A Study on the Challenges of I&C Technology for the Successful Application of Nuclear System to Oceanic Industry

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1. Introduction

On a global scale, South Korea is one of the world's most technologically advanced countries in the field of nuclear power industry, shipbuilding and oceanic industry. Nevertheless, they has not seriously considered developing a nuclear power system that can be applied to the oceanic industry even though it is a world-recognized technology powerhouse. At present, most countries that leading nuclear technology have experience in designing and operating nuclear systems that can be used in the ocean environments for commercial or defense purposes. Therefore, it is necessary to make efforts to accumulate and secure technologies with an interest in the development of nuclear power systems that can be applied to the Korean oceanic industry. In this paper, we have tried to review and study the required role and technology of instrumentation and control (I&C) for successful application for oceanic industry.

2. Application of the reactor system to oceanic industry

There are many ways to use nuclear energy in the oceanic industry, in this paper, we have considered three types for applications. 1) a type of submerged offshore plant using fixed structures in the ocean, 2) a type of floating offshore plant that reactor system is mounted on floating structures in the ocean, 3) a type of reactor power system for ship propulsion. The submerged offshore plant type has the structural advantage of securing the safety of natural disasters such as tsunamis. The floating offshore plant type is that supplies energy to necessary process facility by installing nuclear power system on the barge or offshore plant, they need a power system that can provide stable and long-term energy supplies to develop resources in the pelagic environment. In case of the nuclear propulsion ships that use nuclear energy as a source of propulsion power, it has an advantages in the availability of Arctic routes, rather than on existing routes. The Arctic route can significantly shorten the existing routes from Asia to Europe. Therefore, it is necessary to develop the technology for special-purpose ships such as icebreakers to be applied to these routes.

In this manner, the nuclear power systems that can meet various purposes of the oceanic industry are expected to require small nuclear power systems of less than 100MWt, and at present, we believe that the most feasible candidate is the integrated primary system reactors in the form of PWR [1].

3. Role and challenges of I&C technology for developing the oceanic nuclear power system

For the oceanic nuclear power system, it may be required for various combinations depending on what purpose it is used for such as single reactor and single turbine generator, multiple reactors and multiple turbine generator moreover multi-purpose balance-of-plant (BOP) such as process heat utilization facility. Therefore, we can begin by solving the technical challenges associated with the inherent characteristics of reactor design concepts that are required in actual development to meet these virtual demands. In this paper, we have reviewed the role and challenges of I&C technology in order to successfully apply nuclear power system to the oceanic industry.

First of all, to gain the legitimacy and merits of using nuclear power system in the oceanic industry, safety must be the most important consideration, but without economics, it may not be able to start. These economic benefits can be greatly improved by applying advanced I&C and ICT technology. Therefore, we have categorized the roles and challenges of I&C technology that can further realize and promote the development of oceanic nuclear power system. 1) Challenges in the I&C field due to the inherent operational characteristics and process characteristics of the oceanic nuclear power system, 2) I&C technology that can improve the economics of oceanic nuclear power system, 3) I&C technology that can improve safety and security of oceanic nuclear power system [2].

In the first category, oceanic nuclear power systems are expected to have different requirements for process instrumentation compared to conventional commercial nuclear power plants. Considering the PWR type integrated primary system reactor which is the most realistic at present, it is necessary to consider how to acquire the process sensing information required for system control, since all major devices and components

are located in the integrated pressure vessel. Nuclear instrumentations are the same. The structural differences in the core of the integrated primary system reactor and in the downcomer flow area inside the pressure vessel are expected to have considerable difficulties in monitoring ex-core neutron flux compared to conventional commercial reactors. Acquisition of in-core neutron measurement information will be also difficult to solve in the conventional way due to the complex internal structure of the pressure vessel [3].

In addition, oceanic nuclear systems may have different Nuclear Steam Supply System (NSSS) configurations, resource sharing between multiple reactor systems, and multiple BOP systems, depending on their application. If we consider a system consisting of a single reactor as one module, there may be significant dynamic coupling that must be considered in plant operation and control, depending on the nature and degree of sharing between modules. The system may need to implement a more sophisticated control system to handle their own unique dynamics. However, these control approaches are not familiar to the nuclear industry. In order to be applied to the nuclear industry, verification work must be preceded, and the impact on safety regulations must also be evaluated. Thus, the new development concepts of process monitoring, component diagnostic system are needed to meet the harsh environment and different measurement requirement expected in design process due to different operating and process characteristics from existing nuclear power plant.

In the second category, the two factors that have a significant impact on the economics of being highly impacted by design and development of oceanic nuclear energy systems are probably the initial cost of plant construction and daily costs of plant management, including operations and maintenance. The initial cost of plant construction will vary depending on the size and complexity of the components and the installation method. By applying innovative I&C and ICT technologies, it can help reduce the cost of manufacturing, installation, inspection, operating and maintenance. Compared with other energy sources, the fuel cost of nuclear systems tends to be quite stable, and fuel costs are a minor part of total operating costs unlike other energy sources. The most economical aspects of daily costs can be attributed to the size of the operators and operators and maintenance activities that rely heavily on and the availability of the plant. In this regard, efficient and effective operation methods and strategic maintenance using advanced I&C and ICT technologies can greatly contribute to these economic costs [2, 4].

In the third category, it is generally known that the integrated primary system reactor type has a higher level of passive safety than conventional loop type by using a convection cooling system and a moderator and fuel assembly with a negative temperature coefficient. These passive natural cooling systems will be able to safely remove residual heat after the reactor has been shut down without active equipment. By incorporating innovative I&C technology in this type of reactor with structurally passive safety, it can help at a high level of safety. Plant I&C system can be optimized and the number of I&C system can be reduced by using the state-of-the-art ICT digital technology. The latest wireless network technology may also minimize the cabling requirements, but there are still some problems that need to be addressed to ensure the integrity of safety-critical functions and to ensure the reliability of the network. Currently, the wireless communication is not applicable to nuclear power plants. In order to construct a wireless-based network system for real-time online monitoring instead of installing expensive cabling, it is necessary to implement a wireless communication system with high reliability and stability of data transmission [3, 4].

4. Conclusions

In this paper, we have presented several ways to utilize the nuclear power system in the oceanic industry and have reviewed the roles and challenges in the field of I&C technology for successful application for that. We have presented challenges of I&C field that may occur or should be solved in applying nuclear power system to new industrial field rather than existing nuclear power plants for electrical power generation. In addition, we have reviewed technical issues which improve economic efficiency, safety and security to promote the development of oceanic nuclear applications. As a result of this study, it is concluded that existing I&C system and related technology cannot be applied to oceanic applications as it is, and we have concluded that advanced I&C and ICT technology can contribute significantly to gain legitimacy and to promote R&D of oceanic nuclear applications.

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