Review on Considerations for Designing the I&C System of Nuclear Power System for Maritime Applications

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1. Introduction

The nuclear system for maritime applications can be roughly divided into nuclear power generation system and nuclear ship propulsion system for that purpose. Depending on its application, it can be mounted on the platforms or ships used for the petroleum drilling and production platforms, floating nuclear power plants (FNPP), ultra-large container ships, and icebreakers and so on. The economic benefits of introducing nuclear systems on these vessels and platforms are significant. The advantage of a nuclear power system is that it is a high-density, large-capacity energy source. So, there is no need for frequent refueling like fossil fuels. And also, in the case of floating nuclear power systems, it is possible to fundamentally solve the problem of securing the site as one of the biggest problems of the construction of a nuclear power plant, and has an advantage of supplying electric power to a remote island region from the mainland [1].

2. Considerations for NPPs I&C system design

2.1 The role of the I&C system in NPPs

The instrumentation & control (I&C) systems are key technologies that can significantly affect the performance and operating costs of nuclear power plants. The role of I&C systems in nuclear power plants is similar to that of the human brain and neural networks. Commercial nuclear power plants for power generation have sensors throughout the plant that sense critical plant status information such as pressure, liquid level, radiation, flow, temperature, etc. The I&C system is responsible for obtaining information from these sensors in order to safely control and monitor the plant, and perform functions such as immediate protection actions in the event of a problem.

2.2. Considerations for designing the I&C systems in existing nuclear power plants

When designing the I&C system in a commercial nuclear power plant, the primary consideration are how to configure the I&C system architecture. The I&C system architecture provides the definition of the I&C system at the higher level of the system. Then, the major considerations for designing I&C systems are to reasonably design the I&C system with considering basic design principles such as independence, diversity and defense in depth (D3), predictability and repeatability regardless of which platform or technology to use. The I&C architecture represents the properties, components, functions, and relationships among these systems of the I&C system. In order to explain these I&C architectures, it is necessary to have the theoretical basis and legitimacy of designing the I&C architecture. And also, the potential consequences of designing that architecture is also analyzed. Through this process, a safe and reliable I&C system is designed considering the basic principles of independence, diversity and defense in depth protection, predictability and repeatability [2].

3. Additional considerations for designing the I&C systems in nuclear system for maritime applications

The I&C system of the nuclear power system for maritime applications mentioned in this paper is limited to the I&C system related to the nuclear steam supply system (NSSS), not the entire plant's instrumentation and control system. When designing the I&C system structure of the maritime applied nuclear system, it is expected that most of the issues that should basically reflect most of the I&C design concepts and the top priorities of commercial nuclear power plants. Prior to the consideration of the platform or detailed technology of I&C system equipment, basic design principles (e.g. independence, diversity and defense in depth (D3), redundancy, predictability, and repeatability) required for commercial design considerations should be reflected as they are.

3.1 Considering the space limitations of I&C system facilities

Applying the I&C system equipment of existing commercial nuclear power plants to maritime applied nuclear system may cause space limitation problems. Although mechanical components such as nuclear reactors may physically become smaller when the reactor power becomes smaller, I&C system equipment will not decrease the physical volume, just can only change the amount of cabinet depending on the function

of the I&C system. As a typical example, in the case of a reactor protection system (RPS), it consider the logical structure and channel multiplexing of commercial nuclear power plants. However, as a maritime applied nuclear power system, the logical structure and the concept of a multiplex of the reactor protection system will not differ greatly from those of commercial nuclear power plants. Since the limitation of the installation space of such I&C equipment is a visible problem, it is necessary to consider compact controllers and related equipment to solve this problem. In addition, the maritime applied nuclear system is expected to have a longer fuel replacement cycle than conventional nuclear power plants, due to the characteristics of the these nuclear system, it is expected that accessibility to on-site measurement equipment and accessibility to plants from outside of site will be considerably poor. In accordance with these anticipated environments, it is possible to cause maintenance and replacement problems of measuring instruments and I&C system equipment, so in order to improve the reliability of the I&C equipment itself and conceive the calibration strategy of measuring instruments, in-depth study is necessary [3].

3.2 Considering the oceanic environment

The nuclear system for maritime applications has several things to consider as the operating environment of the plant changes from land to sea. In the oceanic environment, it may experience transient conditions such as slope, fluctuation, and sudden load fluctuation of the plant due to external factors such as weather conditions. Therefore, it is an essential consideration to correctly identify the effects of transient conditions inherent in the oceanic environment and ensure that these transients do not pose a risk to the health of the nuclear system. And also, it is necessary to considerations when designing and manufacturing I&C system equipment to withstand harsh environmental conditions for environmental factors such as salinity and humidity.

3.3 Considering the functional aspects differ from commercial NPPs

The nuclear system for maritime applications may require a single reactor or more than two reactors depending on the needs of the user. Turbine systems may also require a single turbine or may require more than one. In the case of single reactor and single turbine system configurations, the basic functions of the I&C system are expected to be similar to typical nuclear power plants. However, in other cases, the operation of the plant may be relatively complex and high-level I&C systems such as integrated control and management systems that control multiple systems should be considered [4]. The integrated control management system can manage the system equipment and equipment information between two or more nuclear systems to realize the conversion and monitoring of the operating modes and control strategies.

4. Conclusions

In this paper, additional considerations have been considered when designing I&C systems for maritime applied nuclear systems based on the existing I&C system design considerations. According to the purpose of these nuclear system, the I&C system can have a variety of structures to provide various functions. However, the concept related to safety should be basically the same as the existing concept, and I&C hardware devices that are applicable to the oceanic environment should be considered. Also, for application environments that require multiple nuclear systems, high-level automation systems and I&C architectures such as integrated control and management systems may need to be considered.

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