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Data Management and Communication Networks for Man-Machine Interface System in Korea Advanced LIquid MEtal Reactor : Its Functionality and Design Requirements

Kyung Ho Cha, Gun Ok Park, Sang Moon Suh, Jang Yeol Kim and Kee Choon Kwon

Korea Atomic Energy Research Institute
150 Dukjin Dong, Yusong Ku
Taejon, Korea, 600-353

Abstract

The DAta management and COmmunication NETworks(DACONET), which it is designed as a subsystem for Man-Machine Interface System of Korea Advanced LIquid MEtal Reactor(KALIMER MMIS) and advanced design concept is approached, is described. The DACONET has its roles of providing the real-time data transmission and communication paths between MMIS systems, providing the quality data for protection, monitoring and control of KALIMER and logging the static and dynamic behavioral data during KALIMER operation. The DACONET is characterized as the distributed real-time system architecture with high performance. Future direction, in which advanced technology is being continually applied to Man-Machine Interface System development of Nuclear Power Plants, will be considered for designing data management and communication networks of KALIMER MMIS.

I. Introduction

The *DAta management and COmmunication NETworks(DACONET)* is being approached as the data management and communication subsystem of MMIS for which protects, controls, monitors, and diagnoses *Korea Advanced LIquid MEtal Reactor* (KALIMER). The KALIMER, which works as a bridge to a commercial reactor, is under conceptual design since its design concept was established for recent years. The DACONET design is slightly different from conventional one in design concept. The distinguishing feature is to design digital data processing under distributed networks in real-time and commercially available technology is applied to develop its generic platform. The DACONET provides the real-time data transmission and communication

paths between subsystems of KALIMER Man-Machine Interface System(MMIS), the quality data for protection, monitoring and control of KALIMER, and the logged data during KALIMER operation. A design effort in the DACONET has been given to support the MMIS tasks, satisfy the operational requirements in MMIS performance, and develop the architectural platform for assuring safety, reliability, and availability in real-time data processing and transmission of KALIMER MMIS. In order to meet these requirements, the conceptual DACONET platform is characterized as the distributed real-time system architecture with high performance and fault-tolerant mechanism is deeply considered for its hardware and software architecture. The DACONET design will consider the future direction in advanced proven technology to be continually applied to MMIS development of nuclear power plants.

II. DACONET Concept and Functionality

The DACONET processes data communication in digitally and provides the plant data for control, monitoring, and diagnosis of KALIMER MMIS. MMIS systems shall access the plant data and MMIS systems communicate with other systems under consistent access and communication mechanisms to be determined in the DACONET. The conceptual DACONET architecture is shown in Figure 1. The dotted box represents a safety system and the dotted arrow indicates a safety data/control flow in Figure 1. The 'i' in the small circles mean 'isolated or isolation'.

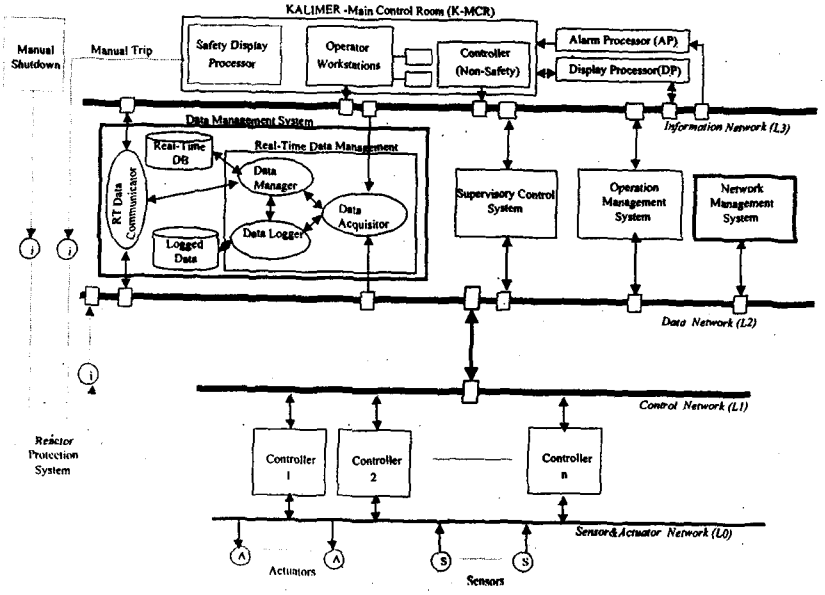

Figure 1. DACONET System Architecture

The following system functions are defined in the DACONET.

(1) The DACONET provides quality data to MMIS systems.

(2) The DACONET provides data transmission paths between MMIS systems.

(3) The DACONET logs MMIS data during KALIMER operation.

Data transmission paths in DACONET are designed for operational KALIMER data and control/interaction signals/commands of MMIS subsystems. These paths are designed by analyzing interface requirements for MMIS subsystems and by determining physical and logical characteristics of DACONET to be regarded as Local Area Networks (LANs).

