A Study on the Engineering Programs used for Improving an Equipment Reliability in NPPs

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1. Introduction

In the early 1990s, the United States, which led the world's nuclear industry, opened electric power transactions between its states by easing regulations of the domestic electricity power market. In addition, as the US Nuclear Regulatory Commission (NRC) introduced a new Reactor Oversight Program (ROP) and applied different regulations to power plants depending on their performance basis, nuclear operators in the U.S. had to consider the safety and economic feasibility of plant [1,2,3].

In this regard, in 1998, together with the US Electric Power Research Institute (EPRI), the Nuclear Energy Institute (NEI), and the Institute of Nuclear Power Operation (INPO), the nuclear operators started to develop processes for Standard Nuclear Performance Model (SNPM) and Equipment Reliability (ER) in order to enhance performance and economic feasibility of their plants and gain public trust. The U.S. operators have achieved, as a result, better plant operation efficiency and higher facility safety and reliability by implementing engineering programs based on SNPM and ER processes. Thanks to this effort, the U.S. has become top nuclear power plant operator in the world, with 90 percent of nuclear power plant utilization rate [3].

Meanwhile, Korean nuclear operator has introduced advanced nuclear operation methods and engineering programs step by step since 2004, including establishment of the organization which is exclusively responsible for engineering tasks, training programs for system engineers, and policy for Risk-Informed Regulation. However, the engineering programs have been shut down or shrunk due to elimination of the engineering department in 2013, a shift of focus to other pending issues after the Fukushima accident and lack of maintenance personnel.

As the advanced engineering programs have been introduced to Korea in a short period of time, each program has been developed separately, lacking correlation with others, rather than through systematic development with well-organized comprehensive review. The programs have not been cohesive as it should be, deepening of data redundancy and causing existence of a number of similar programs so that less domestic operators have used them as the programs are inconvenience to use. As a result, the engineering work in Korea's nuclear operation has been shrinking significantly. This will ultimately threaten the safety of the domestic nuclear power industry and have a negative impact on the overall industry. Moreover, as the public's attention has focused on a nuclear power plant's equipment malfunction and unexpected reactor scram since the Fukushima accident, securing ER for the nuclear operation has become important than ever before in order to restore public acceptance of nuclear power plant.

This research is to find out methods to integrate data and systems in the current engineering programs in Korea for more correlation among the programs.

2. Research Subjects Analysis Methods

2.1 Research Subjects

The purpose of this research is to propose the improvement plan for the domestic engineering programs based on the result of examining the possibility of integrating their data and systems. In this regard, this research has identified the current status of data and operation systems in the program and the execution of the program.

This included nineteen essential programs (Table I) among the ones developed according to the introduction of the advanced engineering process and the implementation of the Severe Accident Implementation Policy, except the programs which does not share any data with others. In particular, nine engineering programs (Table II) operating computer systems were analyzed together in this research.

Table I. List of the Analyzed Programs

Name of Program	Name of Program
Equipment Master	Engineering Workstation
Functional Importance Determination	System Monitoring Plan
Maintenance Rule	System Health Report
Single Point Vulnerability	Component Health Report
Preventive Maintenance	Proactive Maintenance
PM Template	Risk Monitoring System
Predictive Maintenance	Outage Risk Indicator of NPPs
Corrective Action Program	Plant Reliability data Information System
Plant Health Committee	Engineering Change status Management System
Long-Term Asset Management	-

Table II. List of the Analyzed Operating Systems

Name of Operating System	Name of Operating System
Maintenance Rule	Risk Monitoring System
Single Point Vulnerability	Outage Risk Indicator of NPPs
Corrective Action Program	Plant Reliability data Information System
Long-Term Asset Management	Engineering Change Management System
Engineering Workstation	-

2.2 Analysis Methods

In overview, this research has described the purpose of each program that the Korean nuclear operators developed and introduced. It extracted and analyzed the entire data of the programs as shown in Fig. 1, the total number of 120, including functional location, notice number, and order number. Based on this analysis, by comparing and reviewing the data distribution among the programs, the research has reached to describe the extent of the data redundancy numerically.

