Study on Economic Evaluation of Nuclear Power Plant's SSC

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1. Introduction

As the operating year of nuclear power plant increases, more improvement plans on degraded SSCs(Structure, System, and Component) are suggested. Because of safety concern, the maintenance and replacing cost of nuclear power plant's SSCs are usually high and it can be a burden to financial control. To satisfy both safety and economic problems, systematic and efficient plans are needed. For this reason, KHNP is now developing the LTAM (Long Term Asset Management) program to establish the long term improvement plans for SSCs, from safety and economic point of views. Actually LTAM program is one of the steps of INPO ER (Equipment Reliability) process [1]. In USA, EPRI (Electric Power Research Institute) has developed the LCM (Life Cycle Management) program and it was applied to some nuclear power plants. In this program, several alternatives are candidated. Then, economic evaluation is applied to each alternative. The result of economic evaluation affects to the final alternative decision. In this study, EPRI's economic evaluation method is reviewed.

2. EPRI Economic Evaluation Method

EPRI developed the LCM program and published many LCM related reports such as sourcebooks for 14 SSCs, demonstration of LCM process and lessons learned reports of sample applied cases on US nuclear power plants.

Economic evaluation is expressed at 19^{th} step of 23 total LCM program steps. Generally, 4 alternatives are candidated and economic evaluation is performed for each cases. Among them, one alternative which has the lowest NPV (Net Present Value) cost or highest B/I (Benefit/Investment) ratio is recommended for final decision.

NPV is calculated using equation (1)

$$NPV = \sum_{f_{first}}^{j_{last}} C_j \left[\frac{1+k}{1+d} \right]^{(t_j - t_{NPV})} \quad (1)$$

where, j_{first} = first year for which costs are to be accumclated
j_{last} = last year for which costs are to be accumclated
C_j = year j cost in today's money
d = discount rate (cost of money)
k = inflation rate plus real escalation rate
t_j = year in which cost is to occur
t_{NPV} = year for which NPV is to be computed

All future costs for managing the SSC for the remaining plant life are brought back to the present using net present value approach.

Also B/I ratio is calculated for each alternative (second, third, etc.) relative to baseline (first) alternative. The governing equation is given by

$$B/I = \frac{\Delta NPV}{\Delta PM\ \ Cost} = \frac{-\Delta NPV\ \ Cost}{\Delta PM\ \ Cost} \quad (2)$$

EPRI developed two economic evaluation tools, Lcm-VALUE and Lcm-PLATO [2,3]. While Lcm-VALUE is based on MS Excel spread sheet and Lcm-PLATO is based on MS Access DB. Both program have similar function, calculate the NPV using the cost data, and compare it with other alternatives. EPRI imiplements the economic evaluation with these programs on lessons learned reports.

3. Input Data

For economic evaluation, two kinds of data which are general data and cost related data. Detail descriptions are given below.

3.1 General Data

Plant electrical output, unplanned lost production cost, labor cost, discount rate, inflation rate, cycle length, NPV calculation date, analysis start-end date, year of cost data, and etc are included in this category. To calculate the future cost and to convert it to present value, these data are used.

3.2 Cost Related Data

For each alternative, specific cost related data are needed. Cost is divided into two categories; one is planned cost that arise out of preventive maintenance activities and the other is unplanned cost that arise out of failures

3.2.1 Planned Cost

Annual and refueling outage preventive maintenance cost, planned modification or components changing cost not caused by the failure is included. If each alternative has different preventive maintenance activities, planned cost is variable.

3.2.2 Unplanned Cost

Unplanned corrective maintenance, lost power production, and consequential (i.e. regulatory risk) costs which arise out of an unexpected failure are included in this category. To get the estimated annual cost of unplanned event, unplanned cost is multiplied by failure rate (per year). For example, if the unplanned cost of pump shaft cracking failure is $10,000 and the probability of such failure is 0.04 per year, then the estimated cost can be calculated as follow :

$$Cost = Failure\ rate\ \ X\ \ Cost = 0.04\,X\ \$10{,}000 = \$400$$

Unplanned cost and failure rate can be varied with failure mode and time. For example, pump shaft cracking failure and impellar failure have different corrective maintenance cost and failure rate. As the operating year increases, failure rate may be either constant or changed (linearly, exponentially).

