Control of the QUENCH Protection System at HERA

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Abstract

We describe the control of the Quench Protection System for the superconducting magnets of the HERA proton storage ring in DESY. General control (operator to hardware) follows “standard model” -like concepts with multiple consoles communicating with front ends via the ethernet. The front end control is based on redundant VME CPUs running the VxWorks real-time operating system. The data-link to the lower level quench microprocessor and PLC based alarm control center is connected via the CAN fieldbus. A network server task communicates with consoles running MS WINDOWS and Visual Basic via UDP. Important quench data are automatically archived following critical events, allowing follow-up expert system analysis while the machine is brought again into operation.

Introduction

The HERA proton ring consists of 422 superconducting dipole magnets and 224 superconducting quadrupole magnets. These magnets are cooled by 4.5 K liquid helium. A current of 5025 A goes through all these magnets for a proton beam energy of 820 Gev. The superconducting magnets are ultimately protected via hardware as opposed to relying exclusively upon software logic, the quench detection electronics being monitored independently. Passive quench protection is achieved by using bypass diodes. Active quench protection is carried out by using transducers to measure the current flow in bridges to detect quenches, and then activating the corresponding dipole heaters to protect the magnets and operating the main current switches. Futhermore, redundant components are integrated into the system as much as possible, at both at the hardware and software levels. The present system uses front end VME-based CPUs running VxWorks and makes use of the CAN fieldbus and PLC modules. A microprocessor-based computer provides local intelligence for monitoring, testing and fault state detection of all the quench hardware components. A PLC-based microprocessor functions as an alarm control center collecting alarm signals, such as quench electronics status, power status, status of switches and alarm status from beam loss monitors. This processor makes critical decisions regarding beam dumps and machine operation. Various hardware test commands can be excuted from the control system consoles. The current state of the quench protection system is collected asynchronously at the consoles from the VME CPUs via the ethernet. The front-end CPUs and the quench microprocessor and alarm control center are linked via the CAN bus. Logically the VME CPU acts as a front end supervisor, collecting data, coordinating the behavior of the quench microprocessors and alarm control center and serving as a network server.

A more detailed description of the quench protection system at HERA is given elsewhere [1]. In this report we concentrate on the design of the software control, starting at the level of the VME crate and progressing to the GUI at the console level. Specific details of the hardware controllerss such as the PLCs will not be presented here. A schematic of the system architecture is given in figure 1.

