Preliminary Design of Instrumentation and Control System Architecture for a Low Power Research Reactor

Seung Ki Shin*, Dane Baang, Yong Suk Suh, and Sang Mun Seo
Division of Research Reactor System Design, Korea Atomic Energy Research Institute
Daedeok-daero 989Beon-gil, Yuseong-gu, Daejeon 34057, Republic of Korea
**Corresponding author: skshin@kaeri.re.kr*

1. Introduction

Research reactors can be classified into three types according to the thermal power level: low power, medium power, and high power research reactors [1]. The ranges of power level for each type of research reactor are commonly as follows.

- Low power: less than 250 kW
- Medium(Intermediate) power: 250 kW ~ 2 MW
- High power: above 2MW

The SLOWPOKE reactors designed by Atomic Energy of Canada Limited [2] and MNSR reactors designed by China Institute of Atomic Energy [3] are typical low power research reactors. The TRIGA reactors developed by General Atomics [4] can be classified commonly as medium power research reactors. The HANARO [5] and JRTR [6] reactors that have been operated or designed by Korea Atomic Energy Research Institute (KAERI) can be regarded as high power research reactors.

The demand for low power research reactors (LPRRs) are relatively high in developing countries because of low cost, inherent safety, etc. Based on the experiences with the JRTR reactor design, a preliminary design of instrumentation and control (I&C) system architecture for a LPRR is proposed in this paper.

2. Advantages of Low Power Research Reactors

KAERI has experiences with operating and designing high power research reactors such as the HANARO and the JRTR reactors. Compared to the medium/high power research reactors, the LPRRs have various advantages as follows [7].

- Low constructing and operating cost
- Low fuel burnup
- Simple and easy to operate
- Inherent safety (large negative temperature coefficient)
- Less restrictive containment and siting requirements
- Versatility (flexibility of operation)

As demands for LPRRs are growing along with its merits described above, KAERI is carrying out a preliminary design for a LPRR. The preliminary design for I&C system architecture is described in the following section.

3. Preliminary I&C System Architecture for Low Power Research Reactors

I&C systems should provide a means of monitoring and displaying of all reactor parameters and a means of controlling and protecting the reactor. As the LPRRs commonly have inherent safety features such as a large negative temperature coefficient of reactivity, the safety class I&C systems are not necessarily required. Therefore, the I&C architecture proposed in this paper consists of non-safety class and minimum essential systems considering development costs.

The I&C systems for the LPRR mainly consist of the control and monitoring system (CMS), field instruments, and a control room including an operator workstation (OWS) and a large display panel (LDP). The overall I&C system architecture is shown in Fig. 1.

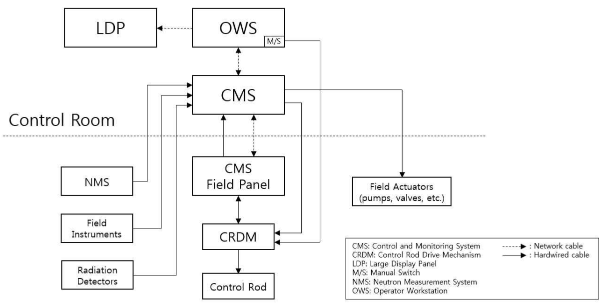

Fig. 1. I&C system architecture for the low power research reactor.

3.1 Control and Monitoring System

The CMS provides overall operation of the reactor facilities. It performs the reactor operation, reactor trip, process control, alarm generation, and monitoring.

The CMS consists of the CMS cabinet in the control room and the field cabinets for rod control. The CMS cabinet have two simultaneously-working control computers to prevent function failure due to single component failure of a computer. Each field cabinet includes the electronics for control rod control and emergency reactor trip. The CMS should be invulnerable to unauthorized access through communication networks.

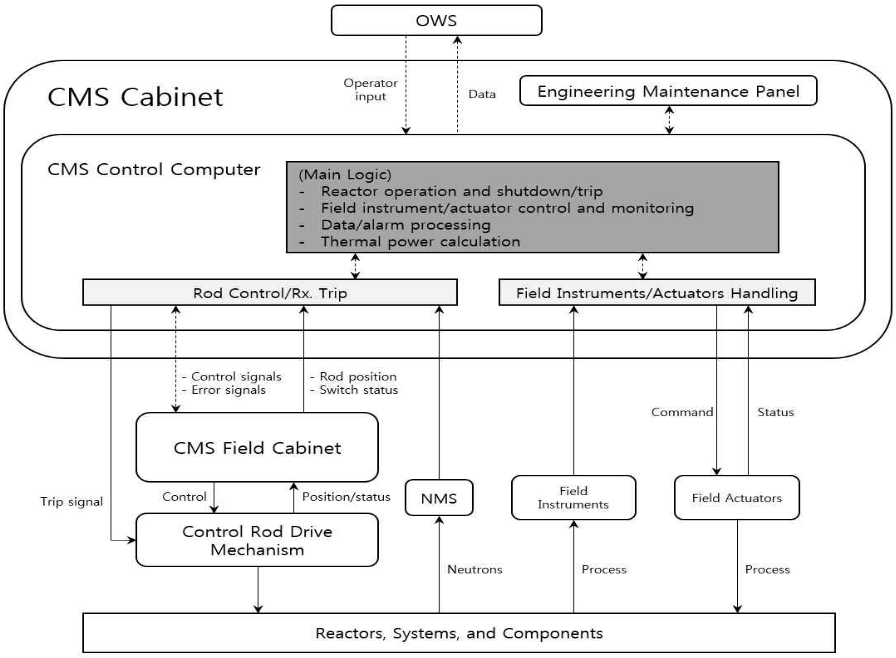

Fig. 2. Configuration diagram for the control and monitoring system.