Name of Programs \ Data used in Programs	Functional Location	Order Number	Equipment Number	Equipment Importance	Plant Group	Unit	Out of Service Time	.....
Equipment Master (EM)	○		○	○	○			.....
Functional Importance Determination (FID)	○		○	○	○			.....
Maintenance Rule (MR)	○	○			○	○	○	.....
Single Point Vulnerability (SPV)	○	○						.....
Preventive Maintenance (PM)	○		○	○	○	○		.....
Preventive Maintenance Template (PMT)				○				.....
Predictive Maintenance (PdM)	○		○	○	○	○		.....
Corrective Action Program (CAP)	○		○	○	○			.....
Proactive Maintenance (PaM)								.....
Risk Monitoring System (RIMS)	○	○				○	○	.....
Outage Risk Indicator of NPPs (ORION)							○	.....
Plant Reliability Information System (PRinS)	○	○				○	○	.....
Duplicate Rate of Data	*0.75*	*0.33*	*0.42*	*0.50*	*0.50*	*0.42*	*0.33*	.....

Fig. 1. Check Sheet of Data Redundancy in the Engineering Programs

2.3 Analysis of Engineering Program Implementation Status

Since 2004 when the Korean nuclear power plants have introduced advanced nuclear operation technologies and engineering programs, they extensively applied them to their plants. However, in February 2013, the power plants came to be faced with a shortage of system engineers and a lack of engineering program implementation personnel due to the elimination of the power plant system engineering department. Even though the engineering department was reorganized in December 2014, most of the members were entry-level workers with less experience as the nuclear industry itself took a skeptical view on the engineering organization and experienced workers avoided working for it. In addition, as driving force for carrying out the programs has weakened, the department has managed to do minimum level of work so far.

Moreover, as a result of safety inspections of nuclear power plants after the Fukushima accident, follow up measures as improvement plan and its detailed action items have become the top priority for the entire nuclear operators. As the focus of the operators has shifted to tasks of essential nuclear power plant regulation, engineering tasks have been interrupted or reduced to minimum level.

2.4 Review of Possibility of linking Engineering Programs

Based on the data of the individual engineering programs and related operating systems, this research has confirmed that grouping can be performed based on specific functions as a result of examining data association among the programs. Fig. 2 below shows an example of the integration possibility.

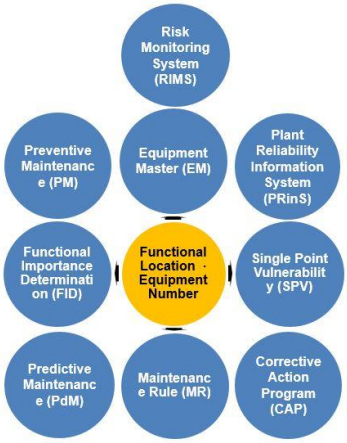

Fig. 2. Functional location-based Engineering Programs

In addition, the total number of data used in reviewing the 19 engineering programs is 120 and 45% (54) of them are redundantly used. Fig. 3 shows an analysis that the data which has 20% of the duplication ratio recorded 30% of data fraction.

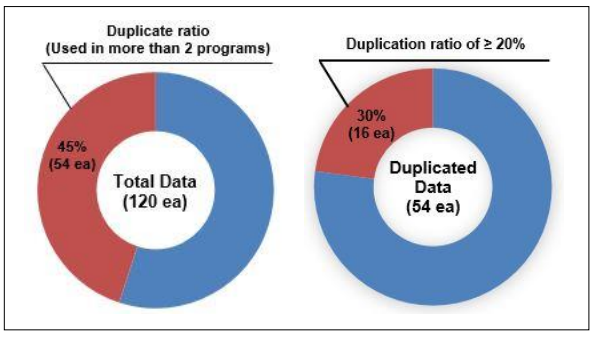

Fig. 3. Duplication Ratio of Data among the Engineering Programs

In addition, as shown in Fig. 4, three programs repeatedly assess the “unavailability of equipment”, thus reaffirming that the integration of the tasks among the programs is available.

