Modeling the CSF Status Tree of a NPP Using FPGA

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FPGA is a semiconductor complex programmable device which can be configured to perform a custom-required function. FPGA includes millions of logic gates aligned in an array and the interconnections between each gate can be programmed in the field. 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 the need for context switching and memory access [1]. This report introduces the FPGA-based technology to the implementation of the Critical Safety Functions (CSFs) status tree logic for a Westinghouse 3-loops NPP simulator provided by LABIHS (Human-System Interface Laboratory) at IEN.

The critical safety function prioritizes operator actions based on the potential threat to the three barriers (fuel cladding, primary coolant system boundary, and containment) and allows the operator to respond to these threats prior to event diagnosis. CSF has a hierarchical information structure that organizes the system variables affecting the plant safety in terms of goal-means relations. It is important that the operator should be aware of the various success paths associated with each CSF in order to respond to unanticipated system failures quickly. When an emergency occurs in NPPs, the operator should monitor CSFs periodically and identify possible success paths as necessary, and try to stabilize or safely shut down the plant using emergency operating procedures (EOP) that include steps to check the CSFs.

Six critical safety functions were identified for the reference plant and they were implemented in the human-system interface (HSI) of the simulator interface to support the operator's tasks to monitor and identify the associated success path for Westinghouse 3-loops NPP. In order of priority, they are:

1. Subcriticality (SC), 2. Core cooling (CC), 3. Heat sink (HS), 4. Reactor Coolant System Integrity (RI), 5. Containment Environment (CE), 6. Reactor Coolant Inventory (CI).

The six CSFs identified for the reference plant were described in digital hardware [2]. The Containment Environment Status Tree is showed in Figure 1:

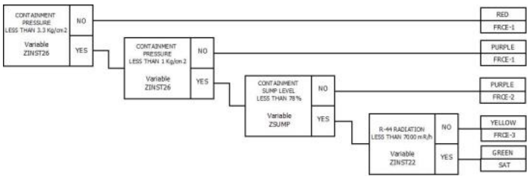
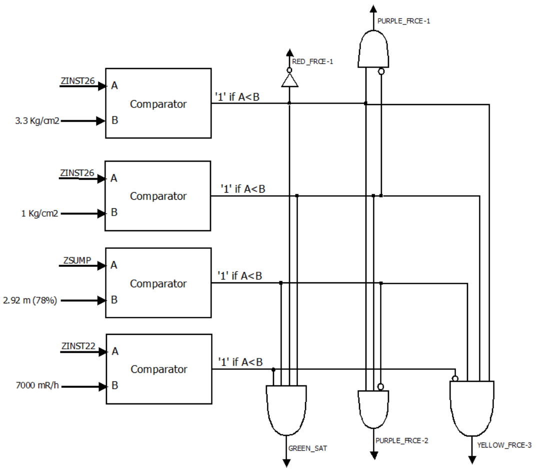


Figure 1: Containment Environment Status.

Figure 2 shows the internal architecture of component *Containment_Environment* (CE). It has four *Comparators* components and some logic gates to perform the CSF Containment Environment Status Tree (Figure 1).

Figure 2: CE architecture.



The simulation results showed that the proposed architecture met the initial goal of designing a hardware that performs the task of resolving the Critical Safety Functions (CSFs) status tree logic of nuclear reactors efficiently. The results show that reconfigurable hardware, like FPGA devices, can be implemented to this task.

References

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