4. Limit of Economic Evaluation

Alternative suggests the SSCs reliability improvement plan such as reinforced preventative maintenance activities, improvement plan of sub components, and replacing plan of SSCs. Generally, SSCs' reliability will be increased with decreased failure rate, during implementation of alternatives. Reduction of failure rate decreases the unplanned cost; increases the benefit.

For the SSC of which failure need forced outage, reduction of unplanned cost is much bigger, because lost power generation factor is very big. For example, 'A' plant reduce the 5% of failure rate for main turbine control valve by improving the valve control oil system. If such valve fails, corrective maintenance cost is $5,000 and 24 hour forced outage needed. 'A' plant's electric output is 1,000MWe/hr and it earned $30 per MWe/hr. Unplanned cost reduction is calculated as follows :

$$\begin{aligned} Benefit &= failure\ rate\ reduction \times unplanned\ \mathrm{cos}t \\ &= 0.05 \times (\$5{,}000 + 24 \times 1{,}000 MWe/hr \times \$30 hr/MWe) \\ &= \$36{,}250 \end{aligned}$$

Figures 1,2 show plot of unplanned cost against the failure rate reduction and corrective maintenance cost, respectively. Failure rate has more strong influence on unplanned cost and NPV than CM cost. So determination of correct failure rate for SSCs and failure rate change is important in economic evaluation

But it is very difficult to calculate the specific SSC's failure rate and its change. For instance, plant applied the rigorous preventative maintenance activities, such as applying the cathode protection system, increasing inspection area, reducing inspection interval, and replacing heat exchanger tube with more corrosion resistive one. By these activities, reliability of SSCs should be increase, but decision of failure rate reduction is not easy.

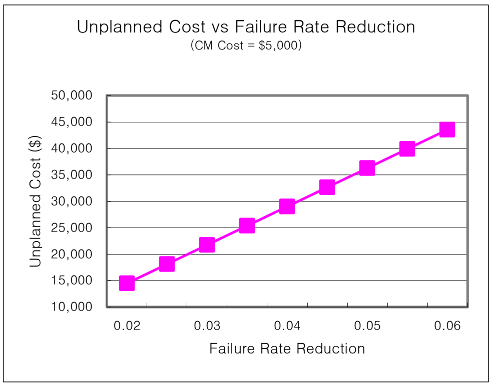

Figure 1. Unplanned Cost vs Failure Rate Reduction

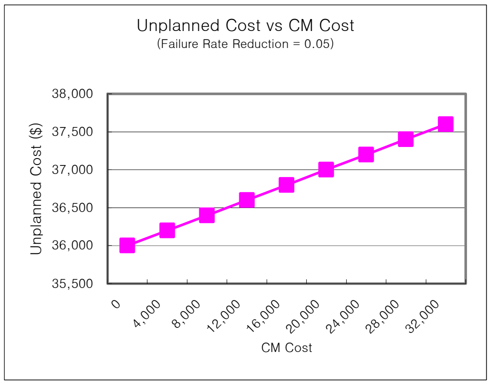

Figure 2. Unplanned Cost vs Corrective Maintenance Cost

5. Conclusion

In EPRI LCM program process, final alternative is recommended with the help of economic evaluation in which NPV and B/I ratio are determined and compared for the alternatives. If the SSC's failure is directly related to forced outage, failure rate has most important effect on economic evaluation result. But, obtaining the correct failure rate and amount of failure rate change are not easy.

Additional research of economic evaluation should be carried out, and careful approach is needed to use the failure rate.

REFERENCES

[1] Equipment Reliability Process Description, INPO, AP-913 Rev. 1, 2001
[2] LcmVALUE, EPRI, Project No. 6118, 2002
[3] LCM Planning Tool(LcmPLATO), EPRI, 1006686, 2002