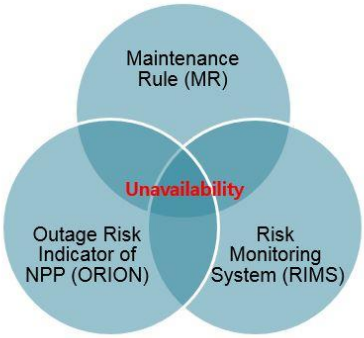

Fig. 4. Example of Functional Overlap among Engineering Programs (example)

Therefore, this research aims to confirm the actual extent of redundancy among the current engineering programs in figures and further to suggest the necessity of securing more correlation among them and establish the integrated management system for the sake of equipment reliability (ER) through enhancing work efficiency for users.

3. Analysis result and Considerations

3.1 Review of Necessity for Analyzing the Integrated Engineering Management System

Based on the results of analysis of the data and operation status of the 19 programs that are essential for the execution of the engineering work, this research suggests the outcome of reviewing the necessity of an integrated engineering management system.

First, many engineering programs operate on their own operating systems using basic and reproduction data and there is no data sharing among the programs. However, the result of the data analysis has confirmed that 75% of the data based on the functional location/equipment number, 67% of the notification/order based data, and 50% of the equipment importance based data are mutually shared. It shows that the task integration and data sharing among the engineering programs is urgently necessary.

Secondly, in order to carry out the tasks of the engineering department, various programs have to be accessed separately to obtain the desired information. In this process, as the users' working time is extended and they feel more fatigue, the users have become not to access the programs frequently. Despite these disadvantages, each individual program has meaningful engineering feature information that can aid engineering judgment, thereby helping engineers make a technical decision.

Therefore, in the process of integrating the engineering programs, it is desirable to construct an integrated portal for the users' easier access to the programs by grouping them based on their function when they share mutual data, rather than merely physical coupling.

3.2 Proposal for the Integrated Engineering Management System

In the existing engineering programs, in order to acquire the desired data, the users had to access the each program sequentially to obtain information. As of July 2017, 181 programs have been confirmed to be in use within a work website of the Korean nuclear operator. As the programs have similar names and functions, it is natural that the users have been confused with the programs. Therefore, this research suggests building an integrated engineering management system (Fig. 6) linking the current essential engineering programs (Fig. 5). It is believed that by establishing the integrated management portal linking the engineering programs, which the engineering department uses every day, the users will be able to obtain necessary operating parameters or related information much easier and faster.

