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A Framework for Evaluation of Safety and Generation Effect of Investment Considering Life Cycle Management in Nuclear Power Plants

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1. Introduction

Along with the increasing pressure to enhance generation availability with low cost or investment, regulatory organization has been focused on the enhancement of safety in performance-based and risk-informed regulation framework. Considering this, the most cost-beneficial solution should be found among the short-term and long-term investment plans.

The objective of this research is to propose a generalized framework to evaluate safety and generation effect of investment plan for equipment in nuclear power plants.

2. Overall Structure

By meeting the regulatory requirement which defines the limit of safety parameter, licensing life of nuclear power plant is decided. During this life cycle, the level of defense-in-depth which is key element of nuclear safety should be guaranteed through the operation within limiting conditions for operations in Technical Specifications and within the safety limit specified in Final Safety Analysis Report. Also, periodic inspection and testing should be performed to assure the performance of safety features in nuclear power plant.

Nowadays, probabilistic safety assessment was introduced to quantify the levels of risk in terms of core damage frequency and large early release frequency. Safety of nuclear power plant is a key feature for which many engineered safety features such as ECCS and containment were designed and installed. Because of these characteristics of nuclear power plants, the portion of cost for maintaining or enhancing safety is much higher than other generation plants.

For utility, the continuous operation of plant and the enhancement of power generation capability through investment for equipment is important issue along with safety concerns. By enhancing the reliability of equipments related to the power production and continuous operation, the total generated power will be increased and the economics of nuclear power plants will be enhanced too.

For balancing the cost for enhancement of safety and production, the effect of investment for equipment should be assessed and quantified. This can be the useful information for the determination of priority of investment.

The framework of evaluation is illustrated in Figure 1.

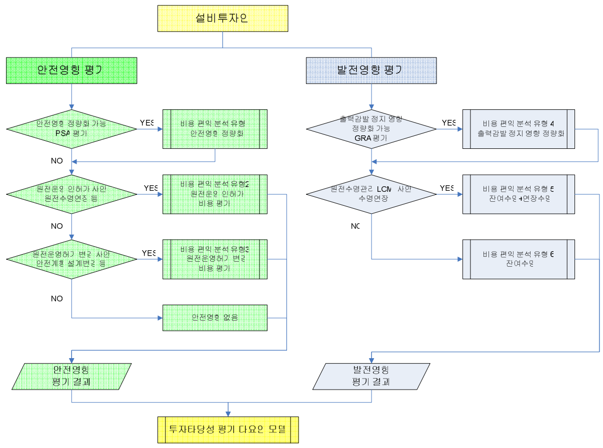

Figure 1. Overall Structure of Cost-Benefit Analysis for Investment Plans in terms of Safety and Production

3. Safety Effect Analysis

The safety effect analysis types are categorized into 3 types and the description for each analysis type is as following.

3.1 Safety Effect Analysis Type 1

By estimating the new Core Damage Frequency or Large Early Release Frequency using expected component failure rates which will be enhanced through the equipment replace or repair, the safety enhancement can be interpreted as cost by assuming the linear relation between safety index such as CDF or LERF. Evaluation process for this type is illustrated in Figure 2.

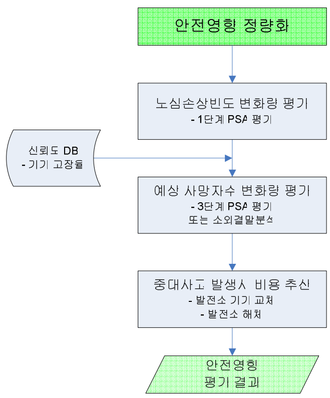

Figure 2. Process for Analysis Type 1

3.2 Analysis Type 2 and 3

The structures, systems or components (SSCs) for analysis type 2 are safety-related but not in PSA model.

The safety requirements for these SSCs are directly related to the licensing basis of construction and operation of nuclear power plant. The cost for safety analysis and licensing process up to the level of construction and operation permission will be expected.

