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A Health Evaluation Method of I&C Systems in NPP

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1. Introduction

Currently, many utilities are considering the modernization of some or all about I&C systems in nuclear power plant to increase availability and enhance safety. And extended use of digital technology in industrial process and accumulated reliability in digital equipment are gradually getting nuclear power plants to replace their old analog systems with some proven digital systems (or components). But, to adapt digital equipment to plants effectively and systemically, there is an essential prerequisite. That is to evaluate the health of the current I&C systems.

Generally, there are several methods to evaluate the status (such as health, reliability, performance, aging, etc.) of I&C system but it is not easy to apply to nuclear power plant. Because nuclear power plant has lots of I&C equipment, the equipment consists of a large number of components and the each equipment affects the others. Accordingly, it requires much effort and time to evaluate a lot of systems or equipment in NPP, besides, it is difficult to totally assure the result evaluated by such complicated methods.

2. Methodology

The method we are proposing is to evaluate some questionnaires including questions which are able to analyze both qualitative and quantitative sides. The related data can be collected from those who are in charge of operation of some equipment, systems, and components in the target plant through questionnaires or direct plant staff interviews. Also some data can be found from historical operating records which include maintenance records, failure records and so on. From the collected data, a model for evaluation is extracted and the evaluation of the status for each system (or equipment) is conducted in the point of health, reliability, performance, aging, etc. Figure1 shows an overall work flow of the methodology for evaluating the status of I&C equipment.

2.1. Factors for Evaluating System Status

System Importance: the importance considering safety class, quality level, functional role in NPP, and failure mode effect on other systems
System Performance: the function and performance of the system satisfying the system requirements
System Maintenance: the status or ability of the system maintenance
System Robustness against Aging: the level of the system robustness against aging
Operation Efficiency: the current operation efficiency that a system has or can make
Continuance of Equipment Supply: the possibility that equipment can be supplied continuously

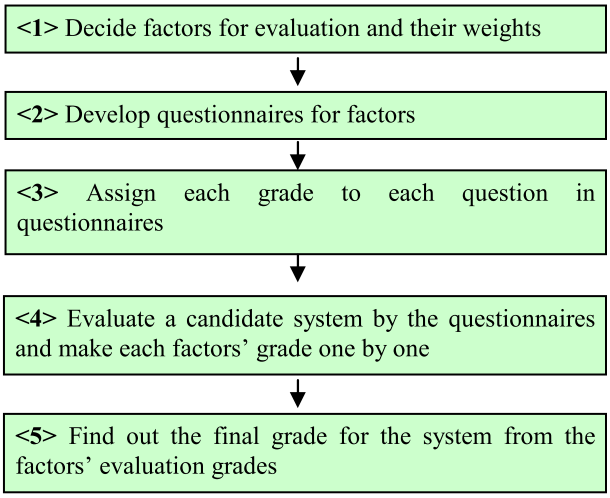

Figure 1. 5- Step of the work flow

2.2. System's evaluation grade using questionnaire

The questionnaire for each evaluation factor consists of several questions related to the factor. The related data to complete each question can be found from interviews of plant staff or plant's historical operating records which include maintenance records, failure records and so on. From the collected data, we can find out and evaluate the status for each system (or equipment) in the point of system importance, health, reliability, performance, aging, etc. and a model for evaluation can be extracted. System importance is more significant factor for evaluation than others. System importance is to be decided from FMEA (Failure Mode Effect Analysis) of the corresponding I&C system. Besides, reliability-based maintenance analysis including MTBF (Mean Time Between Failure) is also to be performed for estimating the life cycle of the I&C system [2,3].

Eventually, to evaluate factors and make a grade for a system, the flowing two step processes are performed.

First step, a questionnaire for each factor has some questions to evaluate system on the factor and each question has an assigned grade according to question's importance beforehand. Each question's evaluation grade is decided by evaluator's answer within the assigned grade already. Accordingly, the factor's evaluation grade is decided by summing question's evaluation grades and the maximum grade of the factor is fitted from 0 to 100-points. Formula (1) is for finding out each factor's grade [1].

