Transactions of the Korean Nuclear Society Autumn Meeting
PyeongChang, Korea, October 30-31, 2008

Economic Evaluation of Safety-Related SSC's Improvement

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1. Introduction

In Korea, about half of the nuclear power plants have been in operation for more than 20 years. As plant operation time increases, SSCs (Structure, System, and Component) are degraded. To increase the plants' safety and efficiency, many SSCs have been improved or changed with large financial investments. But with limited capital sources, not all the improvement plans can be executed at one time. Economic evaluation is one effective tool to decide the priority of each improvement plan. Basically, economic evaluation calculates the benefit between the present and future states after the improvement of SSCs. This method is useful for power-production-related SSC investment priority decisions. However, if the same method is applied to safety-related SSC plans, we get negative profit value. In the case of safety-related SSC plans, safety benefit value should be calculated in addition. In this study, an economic evaluation for safety-related SSC improvement plans is introduced.

2. Economic Evaluation Method

2.1 Power Production Effect

EPRI (Electric Power Research Institute) developed two economic evaluation programs, Lcm-VALUE[1] and Lcm-PLATO[2]. These tools are applied to the LCM (Life Cycle Management) process, and calculate the cost reduction from decrease of lost power generation or maintenance activities. EPRI did not consider safety-related value, because the LCM process is usually applied to power-production-related SSCs.

The basic information of power plant, SSC maintenance cost, investment cost, failure effect on power production, and SSC failure rate before and after investment are input data of LCM economic evaluation programs. The main benefit comes from lost power generation saving. Lost power generation is estimated by multiplying failure rate, power production effect and plant's production capacity. So, if the SSC is closely related to plant's power production system, profit will be large. If the essential component for power generation (ex. turbine and main generator) fails, plant's losses come to a large amount. After replacement or improvement of such a component, we will expect the failure rate of a component to be decreased. The failure rate difference between before and after improvement comes to a benefit of lost power generation reduction.

However, safety-related SSCs usually consist of multiple trains and have redundancies, so these SSCs do not directly affect power production. If the same economic evaluation method is applied to safety-related SSCs, the benefit will be very small. This result should not be used to decide the priority of an investment plan. So another evaluation tool, considering safety factors, is needed.

2.2 Safety Effect

Quantifying safety effect value is not easy, and variation of value is very large according to which criteria are used. But if we can evaluate a 'reasonable' safety effect value, it will be useful to determine which plan is preferable.

The U.S. NRC published the NUREG/BR-0058 Rev. 4[3] and NUREG/BR-0184[4], recommended regulators to analyze the economic benefits that come from reduction of accident frequency. Although this report was published from a regulatory point of view, the estimated safety factor value can be helpful to decide the priority of investment plans.

NUREG/BR-0184 introduces a practical way of estimating the consequential cost from a nuclear power plant accident. The cost consists of four components: public health, occupational health, offsite property, and onsite property. The health factor is estimated by person-rem value from the accident, the property factor is calculated from the worth of the power plant and nearby property. Benefit from the safety effect can be calculated by multiplying the accident reduction frequency for each factor. These values are used to calculate the net present value, which considers the plant's remaining operation years and discount ratio. The sum of all benefits becomes the total benefit from accident reduction. Also, this report provides the average value for all factors, based on U.S. conditions. Some value should be changed to Korean specific values reflecting the different situation from the U.S.: for example public health and offsite property in Korea is supposed to be larger than those of the U.S.

2.3 Example of Safety-Related SSC's improvement

An EDG (Emergency Diesel Generator) is one of the safety-related component that is closely related to core damage frequency. Also, because of plant's technical specifications, EDG failure influences power production. However, this component is not directly related to power production and does not run in normal operating

conditions. So, EDG's power production effect is assumed to be low.

Table I shows the results of economic evaluation of EDG improvement plans. 1,500 million won for improvement of the EDG exciter in year 2010, minus 10% failure rate (90% value before improvement), minus 4.96×10^{-7} CDF (from 10% reduction of EDG basic event failure rate), 7% discount ratio, 5% inflation ratio, 20 years remaining life, and other maintenance costs are assumed. When the power production effect is considered alone, this plan has no economic benefit. Safety effect value, which comes from CDF reduction, is 1,405/1,765 million won for 20/40 years remaining life each, shown in Table II. Actually we used different values for some factors from the NUREG report that were suggested as average values for the U.S. By summing up power production and safety effect, the evaluation result is revealed to be a benefit.

Table I: Economic Evaluation Result

Alternative		Power Production Effect Only		Safety Effect Added	
		NPV Cost[1)]	B/C Ratio[2)]	NPV Cost	B/C Ratio
20Y	Use as is	3,513	1	3.513	1
	Improvement	4,764	0.13	3,359	1.11
40Y	Use as is	5,854	1	5.854	1
	Improvement	6,955	0.24	5,190	1.44

1) Net Present Value conversed to 2008 year, million won
2) Benefit Cost ratio = total benefit / total cost

Table II: Safety Effect Evaluation Result

△CDF		4.96×10^{-7}	
Remaining Life		20Y	40Y
Benefit[1)]	Public Health	1,062	1,324
	Occupational Health	4	7
	Offsite Property	316	394
	Onsite Property	23	40
Total Benefit NPV		1,405	1,765

1) million won

3. Conclusion

Because safety-related SSCs are not directly related to plant power production, economic evaluation considering only power production effects shows that it has no benefit. Accordingly, another evaluation method is needed for safety-related SSC improvement plans to decide the priority.

If the NUREG/BR-0184 method, which calculates the benefit from accident frequency reduction, is applied, we can estimate the benefit from safety effects. In this case, modified values should be used, regarding difference between the domestic and the U.S. situation. Considering both power production and safety effects, we may get a quantitative economic evaluation result for safety-related SSCs. This result is helpful for management to decide the priority of many investment plans.

REFERENCES

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[3] "Regulatory Analysis Guidelines of the U.S. Nuclear Regulatory Commission", Revision 4, U.S. NRC, Washington D.C., 2004
[4] "Regulatory Analysis Technical Evaluation Handbook", U.S. NRC, 1997