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Developing Major Steps for a Feasibility Study for Upgrading I&C Systems in a Large Scale for an Operating Nuclear Power Plant

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1. Introduction

According to the IAEA report as of Jan. 2008, 436 nuclear power reactors are in operation over the world [1] and 368 nuclear power reactors exceed their operating ages by 20 years [2]. The average I&C equipment's life span is 20 years comparing with that the average reactor's life time is 40 to 60 years. This means that a reactor must be faced with I&C equipment obsolescence problems once or twice during its operating years. The I&C equipment is replaced with new equipment only when the obsolescence problem occurs in a nuclear power plant. This is called an equipment basis upgrade in this paper. This replacement is such a general practice that occurs only when needed. We can assume that most of I&C equipment of a plant will meet with the obsolescence problem almost same time since it started operating. Although there must be a little time difference in the occurrence of the problems among I&C equipment, the replacement will be required in consecutive years. With this assumption, it is recommendable to upgrade the equipment, which is to meet with the problem at the same time, with new equipment at the same time. This is called a system basis upgrade in this paper. The system-basis replacement can be achieved in a large scale by coupling systems whose functions are related each other and replacing them together with a new up-to-date platform. This paper focuses on the large scale upgrade of I&C systems for existing and operating NPPs.

While performing a feasibility study for the large scale upgrade for Korea standard nuclear power plants (KSNPs) [7], six major steps are developed for the study as shown in Fig. 1. This paper is to present what to perform in each step.

2. Major Steps

In step 1, the goal of an upgrade is established. In order to assist the establishment, economic factors for the upgrade are evaluated and state-of-the-arts of the upgrade over the world are investigated. Comanche Peak NPP in USA, operating since 1990, had a plan for I&C modernization with nine stages from 2001 to 2014 [3]. Whereas, I&C modernization in Japan has been done in one-shot. Genkai NPPs was done for six months in 2001 [4] and Ikata NPPs will be done 2009. In Korea, one-shot I&C renewal was done for Kori-1 NPP in 1998. Thanks to the improvement of digital technology, one-shot I&C upgrade is achievable with a distributed control system (DCS) platform. Based on EPRI TR-1009611, one-shot I&C upgrade brings 23% cost savings compared with staged I&C upgrade [5].

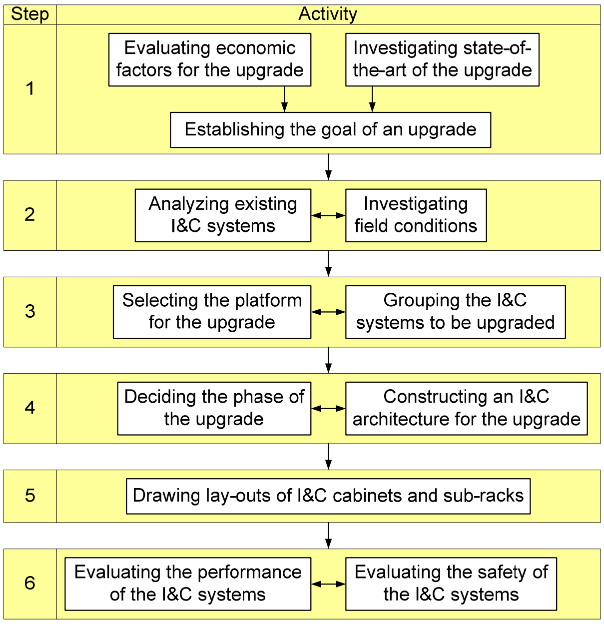

Figure 1. Major steps for the feasibility study.

In step 2, existing I&C systems are analyzed to extract functions, interfaces, design and operation requirements from field materials and documents and existing I&C cabinet and cable conditions are gathered by investigating field equipment buildings and rooms. As an example, 22 I&C systems are defined and 183 cabinets are installed in KSNPs [6]. The I&C cabinets are not welded but bolted on the raised floor. Cables between the cabinets are guided through trays on the raised floor, so the I&C cabinets and cables can be easily removed and installed. The field cables from the I&C cabinets to the field transmitters and components are, however, flowing through complicated routings. Furthermore, the cables are molded on the floor that is located between the I&C equipment room and the cable tray room. So the field cables are difficult to manipulate. Field cable connectors are standard lug types so they can be reused.