The major functions of the CMS are as follows.

(1) For reactor operation, the CMS provides the functions of manual/automatic control for control rods, reactor power auto-control, thermal power calculation, and setback.
(2) For emergency reactor trip, the CMS disconnects the electricity for the electro-magnet of each control rod. The CMS automatically cuts off the electricity to drop all control rods into the core when a trip variable exceeds its setpoint.
(3) For process control, the CMS receives and conditions various field instrument signals and operates field actuators according to operator input or automatic control function.
(4) For alarm generation, the CMS generates alarm requests after comparing most important variable with pre-defined setpoint. The alarm requests are transmitted to the OWS computer which actually generates alarms.
(5) For monitoring, the CMS receives most field signals from the sensors of neutron detectors, control rods, process transmitters, radiation detectors, etc. The CMS also receives operator inputs from the OWS. These signals are properly conditioned and used to perform the functions described in (1) to (4), and transferred to OWS for display, alarm generation, and storage.

The configuration diagram for the CMS is shown in Fig. 2.

3.2 Control Room

All control and instrumentation signals required for the reactor operation are centralized in the control room so that the operator can operate the reactor safely during normal operation and maintain the reactor safely even during emergency situation without any problems.

The control room is mainly composed of the OWS and the LDP through which most of the important control and monitoring activities are carried out.

The OWS is designed as follows.

(1) The OWS is composed of one operator console, OWS computers, manual switches for reactor trip and individual rod drop test, and important parameter indicators.
(2) The OWS computers receive various signals from the CMS such as field instrument signals, processed signals, alarm request signals, etc., store all the signals, and provide the operator with all the information required to operate the reactor.
(3) The OWS computers receive control input signals form the operator and transfer those signals to the CMS.
(4) The OWS computers generates alarms when required and provide visual and auditory alarms to the operator.
(5) A physical key switch which disconnects the electromagnet power of all control rod is mounted on the operator console to prevent unauthorized reactor operation.

The LDP is designed to present one display among the OWS computers and the operator is able to select the OWS computer to be displayed on the LDP.

In all the processes of designing the control room and the equipment installed in the control room, human factors principles should be considered.

The conceptual layout for the control room is shown in Fig. 3.

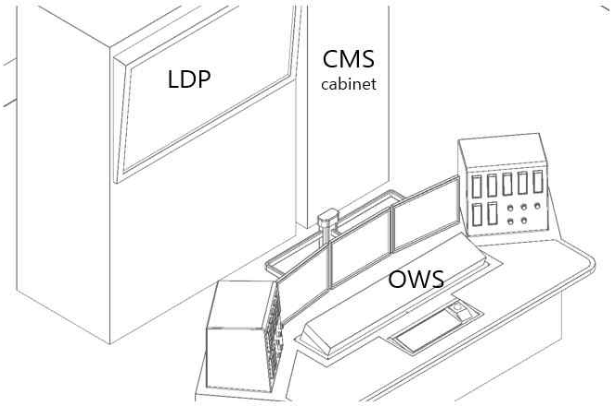

Fig. 3. Conceptual layout for the control room.

4. Summary and Conclusion

The LPRRs have various advantages such as low cost for construction and operation, simple operation, inherent safety, etc. In this paper, a preliminary design for the I&C system architecture was proposed in consideration of the general features of LPRRs.

This work will enhance the capability for designing LPRRs and competitiveness in research reactor technology. Detailed design and appropriate modifications for the proposed I&C architecture should be carried out after a target reactor is identified and detailed characteristics of the reactor such as core design, other systems design, safety criteria, etc. are defined.

5. Acknowledgements

This work has been conducted as a part of the Development of Research Reactor Technology project sponsored by Ministry of Science and ICT of Korean government.

REFERENCES

[1] International Atomic Energy Agency, The Applications of Research Reactors, IAEA-TECDOC-1234, 2001.

[2] Saskatchewan Research Council, SLOWPOKE-2 31 Years and Still Glowing, Presentation Material for Canadian Nuclear Society Conference, Jun. 10-13, 2012, Saskatchewan, Canada.

[3] Z. Yongmao, A Safe Private Nuclear Tool – The Miniature Neutron Source Reactor, Proceedings of the Sixth Pacific Basin Nuclear Conference, Sep. 7-11, 1987, Beijing, China.

[4] International Atomic Energy Agency, History, Development and Future of TRIGA Research Reactors, Technical Reports Series No. 482, 2016.

[5] Y. Kang, B. Kim, M. Cho, K. Choo, and Y. Kim, Current Status and the Future of the Irradiation Services in the HANARO Reactor, Proceedings of the Americas Nuclear Energy Symposium, Oct. 3-6, 2004, Miami, USA.

[6] Korea Atomic Energy Research Institute and Daewoo Engineering & Construction, Jordan Research & Training Reactor Final Safety Analysis Report, 2016.

[7] H. Bock and M. Villa, Survey of Research Reactors, AIAU 21305 (IAEA Report), 2001.