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Evaluation of Commercial Digital Control Systems for NPP I&C System Upgrades

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1. Introduction

Nuclear power plants (NPPs) in Korea have had long successful operating histories. Meanwhile, systems in the plants are growing older, equipments or parts obsolescence and technical disconnections became more the incipient problems.

Instrumentation and Control (I&C) systems are identified as major weak points to the challenges.

In the beginning of the old system upgrades, plant technical staffs are seriously concern about which candidate platforms are most profitable –economic savings in purchase and trouble free during system occupancies.

This work was carried out to evaluate candidate commercial digital systems for replacement of analog based old control platforms in domestic NPPs.

2. Objectives

Nuclear power plant control systems are complex and require high quality and reliability.

The core objectives of this work are,

- To determine more practical evaluation models for commercial digital control systems acquisition
- Sample commercial system test evaluations with developed LCC models
- Interpretations on the evaluation results.

3. Approaches

There are two different views to a system of power plants. Managers in NPP plants are generally more concern about economic benefits, which means most cost saving system at purchase time is their favorable selection. The other view is of the engineers or operators of the plant site, who are more declined to select technically improved I&C systems.

3.1 LCC Model Selection

There exist many system life cycle cost (LCC) models and some of them can be adapted for I&C system cost evaluation. But, most LCC evaluation programs are financial aspect analysis and include many hidden assumptions to simplify the process.

The LCC of plant control systems is composed of many factors and most of the factors are cross-related. Thus, an analysis which encompasses all cost influent factors is not practical and validity of the results is hard to prove, because years to decade collection of cost affected data sets is not easy.

The "Cost-Effectiveness Model" is one of simple and widely understood system LCC model [1].

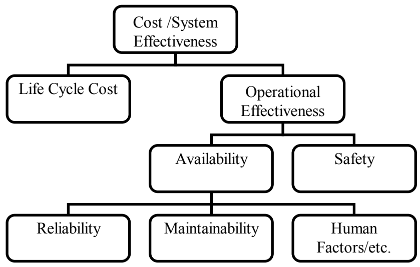

Figure 1. Simplified Complex System Cost-Effectiveness Model

Generic LCC model of any equipments are composed of acquisition cost plus maintenance cost during operational period and disposal cost.

As NPP control systems generally have 10 to 20 years of long useful life, system acquisition costs are less dominant factors than sum of all lifetime maintenance costs for LCC evaluation.

3.2 Sensitivity Analysis

There exist several candidate digital control systems in current market, and almost all of them have long supply lists and successful reputations. Migration from old analog based nuclear power plants control system to high-tech digital control system seems to have no show-stopper. But by the nature of complex digital technologies, if not well managed, digital control system can be more troublesome than replaced old systems.

Throughout the sensitivity analysis, single failure prevention features are shown as most critical factors for LCC reduction. Maintenance and test time reduction features are followed as next important cost saving factor. Table 1 shows variables and data used for occupation period LCC model sensitivity analysis.

Input value / Input variables	Worst case	Base case	Best case
Outage days (/failure)	0	1	3
Failures (/ life time)	0	2	4
Generation Loss Cost (Won/day)	800M	1,000M	1,200M
Acquisition Cost	600M	800M	1,000M
Test Time Reduction (day)	1	2	4

Maintenance labor cost (Won/day)	1,500K	2,000K	3,000K
Useful Life	10	15	20

Table 1. Input variables and data for LCC sensitivity analysis

The sensitivity calculation results are shown at Figure 2.

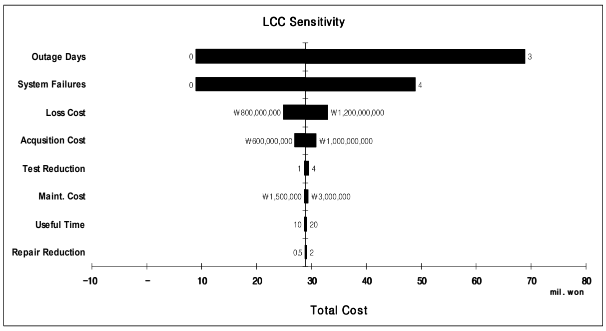

Figure 2. LCC Sensitivity analysis result

3.3 Assumptions for Evaluation

Following common assumptions are established to simplify the evaluation.

- Every digital control systems in current market have sufficient reliability records. Each vendor shows high order of MTBF or availability figures. But they are hard to justify.
- Advertisements of very short repair time (few hours) are neglected. Any failure of a system is assumed to be repairable within a working day (8 hours MTTR).
- Test time and calibration time reduction features are very valuable for unavailability reduction (increase availability).
- System which has market reputation is favored as evaluation candidate.

3.4 Control System Evaluations

Operation and maintenance costs are composed of system failure recovery prices, preventive maintenance prices and plant unavailability costs during down period.

Required control system functions are categorized as follows;

- Single failure prevention features
- Test and calibration time reduction features
- Repair time reduction features

If a function can be classified more than two categories, weighting values are assigned. Examples of multiple category requirements are as follows;

- Secure failover features between redundant modules
- Remote control change-over and forcing any inputs or outputs point value as required

Total 62 items for evaluation list are collected [2], among them, 31 items are not feasible to evaluate without detail control logics and specific MMI designs. Examples of these drop-out features are;

- Methodology for redundancy (dual or triple, voting logic etc.)
- Channelizing
- Segmentation
- Access Control
- Application program and logic testing
- Bypass or inoperable status indication
- Failure detection and indication
- Tag-out
- Etc.

Using these check lists, three commercial control systems are evaluated. Some software tool's features for configuration management, off-line/on-line diagnostic and calibration/test support which rather independent of user applications are included to evaluate. Software tools review points are easy to understand, well organized with consistent MMI, and no specific domain knowledge required for operation.

4. Results

As domestic NPPs control systems are growing older, upgrading of these analog based systems has no alternatives other than digital only control systems.

Plant technical staffs want to select most cost-effective and maintenance relieved control system during life time occupancy. Throughout a sensitivity analysis, major cost impact factors are selected during I&C system occupancies.

Three candidate digital control systems are selected for the evaluation, which have successful application histories in domestic PWR plants.

Normalized evaluation scores of the systems are range from 89.7(worst) to 94.1(best). The difference of the compared system is less then 5%. These results can be interpreted as follow;

- Each system has sufficient cost saving features and can be selected for upgrading platform
- Technical features discrimination is not practical without the detailed application designs (include MMI design).
- Total system efficiency is more dependent on application design and engineering.

REFERENCES

[1] A. Birolini, Reliability Engineering - Theory and Practice, Springer, p 13, 2004.

[2] J. Naser, Guidance to Maximize the Benefits of Digital Technology for the Maintenance of Digital Systems and Plant Equipment, sec. 2 –sec. 5, EPRI, 2004