FPGA-based instrumentation and control for nuclear reactors

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Introduction

The FPGA (Field-programmable gate array) is a semiconductor complex programmable device which can be configured to perform a custom-required function. The FPGA includes millions of logic gates aligned in an array and the interconnections between each gate are allowed to be programmed in the field. The FPGA technology offers an alternative to microprocessor technologies. The FPGA is parallel in its nature, so the array elements in the FPGA can operate simultaneously. This parallel nature of FPGAs not only contributes to higher performance, but also reduces complexity of microprocessor-based systems by eliminating needs of context switching and memory access [1]. This report presents the prospects of using FPGAs in Instrumentation and control reactors in Brazil, based on initial studies and experiments at DENN.

Application of FPGA in nuclear reactors

FPGAs were first introduced in non-safety systems in NPPs (Nuclear Power Plants), where no specific process over general FPGA development process is required. However, to use FPGAs for safety systems, more stringent processes will be imposed by nuclear regulators to ensure the reliability and safety of the systems [2]. The logic to be programmed into the FPGA is described using hardware design languages (HDL). Because the development process of FPGA is similar to that of software for microprocessor-based systems, the conventional safety software development process including V&V methods that can be applied. New IEC standards are dedicated to this topic [3].

In traditional systems that are computer-based, a separation can be drawn between the hardware and software portions. But with FPGAs, I&C designers may build application functions directly in one integrated circuit. According to IEC 62566 [3], in order to achieve the reliability required for safety I&C systems, the development of FPGA-based system shall comply with strict process and technical requirements.

The safety function applications implemented by FPGAs are executed without running any system software or operating systems, which is an advantage. This reduces the vulnerability of the digital I&C system and can make easier the licensing process.

A second advantage, FPGA-based applications have more resilience due to the portability of the HDL code between various versions of FPGA-chips produced by different manufacturers.

As initial study we are applying FPGA-based technology in implementation of the Critical Safety Functions (CSFs) status tree logic for a Westinghouse 3-loops NPP simulator provided by LABIHS. The hardware description of these functions will be simulated in ModelSim[tm], a hardware simulation and debug environment, to be validated. After this an implementation in FPGA devices will put these functions in hardware. We have been working with FPGAs of different features and capabilities from companies Actel and Xilinx. In near future will be possible to develop circuits with FPGA technology for safety and non-safety functions in nuclear research reactors.

Conclusion

FPGA-based systems can provide cost-effective options for I&C systems in nuclear reactors, ensuring safe and reliable operation. With FPGA-based system, meeting licensing requirements, such as separation, redundancy and diversity, can be provided in more convincing way due to its design simplicity. However the description of hardware involved in the programming of FPGAs is not simple. It requires proper training in the subject, proposed by group, in consequence of the demands arising from new projects, as I&C modernization projects and the RMB.

References

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