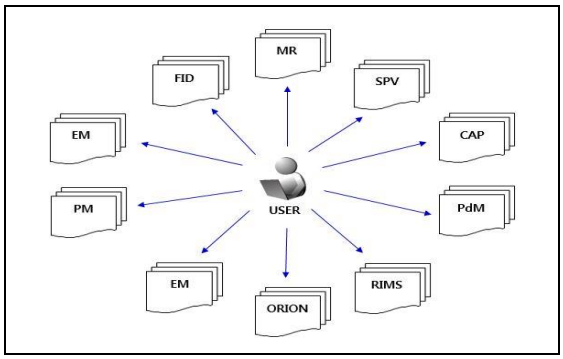

Fig. 5. The Current Engineering Work Process

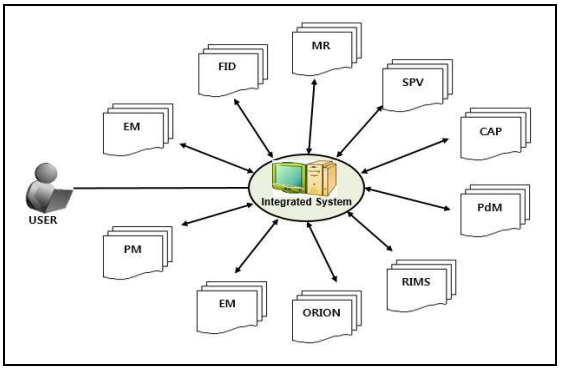

Fig. 6. Engineering Work Process after Integration

First of all, as shown in Fig. 7, the engineering programs are classified into four groups (equipment classification, performance monitoring, maintenance, mid / long-term management), that can be functionally integrated. Auxiliary tools that require administrative support for task operation are added to the group as the "technical support." Finally, the main page of the portal shows the five groups as shown in Fig. 8.

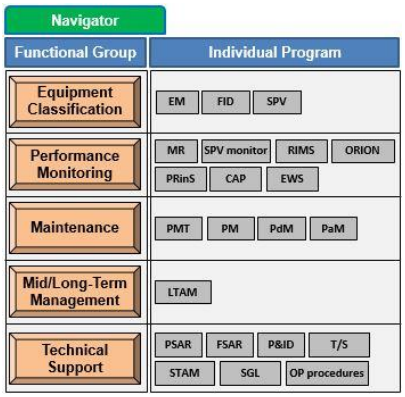

Fig. 7. Functional Integration in the Engineering Programs

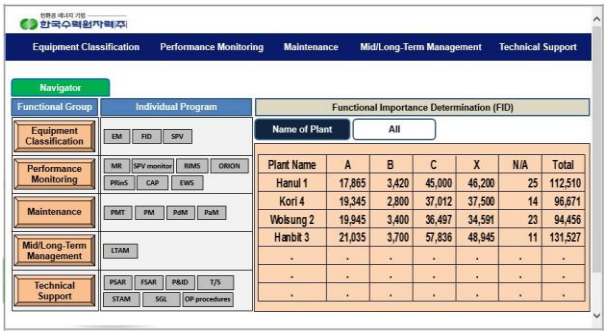

Fig. 8. Main Page of the Integrated Engineering Management System

4. Conclusions

Nuclear power has played a pivotal role in Korea's industrial modernization by supplying stable electric power since the first nuclear power plant in Korea started commercial operation in 1978. However, in the first year of operation, the utilization rate of nuclear power plant was 46.3% and the number of power plant trip was 17 times [4]. However, after advanced nuclear power management technologies and the engineering programs were applied to the power plants since 2004, they showed a surprising operation results such as 89.5 % of average utilization rate, and average 0.1 trip case per year in nuclear power plants [4].

However, the engineering programs have been interrupted or less used due to the elimination of the engineering department, the lack of system engineers, and increasing number of the pending issues of the industry after the Fukushima accident. As each individual program has been introduced separately, depending on certain users' need and demand, an excessive number of programs are currently registered, lacking the interrelation among them and causing less operation of the engineering department due to the redundancy among the programs.

This research surveyed the status of the basic data and the configuration of the operating system in each program and confirmed the actual operation status of the program at the nuclear power plants in order to set a direction for future improvement.

First, the necessity of development of an integrated management system portal for engineering is confirmed because the data redundancy is higher than expected among major engineering programs in order to maintain plant safety and improve the equipment reliability.

Second, even though each individual engineering program is operating in its separate and isolated environment, all of the programs have useful information for better engineering judgment. Therefore, it is more desirable to group them based on their function when they share mutual data, rather than physical coupling.

Third, in order to change the industrial culture in the workers have avoided working in the engineering department so that the department has been consisted of new workers, continuous attention and support from management level in the industry as well as stronger job performance trainings for the department are highly needed.

In conclusion, this research is believed to strengthen the domestic engineering capability, which has not been improved so far, and contribute to the enhancement of ER by building the integrated engineering management system of the program for functional reshaping of the programs and higher work efficiency. In this research, a basic direction for future improvement has been suggested through the analysis of the causal factors. Conducting stronger job performance trainings and developing the integrated engineering management system is left as a future task.

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