Transactions of the Korean Nuclear Society Spring Meeting
Jeju, Korea, May 9-10, 2024

Study on I&C Design Features for Implementation of the MSR Powered Ship

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Keywords : Molten Salt Reactor (MSR), I&C design, passive safety, online calibration

1. Introduction

The Molten Salt Reactor (MSR) is one of the most valuable new generation nuclear power system to be further developed. The option which common MSR design has can be more variant, but the design is herein limited to MSR powered ship that means being subject to marine purpose. The MSR has some strong features such as passive safety with no emergency core cooling, containment cooling, automatic depression equipment required. Moreover, marine vessel far from shore with MSR has little concern of radiation release risk. However, due to high temperature and radiation, the survivability of instrument to be applied is a major concern and hence system design optimization is inevitable. The I&C design concept, its classification and challenging instrument issue are presented herein.

2. Basic Design Features of MSR

In this section, the more feasible design concept for MSR is described. In order to enhance the MSR design with given circumstance, the firmed passive safety, more reliable operation, and the last but not least, economical advantage are focused on. The major design features for this are introduced as followings.

2.1 Top priority; Passive Safety

The most remarkable feature of MSR design is no need for consideration of serious accident such as LOCA and core melting. This was already proven through MSRE from ORNL about 60 years ago. This inherently solid safety provides a room for state of the art technique in terms of I&C application. Such large temperature margins to boiling and ambient pressure make system more thermodynamically inert.

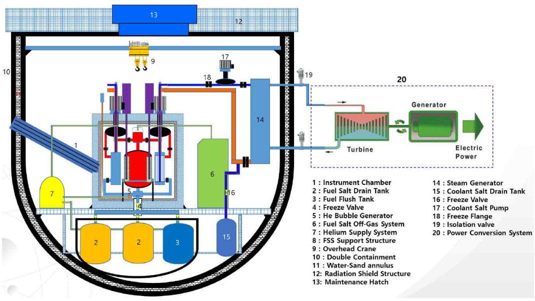

Fig. 1. MSR reactor structure and components.

There is an option which of system has redundancy of multiple trains of reactor subject to operational condition. Basically, the important issue is to ensure safe shutdown in no time and mitigate severe accident. The freeze valve is equipped as shown in Fig.1 to immediately drain all fuel salt by gravity without power, which is operated automatically in case of power cutoff or trip signal. On the other hand, to have such solid safety has disadvantage of some challenging design, which are the off-gas system for removal of radioactive noble gas and the continuous heating system should be operated in secured manner.

2.2 More Aggressive approach for Cost Down

Aforementioned, it is difficult to ensure robust design safety and moreover the physical health of concrete structures without embedded sensors are demanding. The cost-saving design is recently on the table so that the MSR can be adapted in many industrial field. For cost down of construction to operation for plant lifetime, all in-containment maintenance, on-line calibration, and the remote repair should be first considered with state of the art technology employed.

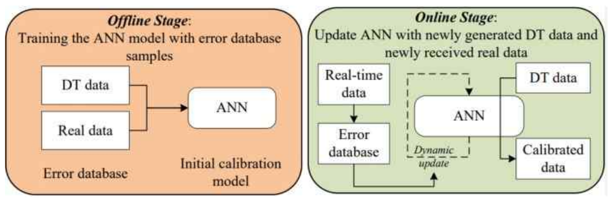

Fig. 2. Example of indirect calibration using ANN.

Particularly, replacing components like cables within containment is literally impossible and may cause huge repair cost. Therefore remote access under high radiation should be done by overhead crane with long rig/tool. The instrument drift analysis and system aging estimation of remained useful lifetime should be also considered for on-line calibration and longtime operation. This technique still remains challenging due to lack of actual operation data.

3. I&C Design Concept for MSR powered ship

3.1 I&C design Requirement for MSR powered ship

The top requirement for I&C design of MSR ship design is to fit the user condition of powered ship and guarantee decent instrument performance for longtime operation. There are major concerns of instrument to be applied to MSR which has robust tolerance under extremely hot temperature of 650℃ and certain chemical environment that is vulnerable to corrosion. In addition, most of components are densely packed around the reactor, which means the access route and maintenance space are not as adequate as it used to be.

Therefore, no contact measurement and online calibration with remote instrument handling are no more option in I&C design of MSR. The I&C design for 100MW MSR powered ship is aimed for propeller power with smaller design. In addition, the operator should be minimized down to one or two and most of check-up before departure should also be performed in an automatic fashion.

3.2 MSR I&C System Classification

The I&C system can be simply classified with many decisions taken into account in the process of WBS as shown in Table 1. The I&C work breakdown has recently been streamlined removing unnecessary design for MSR powered ship to save space as well as cost such as supplementary control room. The safety group for shutdown and accident prevention comprises the RPS and AMS. The rest of group is composed of reactor control, instrument and process control, and operation stuff.

Table 1: MSR I&C System Classification

NO	System Classification of I&C	Acronym
1	**Instrument and Control System**	**ICS**
2	Reactor Protection System	RPS
3	Reactor Power Control System	RPCS
4	Accident Monitoring System	AMS
5	Information Processing System	IPS
6	Process Instrumentation and Control System	PICS
7	Main Control Room	MCR
8	Ex-Vessel Nuclear Instrument System	EVNIS
9	Radiation Monitoring System	RMS

3.3 Basic Design Feature for MSR I&C

The I&C system has to accommodate the enhanced maintenance capability for harsh condition of MSR operation. Due to high radiation, chemical condition, and hot temp no operator can easily access to operating zone. This forces I&C design to have indirect measuring approach and employ on-line monitoring with remote-sensor based fault diagnosis. For example, flow measurement can adopt clamp-on ultrasonic flowmeter (Fig. 3) to avoid salt contact or estimate the fuel salt flow using delayed neutron activation in primary heat exchangers instead of DP transmitter.

The simplified structure of I&C in MSR contributes to lower the burden of reactor protection design which helps remove the in-core instrument for measuring local power in the core. In turn, ex-core neutron measurement is more weighed because it only has commitment to measure the reactor power with broad range to cover the full power in more reliable way. In measuring level of salt inventory or sump tank, the ultrasonic probes or bubble type level transmitter can be applied as an alternative. However, The potentially adaptable instrument for MSR is still on the way to study further.

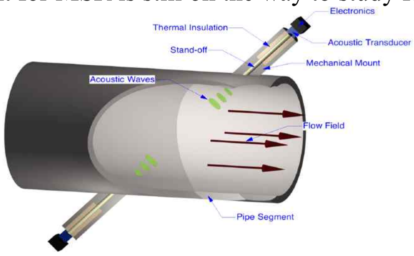

Fig. 3. Clamp-on Ultrasonic Flowmeter.

4. Conclusions

The MSR with developing I&C design for ship has been under research and on the phase of basic design. In spite of many advantages of safety and stability of MSR system, the matter of environmental condition such as temp, radiation, chemical issues are still found challenging to be implemented. In order to resolve this issue, simulation and analysis in case of instrument to be employed should be performed ahead of prototype fabrication so that its performance will be assessed prior to making decision of MSR system design.

Acknowledgement

This work was supported by the National Research Foundation of Korea(NRF) grant funded by the Korea government(MSIT) (RS-2023-00259713)."

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