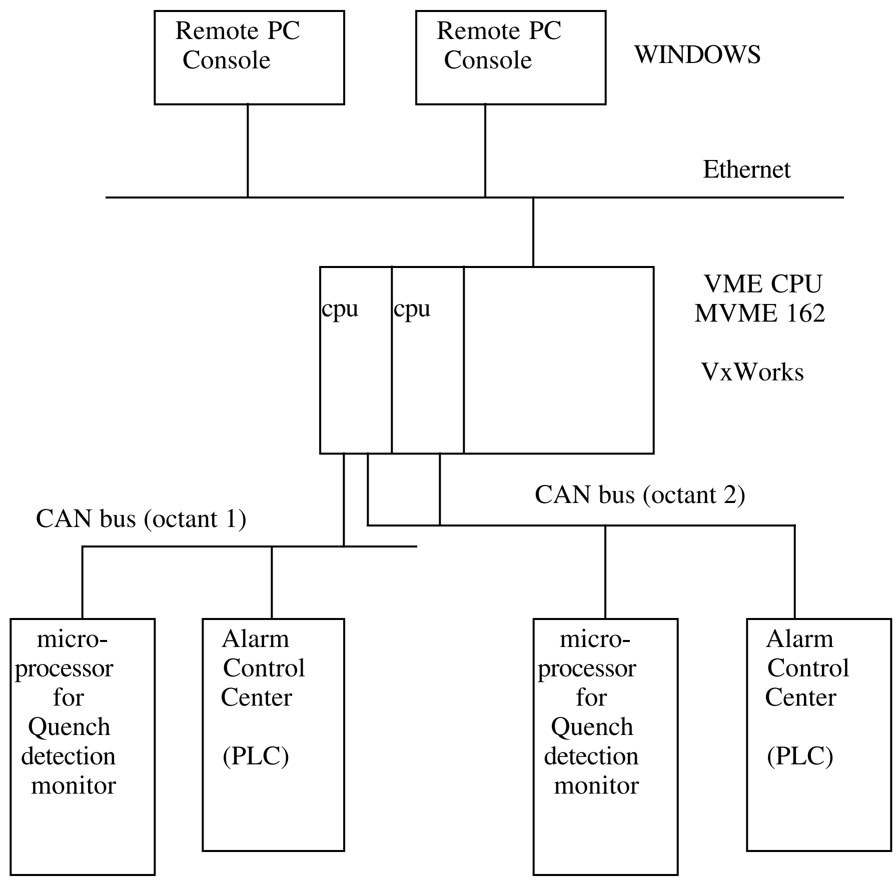

Figure 1. Schematic drawing of the hardware architecture for a quadrant

The Console Software

We use PCs running MS WINDOWS 3.1 in the machine control room as consoles. Several application programs written with VISUAL BASIC are responsible for controlling and monitoring the quench protection system. Data exchange between application programs and the front end servers is via ethernet. We use a socket-based RPC-like protocol, developed for the HERA PC control system [2]. Changes of state are noted promptly at the console via asynchronous messages from the front end. Furthermore, the front end appears as an integrated device at the console, allowing specific commands, such as to activate a heater test, to operate specified main current switches, or even to dump the beam to be performed by a mouse click on a synoptic display. The total response time (mouse click to hardware setting and return) for command execution is typically less than one second.

Front End Hardware

A total of eight MVME162 CPUs are used for front ends, two CPUs being housed in a VME crate in each of the four HERA halls.They are used to control and monitor quench operation and the alarm center. One of these CPUs is always executing as the master, the other as a redundant partner. The data-link to the lower level quench microprocessor and PLC-based alarm control center is provided by the CAN fieldbus. Two separate CAN buses are connected to each of these CPUs. One CAN bus connects one alarm control center and four quench microprocessors. Two of these four microprocessors provide redundant control for the dipole magnets, and the others deal with the quadrupoles, and groups of dipoles and groups of quadrupoles. The CAN data transmission speed is set to 500 kHz, and the overall time of one CAN telegram transmission is 250 μs.

Live insertion cards are used for the VME CPUs. One can remotely or locally power one CPU on or off, without disturbing the operation of the othes. All front end hardware is powered through an uninterruptable power supply (UPS). Furthermore, each front end in the hall operates independently of the others and is capable of operating in a stand-alone manner.

Front End Software

The front end software has been developed for the VxWorks real-time multitasking operating system. A network task services remote consoles and runs at rather low priority. As mentioned above, the HERA PC control RPC protocol is used for updating registered consoles. Commands which change the state of the machine can only be executed by allowed users.

A PLC task is responsible for communication with the alarm control center, by sending a request command via the CAN bus every second. A hardware redundancy check is also performed upon request from the alarm control center. According to the result, it will send an alarm to the alarm center to dump the beam if warranted. A message queue is used for collecting console commands from the network task. A test task can be excuted for testing transducer and heater electronics if the console application sends a test request.

A CAN message receive task collects CAN bus data, and sorts and distributes them to mailboxes; it operates on semaphores according to CAN-IDs. During quench detection, it will perform heater status checks and send heater commands to the quench microprocessor if necessary. Quench telegrams come at speeds of 200 Hz, the maximum speed from 4 crates at once being 800 Hz. This means that the CAN data transmision must take place less than 1ms. The 250µs message transfer time mentioned above is more than adequate. A massive quench situation has been simulated with programs written for VxWorks, to test this extreme situation. No performance problems were detected.

A monitor task, running at 10 Hz, checks the status of all other running tasks and the data integrity with that of the redundant CPU, as well as the status of the CAN bus connections. According to this check it marks itself as 'OK' or 'NOT OK", and sends its status information to its partner CPU via the CAN bus. Upon receiving this CPU status information, it will determine whether it should continue to act as slave or take over as master.

Only the master CPU responds to the console commands and sends commands via the CAN bus to the quench microprocessor and alarm center. Although the slave acts as a passive listener, it runs exactly the same code and possesses all current information.

In the unlikely event of a CPU hang, a 'COLD BOOT' is still possible by toggling the power on the live insertion card remotely from the console program.

The Quench Archive

A dedicated client application running on a PC is responsible for archiving important data upon quench or beam loss alarm. It monitors the quench status and initiates a data archive if necessary. The archive data contain the complete state of the machine at the time of the quench or other critical events. The experts can then use these data at their leisure while the machine is brought up into operation again. The archived data are read by the same application program in the same way, but the data link is to an archive file, instead of the front end program.

Performance

The current system has been in operation since April 1995, and operates as designed. Although the whole system is composed of so many different hardware and software components and involves data exchange from different platforms on the field bus, it has proven to be a reliable system. During the half-year of operation, the built-in master-slave redundancy has not been invoked.

Acknowledgements

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References

[1] K.H. Mess et al. "Quench Protection at HERA", proceedings of HEACC 92 in Hamburg
[2] P. Duval, "Implementation of PCs in the HERA Control System", ICALEPCS 95 in Chicago, these proceedings