Considerations for IPS Network Design in Multi-Module Nuclear Power Plants

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1. Introduction

The Information Processing System (IPS) is a non-safety digital system that collects, processes, stores, and distributes plant information required for monitoring and control in a nuclear power plant.

The IPS network in a conventional NPP (Nuclear Power Plant) such as APR1400 has generally been designed on a single-unit basis. The network was designed to satisfy network requirements, including isolation from safety systems, reliability, redundancy and sufficient capacity.

However, a multi-module small modular reactor (SMR) requires additional network design considerations. In particular, the network should support information processing for multiple reactor modules while maintaining the independence of each module.

Therefore, this paper compares the network characteristics of single-unit and multi-module nuclear power plants, identifies major considerations for IPS network design, and presents a network design workflow.

2. Network Design Considerations for SMR

2.1 Single-unit NPP

Non-safety MMIS networks in conventional NPPs have typically been designed on a single-unit basis. In addition to isolation from safety systems, the following requirements must be considered.

- Deterministic communication: Data transmission delays should be bounded and predictable, and the required communication performance should be maintained even during fault recovery conditions.

- Redundancy: To minimize single points of failure (SPOFs) and ensure high availability, redundant communication paths should be provided. Seamless redundancy is required to maintain communication without interruption during network failures.

- Network load: Network load should be managed so that communication performance can be predicted under both normal and abnormal conditions. Sufficient margin should also be considered in network capacity design.

2.2 Multi-Module NPP

In a multi-module NPP, multiple reactor modules are operated within a plant. Therefore, the network should support information processing for multiple modules while maintaining the independence of each module.

Compared with a single-unit NPP, the number of network nodes, data sources, and communication traffic may increase as the number of modules increases. In addition, a network failure or abnormal traffic condition in one module should not affect other modules.

Accordingly, multi-module NPPs require additional consideration of network capacity, scalability, traffic management, and isolation between modules in addition to the basic network requirements applied to single-unit NPPs.

2.3 Network Design Considerations for SMR

Based on the above characteristics, the design of a multi-module network should incorporate the following requirements.

1) Seamless Redundancy
Redundancy should be applied to minimize the impact of network failures. In particular, seamless redundancy technologies such as PRP (Parallel Redundancy Protocol) and HSR (High-availability Seamless Redundancy) can maintain data communication without interruption. Accordingly, these technologies may be considered for multi-module networks requiring a high level of availability.

2) Quality of Service (QoS)
In a multi-module architecture, a QoS-based network design is required. It can assign priorities to specific traffic and allocate network resources. For network performance, the following characteristics should be considered.

- End-to-end latency and jitter
- Packet loss ratio
- Out of order packet delivery

It should be designed to satisfy performance requirements even under worst-case conditions in terms of end-to-end latency, jitter, and packet misordering.

3) Scalability
As the number of modules and operator support functions increases, network traffic may also increase.

Accordingly, Gigabit Ethernet can be considered for the IPS network to provide sufficient network capacity.

4) Segmentation
To ensure the efficient utilization of network resources and enhance security, combining physical network isolation with logical network segmentation can be implemented. For example, Virtual Local Area Networks (VLANs) can be utilized to define security boundaries and help prevent internal threats from spreading across different networks.

3. Network Design Workflow Based on User Requirements

With the digitalization of NPP I&C systems, the significance of network infrastructure is increasing. Accordingly, network design should consider not only regulatory requirements but also user-related requirements derived from actual operation and maintenance experience.

In conventional NPP projects, network designs have generally been developed in accordance with regulations and requirements. The detailed network technology selection may be influenced by supplier-specific platforms within the defined network requirements. However, for a new SMR project, network requirements should be further refined by incorporating user requirements related to actual operation and maintenance experience.

Based on these enhanced requirements, appropriate and proven network technologies can be selected, and their applicability and performance can subsequently be verified through the design and validation process. Finally, the validation results are incorporated into the final network design specification. Therefore, the network design workflow is organized into four stages.

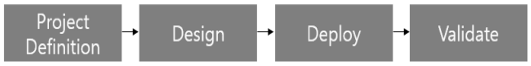


Fig.1 Network Design Workflow

- Project Definition: Identify and prioritize stakeholder and user requirements and define the project scope. The requirements are established through surveys on user experience from conventional NPP and the characteristics of multi-module SMR.

- Design Project: Develop the network architecture and select candidate technologies considering capacity, redundancy, segmentation, QoS, and scalability.

- Deploy Project: Implement and configure the designed network in a test environment.

- Validate Project: Verify network performance under test conditions and incorporate the results into the final design specification.

4. Conclusion

The network design optimized for a single unit of a conventional NPP may not be suitable for a multi-module SMR. In a multi-module SMR, the integrates data the characteristics of SMR in addition to basic network design requirements. The network should support information processing for multiple modules while preserving module independence.

In addition, in the project definition stage, user requirements should first be derived from operational experience in conventional NPPs. During the design stage, it is necessary to review the applicability of network technologies such as logical segmentation for efficient use of network resources. The applicability and performance of these technologies should be verified through implementation and validation in a test environment. The validation results should then be incorporated into the final network design specification, thereby establishing a verified design basis for SMR non-safety networks.

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