2.1 Data Acquisition

Data management of the DACONET shall provide the quality data for control, monitoring, and diagnosis of MMIS systems which these systems can access and utilize data with a consistent mechanism. The DACONET logs the plant data during KALIMER operation. To support DACONET functional requirements, data management collects plant data through DACONET networks with which MMIS systems are distributed and interconnected. The DACONET data management shall also provide MMIS systems with timeliness guaranteed, reliable and qualified data services. Source system for DACONET data acquisition includes Plant Control System (PCS), safety- and non safety-instrumentation systems including sensors while destination system is regarded as Human-System Interface (HSI), Operation Management (OM), and Supervisory Control System (SCS). Source system for control signals and commands includes HSI, SCS, OM while destination system includes controllers and actuators.

2.2 Real-Time Data Processing

DACONET shall provide MMIS data in real-time. The DACONET data processing, i.e., data acquisition, validation and qualification including conversion, error and fault handling, and store/logging, is performed to be met data processing requirements of each MMIS system. Data transmission and communication between MMIS systems are also processed and controlled to be fail-safe in real-time. To meet the real-time requirements in data processing, a real-time data coordinator is designed as a fail-safe software component for DACONET data management while a network manager is also designed within DACONET. In addition to real-time design, real-time performance is improved by fault-tolerant architecture, real-time operating system and real-time programming, and high-speed communication protocols and media.

2.3 Data Transmission and Communication

The DACONET shall provide one or more available data paths between inter-systems and intra-systems of being connected with distributed communication networks and shall assure safe and reliable data communication during KALIMER operation. The DACONET shall also control MMIS data to be transmitted and communicated through networks.

2.4 Data Logging

Periodic and aperiodic data for normal and abnormal behaviors of KALIMER are logged and maintained by a separate mechanism including storage, security, etc.

III. DACONET Design Requirements

In addition to above functional requirements, the following requirements are considered for DACONET design.

3.1 Structure

DACONET networks are structured with 4-level distributed system architecture as shown in [Figure 1]. Information networks(L3) are designed for data communication of HSI. It connects both HSI components and L2 systems including OM, SCS and DM. Data networks(L2) are mainly designed for supervising and managing KALIMER processes and L2 systems are connected. Control networks(L1) are designed for high-speed data transmission between control systems and data networks. Control processors and systems are connected to control networks. Finally, sensor and sensor&actuator networks(L0) are designed for transmitting bit-level data and it is regarded as fieldbus or Controller-Area Networks(CANs). Ssensors and actuators are connected. Internetworking is designed per each level and between two levels in DACONET networks with redundancy.

3.2 Safety, Reliability and Availability

The DACONET shall consistently and timely provide KALIMER systems with high quality. The data shall be considered for data consistency and integrity, timeliness, data accuracy, resolution, sampling rate, repeatability, range and safety[1,2,3]. The DACONET shall be designed with a separated data communication between protection system and the other MMIS systems. Redundant architecture, fault-tolerant and safe computing shall be applied to assure safety, reliability and availability. Otherwise, diverse design is also considered for avoiding common mode failures while

MTBF(Mean Time Between Failures) data for equipment and component shall be provided for implementing the DACONET.

3.3 Performance

The DACONET shall not degrade KALIMER performance. Communication workloads, errors and fault/failure handling shall be considered for designing the DCONET network performance through overall design stages.

3.4 Network Protocols

Network protocols shall be designed by selection from existing industrial standards and/or by development of new protocols. Network protocols shall be validated for task supportness of MMIS and risk avoidance including hazards-free and reliability. A new protocol design shall be analyzed and validated by reachability (i.e., hazard free), safety and liveness, real-time performance, and optimized serviceability while the selection from existing protocol standards shall consider for operational performance, safety, reliability, and real-time performance [9].

3.5 Internetworking

System interfaces shall be deeply considered for internetworking for access and communication method, error detection and avoidance, fault recovery, data path and the other available data path. Internetworking shall be considered for both interconnection between two levels of DACONET networks and interconnection within each level in DACONET networks. DACONET internetworking shall consider NUREG/CR-6082 recommendations.

3.6 Verification and Validation

The DACONET shall be evaluated by a formal methodology for verification and validation through overall design phases. Reliability, availability and safety designs shall be verified and validated with quantitative one. Simulation, prototyping, experimental evaluation, or case study shall not be limited for piloting or supporting the design quality.

IV. Conclusion

The DACONET under conceptual design was described with its functionality and design requirements. The DACONET, as an embedded system of KALIMER, is being approached to develop a generic network architecture for digital control, monitoring,

and diagnostic systems for KALIMER MMIS. In general, designing data management and communication networks in nuclear power plants should consider much difficult problems in timeliness, safety, reliability, protocol, data transmission, communication load, communication media, diversity, and performance. Design difficulty can also occur when advanced technology is applied to design MMIS and commercial network technology is applied to design data communication for MMIS in nuclear power plants. DACONET design is being challenged to consider these technological issues and more advanced technology, including the Commercial-Off-The-Shelf(COTS) equipment, Application-Specific Integrated Circuits(ASICs) and commercial networks, will be available as an alternative design for a distributed digital data management and communication in a LMR plant.

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