Development of Communication System for Nuclear Safety Data Network

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1. Introduction

The nuclear safety data network should be satisfy the safety and verification characteristic required as an essential requirement of nuclear safety system.

The nuclear safety data network should be designed to meet deterministic communication structures, clear separation and isolation of transmission paths, high reliability, and verification requirements. [1, 2, 3]

In this paper, describe the structure and medium access control (MAC) method of safety communication network, and the results of design, implementation, verification and validation.

2. Safety data network structures

The transmission medium of safety data network adopted optical cable that have excellent in electrical isolation and EMI characteristics.

The physical layer adopted the IEEE 802.3 standard 100BASE-FX.

The Medium Access Control (MAC) of the data link layer adopted the guaranteed time division method (GTS) which performs periodic transmission of IEEE 802.15.4

The safety data network consists of a network switching module (NSM) and a network communication module (NCM). The network switching module is divided into Central Switching Module (CSM) and Intermediate Switching Module (ISM) depending on the function.

As shown in Fig. 1, the safety data network places the ISM according to the function and the site structure based on the CSM, and connects with the NCM to form a hierarchical star topology.

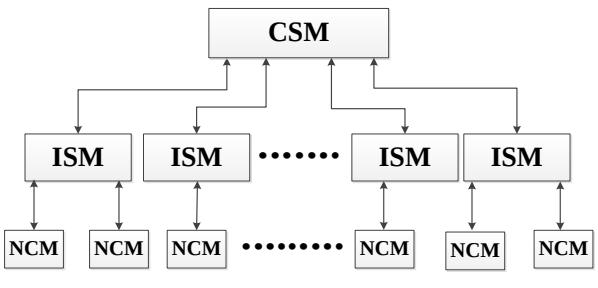

Fig. 1. Safety data network Configuration

The NCM connects a one-to-one link with the assigned network switching module (CSM or ISM) according to its hierarchy. Data transmission / reception between NCMs is performed through a network switching module. In order to construct a safety data network, one CSM is indispensably required and ISM is selectively applied according to the application structure of the safety data network. The NCM is rack mounted and communicates with the processor module and NSM to perform data transmission and reception.

3. MAC method of safety data network

The transmission right of the safety data network adopted the guaranteed time division method, and the CSM controls the transmission right.

The fig.2 shows the data transmission sequence of the safety data network.

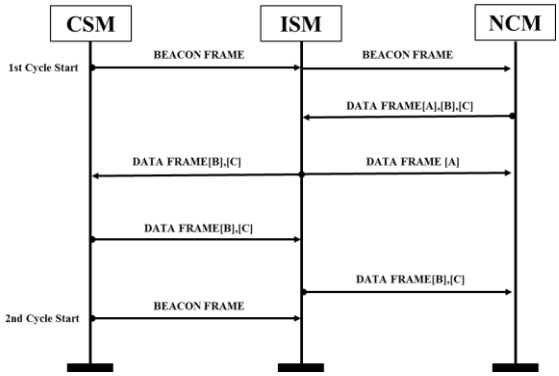

Fig. 2 transmission sequence of the safety data network

The CSM sends a beacon frame every cycle. The beacon frame contains transmission time information that determines the transmission rights of the ISM and NCM. The transmission time information includes transmission start time and transmission holding time.

The ISM and the NCM receive the beacon frame and interpret the beacon frame to confirm their transmission time.

After receiving the beacon, the NCM starts transmission of the data frame at the designated transmission time. The data frame includes a source address and a destination address. The source address is the address of the NCM transmitting the data frame and the destination address is the address of the NCM receiving the data frame.

The ISM identifies the destination address of the received data frame from NCM and transmits the data frame to the NCM or CSM specified as the destination address at the designated transmission time.

The CSM identifies the destination address of the received data frame, transmits the data frame to the ISM specified as the destination address at the designated transmission time. The ISM identifies the destination address of the received data frame from CSM, transmits the data frame to the NCM specified as the destination address at the designated transmission time.

The NCM performs a CRC check on the received data frame to check the integrity of the data and checks the validity of the data frame. Also, NCM checks whether the destination address of the received data frame matches its own address.

4. Design and Implementation

Fig.3 and 4 show the hardware shape of NCM and NSM. The hardware of NSM and NCM consist of FPGA, Physical Layer Chip, Optical Transceivers, LED, Dip switch.

Fig. 3 Shape of NCM hardware

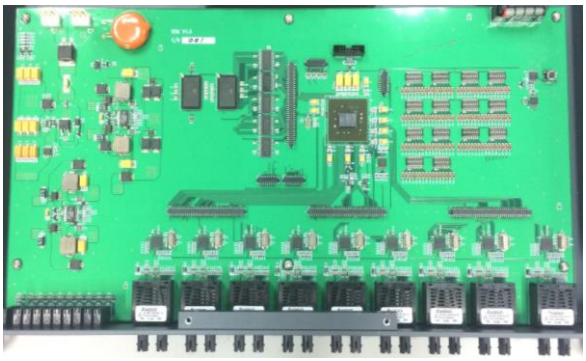

Fig. 4 Shape of NCM hardware

The software (control logic) design of NSM and NCM was performed according to the V-Model life cycle of IEEE1017. [4]

Software requirements specifications and design specifications are based on system design specifications [5] for safety data network. The software (control logic) of NSM and NCM is implemented using Verilog-HDL.

