$

Where, **v(x)** is the solution value

i=1 to n is the number of the value measure

$\mathbf{x_i}$ is the candidate solution's score in the i^{th} value measure

$\mathbf{v_i(x_i)}$ is the single-dimensional value of the score of x_i

$\mathbf{w_i}$ is the measure weight of the i^{th} value measure

Using the above equation, the weights for each measure developed in the swing weight matrix and the value matrix, we yield the total solution value for each reactor technology as following:

Candidate Solution Value	
Available Reactor Technology	Solution Value
Active Reactor (GEN Ⅱ : OPR-1000)	8.82
Advanced Reactor (GEN Ⅲ : APR-1400)	9.228
Passive Reactor (GEN Ⅲ+ : AP-1000)	8.953
Small Modular Reactor (GENⅣ)	8.521

3. Analysis of Uncertainty and Risk

The major sources of uncertainty and risk in system development are technology development challenges and potential actions of competitors and adversaries. Utility needs a more comprehensive methodology for identifying and managing uncertainty and risk of system and verifying alternatives.

Risk is inherent in all activities and composed of knowledge of two characteristics of a possible, negative future event. Risk management is associated with a clear understanding of probability. Probability of each criterion can be obtained by this equation:

$$P_i = \frac{v_i}{\sum_{i=1}^{n} v_i}$$

Where, $\mathbf{v_i}$ is the i^{th} value measure.

i= 1 to n for the number of value measures.

$\mathbf{P_i}$ are the corresponding Probability.

The probabilities are then calculated from the data in the probability matrix. The result is shown in the following table:

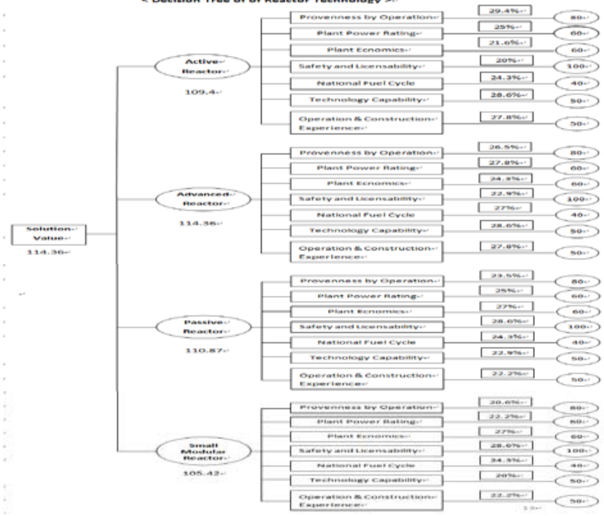
< Probability Matrix of Reactor Technology >

	Active Reactor (GEN Ⅱ : OPR-1000)	Advanced Reactor (GEN Ⅲ : APR-1400)	Passive Reactor (GEN Ⅲ+ : AP-1000)	Small Modular Reactor (GEN Ⅳ)
Criteria	Probability	Probability	Probability	Probability
Provenness by Operation	0.294	0.265	0.235	0.206
Plant Power Rating	0.25	0.278	0.25	0.222
Plant Economics	0.216	0.243	0.27	0.27
Safety and Licensability	0.2	0.229	0.286	0.286
National Fuel Cycle Stratagy	0.243	0.27	0.243	0.243
Technology Capability	0.286	0.286	0.229	0.2
Operation & Construction Experience	0.278	0.278	0.222	0.222

Analysis of uncertainty and risk focuses on integration and consistent treatment of all factors important in the decision making and explicit representation and analysis of key uncertainties. I use a decision tree to determine impact of the uncertainties on the preferences.

From the above probability of each criterion and utility function of criteria(swing weights), I can get decision tree and determine impact of the uncertainties on the preferences like :

< Decision Tree of of Reactor Technology >



4. Conclusion

From the calculated overall candidate solution values and analysis of uncertainty and risk above, it can be seen that preference is given to the Advanced Reactor (GEN Ⅲ : APR-1400) for the reactor technology of Korea. Of course the evaluation and selection of preferred alternatives in real situation are more complex and need more input data as well as efforts.

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