**Real Time Computers for Instrumentation and Control of PFBR**

**EXECUTIVE SUMMARY**

The advent of powerful Microprocessors has enabled the extensive use of computers in Instrumentation and Control Systems in Nuclear Power Plants. They are presently deployed in all categories of Reactor Control including Safety Critical Systems such as Core Temperature Monitoring and Reactor protection. It is proposed to deploy Real Time Computers with Triple Modular Redundant architecture for Safety Critical and Dual, Hot standby redundant configuration for Safety Related Systems for PFBR.

**OUTLINE**

The use of Real Time Computers in Safety Critical applications is pioneered by the fast reactor program. Fast reactors have a higher power density in the order of 500 kW/litre in the reactor core and the liquid metal coolant flows through the fuel subassemblies to remove the heat efficiently. Plugging in any one of the fuel subassemblies can lead to clad hotspot and fuel melting and hence has to be detected immediately in order to initiate safety action. This necessitates the monitoring the output temperature of all the fuel subassemblies and further derivation of mean output temperature, mean temperature gradient across the core and the comparison of the actual temperature rise with the expected temperature rise for every subassembly for early warning on plugging. Since many derived parameters from all the fuel subassemblies and extensive computational requirements, the use of computers in Safety Critical Systems becomes inevitable in Fast Reactors. Computer based control systems for safety applications in nuclear power plants have to meet not only functional performance and interface requirements, but in addition they have to meet the regulatory requirements like enhanced reliability, safety and security. To achieve high reliability and availability, redundancy and fault tolerance features are to be provided and the overall system design should have high mean time between failures and low mean time to repair.

To cater the requirement of Real Time Computers for fast reactors, Electronics & Instrumentation Division, IGCAR has standardized on Versa Modular Euro card or VME backplane bus for entire range of computer based systems. Motorola MC68020 processor board (Fig. 1) and host of Input and Output cards have been developed and tested. The salient features of the cards include advanced diagnostics feature like single bit memory correction and double bit error detection for static memories, smart Analog input card (Fig.2) with built in calibration facility, Analog Output Card, Optically Isolated Digital Input/Output card with online testability and status display feature, Monoshot configurable Relay output card incorporating fail safe logic, ensuring the safety of the plant in case of either failure of the host central processing unit or software crash. In addition Switch over Logic card has been developed which will be used in hot standby configuration. The function of this card is to detect healthiness of the redundant computers. The healthiness is primarily determined by presence or absence of watchdog pulses. Pulse failure is considered as non-availability of the system and the Switch over Logic card route the relevant outputs of the healthy computer to the plant.

All the boards have been designed as per AERB safety guide. VLSI device have been used to reduce the number of components and interconnects on board. State of the art, Industrial standard, analysis software packages such as Signal Integrity, Thermal-hot spot and EMI/EMC were used to identify earlier design errors on board prior to fabrication. All the boards were also subjected to stringent environmental tests such as Temperature cycling, Damp/Dry heat tests and are qualified to work in harsh Industrial environments. The verification and validation on digital design as sequencer logic of analog input card and interface logic of analog output card has been successfully carried out on digital designs such as IIT Madras.

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**Fig. 1 : VME bus based MC68020 CPU card features:**
- CPU: MC68020 @ 25 MHz
- FPP: MC6882 @ 25 MHz
- VME controller: VIC068A
- EPROM: 1MB, 16 WIDTH
- Serial Ports: 2 Numbers
- Local Area network: Two hardware TCP/IP modules

**Fig. 2 : VME bus based Analog Input card features:**
- Number of channels: 30
- Input Voltage range: ± 5V, ± 10V
- ADC resolution: 16 bits
- On board sequencer for scanning operation.
VME BUS

VME bus is IEEE 1014, 1987 standard, which specifies a high performance backplane bus for use in microcomputer systems that employ single or multiple processors. The bus includes four sub-buses and supports 8, 16 or 32 bit data transfers over non-multiplexed 32-bit address and data highway. The transfer protocols are asynchronous and fully hand-shaken. The interrupt bus provides the Real Time Interrupt services to the system, whereas the Arbitration buses provide the services of allocation of bus mastership in case of multiple processor system. The mechanical specifications of boards, backplane, sub-racks and enclosures are based on IEC 297 specification, also known as Euro Board form factor.

INCORPORATION OF FAIL SAFE FEATURE IN THE DESIGN

Safety is very important especially when Real Time Computers are executing Safety Critical Functions. Provision for fails safe feature calls for improved strategy right from design to final deployment.

The high Mean Time between failures for such systems is achieved by providing adequate design margins, noise immunity, proper cooling, adhering to stringent quality policy for hardware component selection and quality control during manufacture. In addition the design must provide built in features for online fault detection and fault indication.

All the cards designed on VME bus incorporate extensive online diagnostics features for fault detection and health monitoring through the watchdog timer. The watchdog timer forms the heartbeat of the entire computer system. Since plant outputs are controlled through actuation of relays, watchdog features were also integrated into the Mono-shot Relay output board. This ensures that, in case of either system power failures or the failure of the CPU software, the plant outputs terminates to fail safe mode, thus preventing the catastrophe on the operating plant.

APPLICATIONS OF VLSI TECHNOLOGY

The state of the art VLSI packages were used to integrate several thousands of discrete digital logics in to the reprogrammable, reconfigurable VLSI chips. This implementation has enhanced the reliability of the individual system due to reduction of components and also catering to the obsolescence of certain digital integrated circuit chips.

ACHIEVEMENT

The Integrated, Dual, Hot standby, Real Time Computer system consisting of CPU, Analog Input, Digital input and Mono-shot Relay cards has been used to successfully replace Unipower-30, which is the part of Central Data Processing System of FBTR (Fig. 3). The present arrangement consists of three independent Real Time Computer Systems to carry out safety Critical, Safety Related and Non-Safety functions.

PUBLICATIONS ARISING OUT OF THIS STUDY AND RELATED WORK

2. G. Venkat Kishore, N. Sridhar, B. Krishnakumar, S. Chandrasekaran and S. Ilango Sambasivan, Report No. PFBR/66120/DN/1000

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