The Relativistic Heavy Ion Collider Control System*

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Abstract

The Relativistic Heavy Ion Collider control system has been used in the commissioning of the AGS to RHIC transfer line and in the first RHIC sextant test. Much of the controls infrastructure for networks and links has been installed throughout the collider. Almost all of the controls hardware modules needed for early RHIC operations have been designed and tested. Many of these VME modules are already being used in normal AGS operations. Over 150 VME based front end computers and device controllers will be installed by the Summer of 1998 in order to be ready for Fall of 1998. A few features are being added to the front end computer core software. The bulk of the Accelerator Device Objects (ADOs) which are instantiated in the FECs, have been written and tested in the early commissioning. A configuration database has been designed. Generic control and display of ADO parameters via a spreadsheet like program on the console level computers was provided early on in the control system development. User interface tools that were developed for the AGS control system have been used in RHIC applications. Some of the basic operations programs, like alarm display and save/restore, that are used in the AGS operations have been or will be expanded to support RHIC operations. A model for application programs which involves a console level manager servicing ADOs have been verified with a few RHIC applications. More applications need to be written for the Fall of 1998 commissioning effort. A sequencer for automatic control of the fill is being written with the expectation that it will be useful in early commissioning.

1 RHIC

The Relativistic Heavy Ion Collider (RHIC) [1], now in its final year of construction at Brookhaven National Laboratory, will provide counter-rotating particle beams in two 3.8 km super-conducting rings which will be collided in four crossing regions to provide interactions for experimenters. Ions are first accelerated through three existing Brookhaven accelerators, a Tandem Van de Graaff, a Booster, and the Alternate Gradient Synchrotron (AGS) before being transferred to RHIC where they are accelerated and stored. Beam fill of the two rings will take a about a minute with the stored beam expected to last about ten hours.

There have been two successful tests of many of the components of RHIC, including many aspects of the control system. The most recent test, the Sextant Test, [2] finished in January of 1997, brought beam from the AGS into one sextant of RHIC. Final installation of the collider is going on now with cool down scheduled for late 1998 and first beam in the rings in January of 1999. Colliding beams for experiments is expected to take place before the end of 1999.

2 RHIC Control System Overview

The RHIC control system [3] is the result of evolution from the present AGS control system. VME chassis distributed around the ring in about 35 equipment locations contain i/o modules which either directly connect to accelerator equipment or connect to field buses which in turn connect to equipment. A single board computer in the VME chassis provides a host for Accelerator Device Objects (ADOs), software objects which buffer data, control the I/O modules and pass messages over an Ethernet backbone to console level computers. Synchronization of equipment is achieved through serial links connected directly equipment.

The console level computers are UNIX-based workstations which function as host for applications programs. The operator interface for the applications use an X-Window graphical user interface allowing X-Terminals to serve as windows on the control system. Manager programs run on the console level computers to provide hosts for higher level ADOs which can interface to the front end ADOs.

The current AGS main control room will serve as the control room for both AGS and RHIC operations. A sixth general purpose console will be added to accommodate more activity in the control room. RHIC and AGS applications will be expected to run in a common environment and be used by the same group of operators.

3 Hardware Infrastructure

The controls hardware infrastructure consists of data links, the Front End Computers (FECs), and hardware modules in the FEC which interface either directly or indirectly to accelerator equipment.

There are six different types of data links. The real time data link (RTDL) [4] transmits up to 256 different tagged 24 bit data values at a 720 Hz rate. The RTDL system will be used to deliver data, such as beam energy, magnet

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current, and corrections, to wave form generators and FEC utility modules. RHIC will have its own event timing system[5] to synchronize the operation of distributed equipment. This system, similar to one in use at the AGS, distributes a master clock and encoded events from a master to all equipment locations. Many locally designed VME modules have inputs for the event link system and there is a utility delay module that can translate an event into a standard TTL pulse. There will be a beam synchronized event system, similar to the real time event system, for each ring, that will deliver beam synchronized events to instrumentation hardware through a general purpose delay module. A beam permit module [6] with a permit link and two quench links, one for each super-conducting ring, has been built. The beam permit module accepts inputs from critical equipment enabling the permit link only when all its inputs are satisfied and its upstream permit link is present. The quench link for each ring is used signal the quench detection/protection modules to dump the current in the super conducting magnets.

The current FEC SBC module is powered by a Motorola 68040 processor. We are evaluating processor modules which contain the Power PC processor and expect to use this newer generation processor in most RHIC FECs. The current Ethernet configuration to the FECs is a 100 Mbit/s fiber Ethernet from a hub to each of six equipment buildings where it is switched to 10 Mbit/s Ethernet for distribution to about 30 other locations. This topology will allow for a 100 Mbit/s connection directly to FECs where required.

The bulk of the I/O channels in RHIC are for the control of the magnet power supplies of which there are about 1000. The analog control, digital I/O and analog measurements for the magnets are split among different modules. A Wave Form Generator (WFG) board, with two channel digital serial fiber output, is used to generate reference voltage for power supplies. The reference voltages are generated in real time using RTDL values, events and locally stored tables. A multiplexed ADC (MADC) [7]system has been built with enough distributed capacity to allow three measurement channels per power supply to be continuously monitored at 60 Hz with sufficient memory to save about 10 minutes of data in circular buffers. Both the wave form generators and the MADC system are already in use at the AGS. The low-level control and status for the power supplies is done using commercial PLC systems. These PLC communicate over vendor's field bus to commercial VME modules in the FEC.

