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Development of Safety Grade PLC (POSAFE-Q) and Performance Test Results

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1. Introduction

The safety grade PLC (POSAFE-Q) is being developed in the Korea Nuclear Instrumentation and Control System (KNICS) R&D project. The PLC satisfies Safety Class 1E, Quality Class 1, and Seismic Category I. The software such as the RTOS and firmware are being developed according to the safety critical software life cycle. Especially, the formal method is applied to design the SRS (Software Requirement Spec.) and the SDS (Software Design Specification.) to be error-free. The POSAFE-Q has several modules such as processor module, input and output modules, communication modules, redundant processor module, redundant power modules, etc,. To verify the function and performance, several tests such as CT, IT and ST were performed. And also, the equipment qualification test for environment, EMI&EMC, and seismic ware performed. All tests are satisfied with the requirements and specification for safety grade PLC, and the criteria for safety system in nuclear power plants.

2. The Specification of the POSAFE-Q

POSAFE-Q is composed of various modules used in the safety system of a nuclear power plant such as a sub rack, power module (PWR), processor module (PM), communication module (CM), digital input/output module (DI/O), analog input/output module (AI/O), and a high speed pulse counter module (HSCM).

The POSAFE-Q hardware satisfies the IEEE standard Safety Class 1E. And it is classified into seismic category I. And, the software such as the RTOS and firmware are being developed according to the safety critical software life cycle.

2.1 The Processor Module Specification

The processor module (PM) consists of SMQ 320C32PCMM-60M (Military) DSP CPU, 4M Words User Program Back up memory(flash type), 512K Words execution code memory(flash memory), 4M Words working memory(SRAM), and other peripheral chips.

The operating system named the pCOS satisfies the real time performance, which is evaluated from the point of view of the priority inversion, interrupt delay time, interrupt response time, interrupt recovery time and scheduling overhead time. The resolution of the scan time is 10ms. The pCOS supports 8 application program tasks (multi-tasking) whose capacity is 1MDW and the user can fix one task capacity within 256KDW flexibly. The pCOS kernel provides a scheduling function for both a built-in system task and an application program task downloaded from the PLC engineering tool (pSET).

The overall response time from an input to the POSAFE-Q exceeding its trip condition to the resulting outputs being set is 100msec or less. The response time include as following combination:

- Filtering and signal conversion time
- Two scan times of an application program containing the equivalent of 2000 simple logic elements.
- The time it takes the main processor to send values to the output module.
- The time it takes the output module to convert output signal level.
- The maximum time required to implement any self-diagnostics.

2.2 The Communication Modules Specification

The POSAFE-Q provides the following communication modules.

- HR-SDL (High Reliability-Safety Data Link)
- HR-SDN (High Reliability-Safety Data Network)
- Profibus-FMS

The communication module consists of two boards such as the CPB(Communication Processor Board) and the DRB(Drive Board), and these boards are connected by a piggy back connector to each other. The CPB provides an interface function between the processor module (PM) and the DRB. The DRB is interfaced with the CPB and other PLCs through communication ports.

The CPB consists of SMQ 320C32PCMM-60M (Military) DSP CPU, 32K Words dual port memory (DPM), 512K Words execution code memory (flash memory), 512K Words working memory(SRAM), and other peripheral chips.

The DRB consists of DSTnI-LX-48M CPU, 8K Bytes DPM, 256K Words execution code memory (flash memory), 256K Words working memory (SRAM), and other peripheral chips.

The HR-SDL and HR-SDN use the Profibus FDL protocol based on SDN (Send Data with No acknowledge). And the Profibus-FMS which is widely

used in industrial applications is an open architecture communication module. The data flow of the FMS is in the bi-direction, and both a broadcasting and a uni-casting mode are provided.

2.3 The Input and Output Modules Specification

The POSAFE-Q provides the following input and output modules.

- Analog input and output modules

The analog input and output modules use the XC161CJ-16F40F-40MHz CPU and other peripheral chips. The analog input module is able to process the input of a voltage and a current. The resolution is 15 bit (except for sign bit). The total accuracy including the repeatability, hysteresis, linearity, and 24 month drift is less than ±0.15%.

- Digital input and output modules

The POSAFE-Q provides the 24VDC, 120VAC, and 250VAC digital input module. And also, The POSAFE-Q provides the 24VDC, 48VDC, 125VDC, and relay output module. The digital input and output modules use the CPLD device and other peripheral chips.

- Temperature input modules

The POSAFE-Q provides the RTD and TC temperature modules. The temperature input modules use the XC161CJ-16F40F-40MHz CPU and other peripheral chips. The resolution of the temperature modules are 15 bit (except for sign bit). The total accuracy including the repeatability, hysteresis, linearity, and 24 month drift is less than ±2℃.

- Pulse input module

The pulse input module uses the FPGA device and and other peripheral chips. The total accuracy including the repeatability, hysteresis, linearity, and 24 month drift is less than ±0.1%. The maximum count frequency is 200 kHz.

3. Test and Results

To prove the function and performance of the POSAFE-Q, several tests were performed. To verify the functionality of the hardware and software in the each module, the component and integration test was performed. The function and performance between processor module and each module was tested by integration test. To verify overall performance of the POSAFE-Q for applying to safety system in nuclear power plants, the system test was performed. The system test items are as follows :

- Response time test
- I/O capabilities test
- Memory capacity and data retention capability test
- Prudency test
- HR-SDL performance test
- HR-SDN performance test
- Profibus-FMS performance test
- Error Handling capability test

The component test and integration test results show that the POSAFE-Q each modules satisfies the requirements and specification. And, the system test results show that the POSAFE-Q performance and capability satisfies the criteria of the safety system in nuclear power plants.

The equipment qualification (EQ) for the POSAFE-Q was performed as following criteria :

- Environment qualification

The temperature and humidity test was performed at 60^{o}C [140^{o}F] and a relative humidity of 95% (non-condensed condition) during 8 hours.

- EMI/RFI qualification

The EMI/RFI test was performed using the EPRI TR-102323 criteria. And, the ESD test was performed by the EPRI TR-102323 Appendix B, Section 3.5. The surge test was performed according to the EPRI TR-102323 Appendix B, Section 3.3 and 3.4.

- Seismic qualification

The seismic test was performed according to the IEEE Std. 344 requirements. Five OBE(Operating Basis Earthquakes) and one SSE(Safe Shutdown Earthquake) were simultaneously applied in three orthogonal directions.

The EQ test results show that the POSAFE satisfies the criteria of the safety class 1E and seismic category I.

REFERENCES

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