A Study on a Large Scale I&C Upgrade of OPR1000 Plants

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1. Introduction

There is a great need to update, upgrade, and modernize the I&C systems of existing nuclear power plants because of their obsolescence and aging. International organizations such as EPRI and IAEA have published many technical documents and guidelines for upgrading, modernizing, and retrofitting current I&C systems. The goal of our research is to establish a basic design for an upgrade plan that can be applied to real power plants. Beginning in 2007, we have studied the large scale I&C upgrade of the OPR1000 using three approaches; system analysis, design with digital platform, and design verification through use of mockups.

2. Design and Verification

Generally, there are two strategies for upgrading or modernizing I&C systems. One strategy is to perform a single major modernization during a extended overhaul and the other is to perform a phased modernization taking place over several regularly scheduled overhauls. Each strategy has various advantages and disadvantages, but our study has focused on a phased modernization as it was deemed more feasible.

2.1 Current I&C system analysis

The I&C cabinets of the OPR1000 are installed in the auxiliary electrical equipment rooms, the computer room, the main control room, and others. The sizes of the cabinets are different from each other and the number of bays per cabinet is also different. A cabinet is divided into several bays in order to satisfy the channel independence of the safety system or to separate functions of non-safety systems. It is necessary to figure out the relationship between the cabinets and the systems. The OPR1000 has 22 I&C systems. The 22 systems are classified into various categories such as: control, reactor protection, ESF actuation, and monitoring. The instrumentation system is separately classified because it plays an important role of gathering signals from sensors in the plant and also relaying them to other systems. We mapped the cabinets to the systems to figure out the relationships between them. After mapping the cabinets to the systems, system dependency was figured out by analyzing signal interfaces between the systems. The systems were dependent on each other when more than one signal was transferred between them. Therefore a system dependency exists when at least one signal line is connected to another system. This dependency will be identically maintained even when the systems are upgraded. The OPR1000 I&C contains following characteristics:

- Hybrid analog and digital systems
- Many termination cabinets due to hardwired interfa ces between the systems
- Difficult system maintenance due to the various ma nufacturers involved

2.2 Design Approach

The upgrade we propose is designed with fully digital systems and networks. Since the systems should be connected to each other with a network, the network based connection gives the advantage of cable reduction. Many of the existing cabinets for terminating hardwired signal lines can be eliminated. The upgrade should comply with the existing licensing requirements, such as single failure criteria, independence, and qualification. Defense against common mode failures for the digital based systems should be assessed. The design criteria for the upgrade were established as follows:

- The functionality of the existing OPR1000 should be maintained or improved if safety and performance requirements are satisfied.
- Functions of the OPR1000 are integrated into a computer based on the analysis of single failure criteria.
- The concept of diversity and defense-in-depth is ap plied to overcome common mode failures (CMFs) p ostulated in the upgrade.
- The hot-swappable equipment is adopted to increase availability.
- The industrially standardized hardware and the software are adopted if possible.
- Multi-loop controllers are utilized based on the analysis of single failure criteria and segmentation criteria.

A phased modernization should consider the impact of the upgrade systems on the existing systems in terms of operability in the main control room (MCR). If the modernization lasts through several phases, the boundaries of parallel operation of the upgraded systems and the existing systems should be clearly defined. The parallel operation will also impact the operating procedures in the MCR. Our upgrade design has been performed through three phases based on the following strategies:

- In the first phase, a DCS encompassing non-safety monitoring and control system is constructed.

- In the second phase, safety systems are upgraded into digital based systems and connected to each other through data links.
- In the third phase, the MCR is upgraded and the I&C upgrade is completed to support the MCR upgrade.

Systems with low burden of licensing effort are upgraded first and the MCR is upgraded in a batch mode. For the MCR upgrade, most of the existing analog equipment are eliminated, so the I&C should be upgrade before the MCR upgrade. One phase in the three phases means one overhaul. In the OPR1000, a period of regular overhaul is about a month and a extended overhaul is about three months.

2.3 Design verification using mock-up

A verification mock-up was developed for digital upgrades of I&C systems employed in OPR1000 type plants. The proposed upgrades are conducted during several overhauls. Therefore, before completion of the full scope of upgrades, there may be some operational phases. After completion of each phase, the plant operation should be performed with old analog systems and new digital systems in parallel. The mock-up we developed is for verifying and testing the interaction and the compatibility of the operation between analog systems and digital systems which will interact with each other.

The mock-up includes a DCS and a PLC as digital systems, and indicators, hand switches, and M/A stations as analog systems (Fig.1). The test scenario for verification involves the control of steam generator levels.

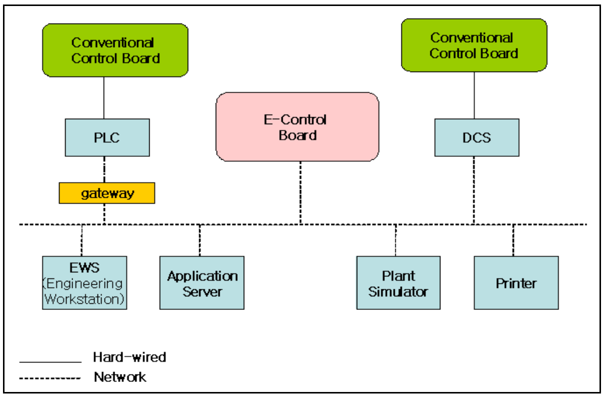

Fig. 1. Mock-up Structure

3. Conclusions

Our study for the basic design of the I&C upgrade has been performed focusing on a 3-phase modernization using three approaches; system analysis, design with digital platform, and design verification through use of mockups. The most important things we have considered are compatibility between current analog systems and new digital platforms such as DCS and PLC, and common code failure (CCF) for using digital system with software. In case of CCF for digital system, it still remains unsolved completely throughout the world.

According to reference [3] "Economical Evaluation of I&C Modernization Approaches in NPPs", it seems that a single major modernization can reduce the cost for an I&C upgrade by more than 21% compared with a phased modernization. However, it is actually difficult to promote a single major modernization because it requires a large budget and a lot of man-power at once. Accordingly, a phased modernization strategy for a large scale I&C upgrade is more likely to be applied to real power plants.

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