Second step, after evaluating factors for a system, there are also weight allocations of factors according to the importance of each factor. Through the two steps as above, a final evaluation grade for a system is found. That is, formula (2) is for a final evaluation grade for a candidate system. Therefore, the evaluation grades of all candidate systems can be found by applying such two step methods to the systems.

$$F_i = \frac{\sum_{j=1}^{n} A_{ij} w_{ijk}}{\sum_{j=1}^{n} A_{ij}} \times 100 \qquad (1)$$

$$S = \frac{\sum_{i=1}^{m} W_i F_i}{\sum_{i=1}^{m} W_i} \qquad (2)$$

Where,

S : Final evaluation grade for a system

F_i : Each factor's evaluation grade

($i = 1,2,\ldots,m$, *m*: the number of factors)

A_{ij} : Assigned maximum grade of question(*j*) of factor(*i*)

(*j*=1,2,…,*n*, *n*: the number of questions)

w_{ijk} : Evaluation rate for answer of question(*j*) of factor*(i),*

($0 \le w_{ijk} \le 1$, $k = 1,2,\ldots,n_j$, *n_j: the number of answers of question(n)*)

W_i : Weight of factor(*i*) (W_i >0)

3. Application and Results

The proposed methodology was applied to 10 systems in Ulchin(UCN) unit 1&2. UCN unit 1&2 are PWR(950MWe) types and have been operated for more than 15 years since 1988 and 1989 respectively.

Table 1 shows the results of the factors' grades for each system. And Figure 2 shows the final grade for system health evaluation on each system. The final grade (*S*) could be divided into three categories such as group I, group II and group III in Figure 2. Group I includes systems which need replacement or upgrade within 1~2 period of overhaul. Group II includes systems which need replacement or upgrade within 3~5 period of overhaul. Group III includes systems which need replacement or upgrade after 6 period of overhaul.

As Figure 2, there are 3 systems in group III and the others in group II. Therefore, we could determine that the 10 systems in UCN unit 1&2 are generally quite healthy and each system must be managed in accordance with its health grade.

Systems \ Factors	System Importance	System Performance	System Maintenance	System Robustness against Aging	Operation Efficiency	Continuance of Equipment Supply
Annunciator System	50.3	68.5	85.1	87.1	100	91.2
Seismic Monitoring System	45.5	71.5	73.7	91.4	84.4	87.6
Radiation Monitoring System	84.4	72.6	76	79.1	92.4	75.7
Reactor Protection System	95.6	71.7	67.6	86.9	77.4	71.8
Feedwater Heating System	54.5	58.2	71.5	72	66.4	68.2
Process Control System	100	76.4	69.6	85.4	55.4	70.4
Flux Mapping System	75.1	61	65.1	80.9	80.1	72.6
Rod Control System	74.5	60.3	76.2	66.9	67.7	68.9
Turbine Control System	71.6	61	65.1	74.6	60.9	78.8
Feedwater Control System	63.6	61	67.1	62.3	65.7	80.4

Table 1. Factors' grades of each system

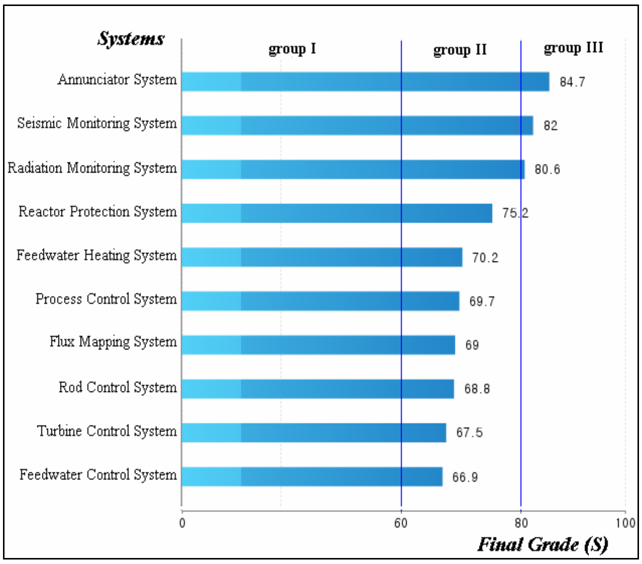

Figure 2. Final grades for system health evaluation

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