SSCs for this analysis type are safety-related but are not in PSA model. Also, the safety requirements for these SSCs are related to the license modification or licensing basis change applications. The cost for safety analysis and licensing process up to the level of licensing basis change are expected.

Evaluation processes for analysis type 2 and 3 are illustrated in Figure 3.

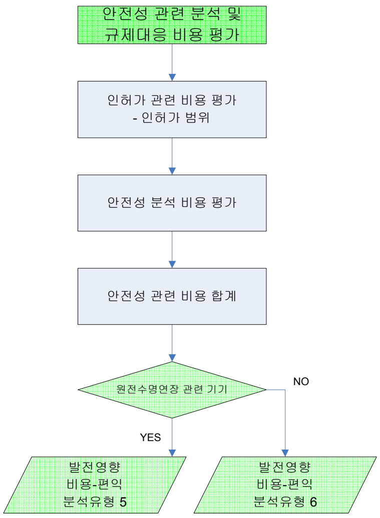

Figure 3. Process for Analysis Type 2 and 3

4. Generation Effect Analysis

The generation effect analysis types are categorized into 3 types and the description for each analysis type is as following.

4.1 Analysis Type 4

By estimating the trip and derate frequencies using GRA model or other method, the generation loss can be calculated. The reduction of generation loss through equipment replace or repair can be calculated through this analysis. Evaluation process for analysis type 4 is illustrated in Figure 4.

4.2 Analysis Type 5 and 6

The structures, systems or components (SSCs) for analysis type 5 are the SSCs for which the replace can be considered when the life extension is considered only. For SSCs in analysis type 6 are the SSCs for which the replace can be considered within the licensed lifetime of plants. In these analyses, the generation for remaining and extended lifetime(type 5) and remaining lifetime only(type 6) are estimated. Evaluation processes for analysis type 5 and 6 are illustrated in Figure 5.

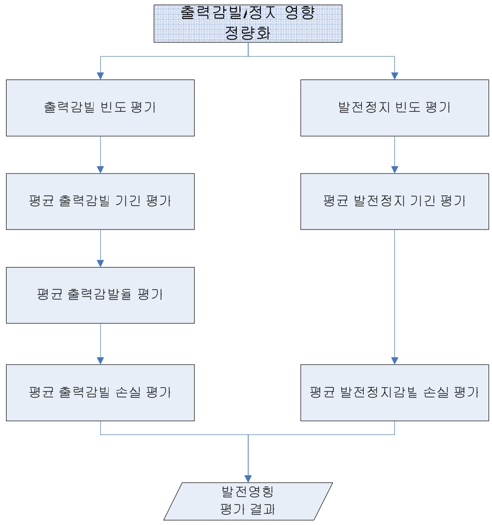

Figure 4. Process for Analysis Type 4

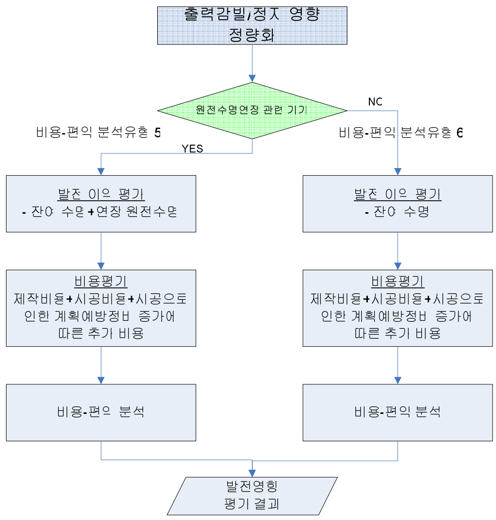

Figure 5. Process for Analysis Type 5 and 6

5. Conclusion

Using the framework presented in this paper, the cost-benefit for equipment investment plans in terms of safety and power production can be estimated. The results through analysis methods in this paper can be used as subsidiary information during decision making process for determining the priority of investment plans.

REFERENCES

[1] EPRI, "Nuclear Plant Life Cycle Management Implementation Guide," TR-106109, Nov. 1998

[2] EPRI, "Generation Risk Assessment (GRA) Plant Implementation Guide," TR-1008121, Dec. 2004