In step 3, the platform and the scope for the system basis large scale upgrade are determined. There are many manufacturers for the DCS platform over the world such as Poscon, Woori Tech., ABB, Invensys, AREVA NP, RTP, etc. Each platform has both common and unique characteristics in providing I&C functions. The common characters are usually standardized among the platforms. The unique characteristics restrict users in implementing the I&C functions. In order to prevent common mode failure (CMF), different types of platform should be considered for safety and non-safety systems as a diverse means. The scope of the upgrade is usually determined by constructing a basic structure of digital based I&C systems as shown in Fig. 2.

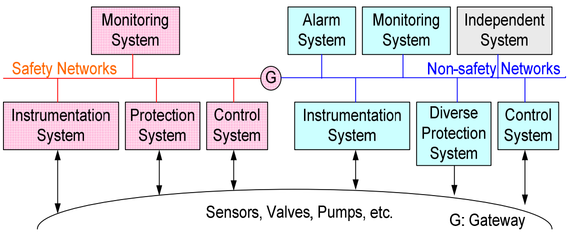

Figure 2. A basic structure of I&C systems.

In step 4, one of upgrade phases such as a one-shot upgrade or a staged upgrade is determined with a consideration of economic and safety aspects. For economic aspects, a one-shot upgrade brings up cost savings. For safety aspects, a staged upgrade brings up more safe plant operation. For example, it is safer that safety systems are upgraded in a second stage after non-safety systems are upgraded in a first stage. After decision of an upgrade phase, an overall architecture for the I&C upgrade is constructed according to the determined phase. During the construction, a media for signal transmission is distinguished into the use of hardwires and networks. In KSNPs, the hardwired field signals usually remain in place because cable routings are difficult to manipulate and the lifetime of field cables are the same as the plant's lifetime. This condition is acceptable only when the field signals are types of standardized signals such as 4-20mA and 0-10V. The network is used for interfaces between I&C systems. The advantage of digital technology is achievable by using a network. For safety systems, the network should be physically separated and electrically isolated. For non-safety systems, the network can be used as a backbone to connect most of non-safety systems. Safety grade gateway should be used to transfer data from the safety system to the non-safety system. A I&C upgrade architecture for KSNPs is constructed in this step [7].

In step 5, I&C cabinets and sub-racks for the upgrade are configured into lay-outs to realize the architecture constructed in step 4. For this, the platform information such as the number of CPUs, network devices, analog and contact signal input and output modules, and power supply modules are acquired from the manufacturer and reflected into the lay-outs. Most platforms provide a module that is capable of multi-channels for signal inputs and outputs and multi-loops for controls, so segmentation criteria should be considered to avoid the risk of a plant operation caused by a failure of one module that causes multiple signal or control failures. In this step, the cabinet lay-out after upgrade is compared with the one before upgrade. During the comparison, a work order of eliminating old cabinet and installing new cabinet is sequentially determined.

In step 6, the performance and safety of the upgrade I&C systems are evaluated with the lay-outs configured in step 5. Response time requirements were acquired from step 2. Amount of data messages to be transmitted between the cabinets are calculated based on the lay-outs. The performance is simulated with this information. Safety evaluation is focused on the CMF analysis. The digital platform based I&C upgrade is vulnerable to a CMF event. In order to defense against the CMF event, diverse mechanisms such as diverse indications and controls which are different from the upgrade platform should be provided to the upgrade. The performance and the safety are trade-offs. For example, when the safety evaluation resulted in requiring redundancy of input and output modules to avoid a single failure, the processing capability should have more than doubled to meet the performance requirements.

3. Conclusions

While performing a feasibility study for the large scale upgrade for Korea standard nuclear power plants (KSNPs), six major steps are developed. The steps mainly consist of setting up a goal, analyzing existing I&C systems, selecting a platform, constructing an I&C architecture, configuring the lay-outs of the cabinets and sub-racks, and evaluating the performance and safety of the upgrade I&C systems. While performing the feasibility study, steps one through five were properly performed. Step six will be performed from now on. These steps can help one perform the same kind of study relating to the large scale I&C upgrade.

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