The function of the implemented NSM control logic is shown in the Fig. 5

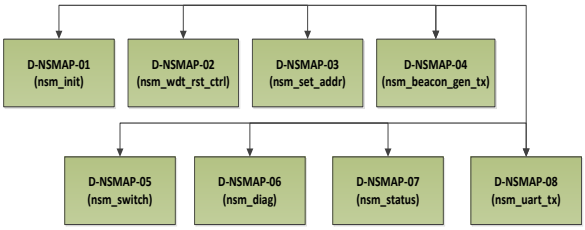

Fig. 5 The function of the implemented NSM control logic

5. Verification and Validation

Software requirements and design specifications were verified and validated according to BTP-14 [6] to ensure that they meet the functional and process characteristics of the design phase.

Component tests, integration tests, and system tests were performed to evaluate the implemented control logic. The component test was carried out by simulation using Modelsim and verification of test execution results.

Fig. 6 shows the component test environment and simulation results.

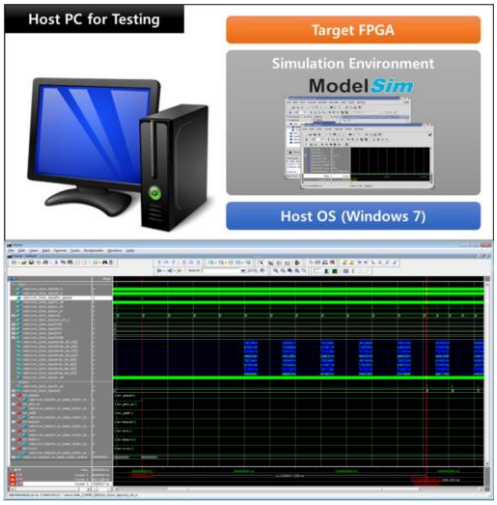

Fig. 6 The component test environment and simulation result

In the integrated test, the implemented control logic is mounted on the target hardware and the input and output signals of the FPGA are verified using the logic analyzer.

Fig. 7 shows the integration test environment.

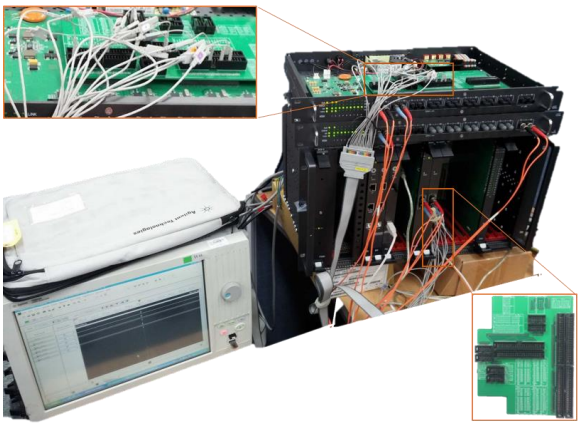

Fig. 7 The integration test environment

In the system test, the performance of the safety data network was tested. Through the test, it was confirmed that the transmission capacity exceeding 20Mbps, which is the performance requirement of the safety data network, was satisfied.

Fig. 8 shows the system test environment for safety data network.

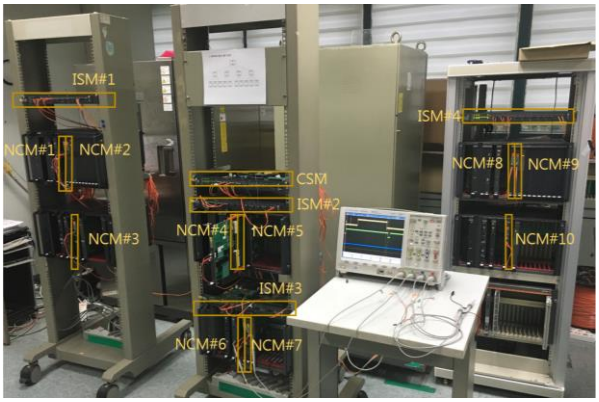

Fig. 8 The system test environment

6. Conclusions

The transmission medium of the developed safety data network adopted the optical cable with excellent electrical isolation characteristics, The Medium Access Control (MAC) of the data link layer adopted the guaranteed time division method to satisfy the deterministic characteristic.

Software requirements specifications and design specifications were verified through verification and validation.

The implemented software (control logic) is verified through component test, integration test, and system test.

Through the performance verification test, it was confirmed that developed safety data network has a transmission capacity of 20Mbps or more.

REFERENCES

[1] “Safety Assessment of Computerized Control and Protection Systems”, IAEA-TECDOC-780, 1994
[2] D.H. Kim “A Safety-Based Protocol for Data Communication Network in Nuclear Power Plants”, 2006
[3] IEEE 7-4.3.2, “IEEE Standard Criteria for Digital Computers in Safety Systems of Nuclear Power Generating Stations”, 2003
[4] IEEE 1074, “IEEE Standard for Developing a Software Project Life Cycle Process”, 2004.
[5] “Safety grade PLC (SPLC) Design Specification”, KAERI, 2015
[6] NUREG-0800, Standard Review Plan: Chapter 7. Instrumentation and Controls, U.S. NRC, 2007