Commercial PLC systems are also in use in vacuum controls for controlling valves. The vacuum gauges and pumps use an RS 485 bus for local communication. An Allen-Bradley co-processor module buffers the commands and readbacks for these devices. The connection of this system to the FECs where the vacuum ADOs reside is via TCP/IP over an Ethernet port in the Allen-Bradley co-processor.

The cryogenics control system is a commercial system with connection to the RHIC control system for logging and monitoring via a shared file system.

The Beam Loss Monitor (BLM) system and the Beam Position Monitor (BPM) system make up the bulk of the instrumentation channels for the control system. MADC modules will be used to digitize the loss monitors. The logic to detect beam losses, fast and slow, are done in a custom designed VME module, in parallel to the digitizing of the signals. These signals from the BLM system play a role in enabling the beam permit link to allow beam. In the BPM system digitization takes place in equipment in the tunnel. Digital data is brought to the FECs using the IEEE 1394 bus. Commercial VME modules in the FEC store the BPM data in memory where it is used by the BPM ADOs.

4 Software Infrastructure

The main software infrastructure in the FEC consists of drivers for VME modules in the FEC, support for Accelerator Device Objects (ADOs), an event system in the FEC, the ADOs themselves, and a commun-ications protocol that exports ADO methods across the network. The Console Level Computer (CLC) infrastructure includes ADO support, methods to set and get ADO parameters across the network and an ADO development environment.

UNIX style drivers (open, close, ioctl, read, write) which run under vxWorks, have been written for the VME modules used in the system. Drivers isolate the details of the operation of the boards from the higher levels of the system.

An ADO is an instance of a C++ class which contain data and methods for a group of parameters. The most important class methods for device control are the set and get methods. The set and get methods can use the device drivers to access the underlying controls hardware. Tasks in the FEC provide a context for executing ADO methods (set and get) in response to accelerator events and to network messages. ADO parameters are the common and the lowest level interface to the control system. ADO classes have been written to support all the current hardware.

The application program interface to ADOs on the CLCs is through the ADO Interface class. The basic methods in this class are the set and get method which are used to set and get parameters from ADOs distributed over the network. The class also contains methods to get parameters asynchronously.

Support for development is an important role played by the CLCs, although not by the actual Console Computers. Because the crafting of ADOs is such an important part of the RHIC control system a preprocessor was written to generate C++ code for the ADO classes from a compact RHIC ADO definition file. The preprocessor takes care of automatically generating the house keeping and communications methods for the ADO allowing the designer to focus on the important set and get methods and event code.

5 Utilities and Generic Tools

The RHIC control system makes use of tools that were developed for the AGS. Because RHIC and AGS operations will use the same control room, operator consoles, and be run by one team of operators, it is important that RHIC and AGS control programs have the same look and feel. To insure a common look and feel the mature AGS GUI library, built on Motif, is used for all user interfaces. A style guide, based on the GUI library, is provided for programmers writing user interfaces.

Early on in the development of the RHIC control system there was a need seen for a generic data driven application which could be used for testing ADOs and in turn, the underlying hardware. A Page Editing Tool (PET) with a spreadsheet like table interface was written, using the GUI library, to support software developers, engineers and commissioners. The PET program is now widely used for many aspects of development and for operation of some equipment.

A messaging system is in place in the FECs to generate alarms in the AGS alarm system. A variety of useful programs and utilities, such as a program launcher, print utility, crash logs, and monitors, developed over the years for the AGS, will be used, as is, by the RHIC control system. Work is currently underway to specify the RHIC needs in the areas of logging, general data display and save/restore. It is expected that existing AGS programs can be modified to fulfill most new RHIC requirements. Services have been written for both ADOs and AGS Logical Devices so that the cdev[8] object can be used as a common interface to the AGS and RHIC control systems.

There are a number of Sybase databases on the console level database server which support the control system from the device level up to the accelerator physics level. All the FEC configuration information, including ADO instances, is managed by the database.

6 Applications

About a dozen applications, most with physics content, have been identified as required for the first year of running. Only a few of these applications were in any way tested in the Sextant Test. Most of the applications will be written by the RHIC Accelerator Physics staff over the next year. After initial success in early tests with the ADOs, it was recognized that console level ADOs would be useful for some applications. Many of the application designs incorporate a manager level program which runs at the Console Level. The manager provides a context for ADOs which are a higher level abstraction of accelerator objects than the rather hardware orientated FEC ADOs. Adding this manager level to applications allows the user interface code to be separated from the accelerator physics part of the application and provides a well defined interface for programs that may need the higher level functionality of the application contained in the manager. The sequencer will use managers. Development of manager ADOs is supported by the same tools used to support front end ADOs.

In order to prevent unforeseen problems with controls when the entire accelerator is being controlled, the RHIC control system will be exercised (without beam) for controls performance measurements, scaling measurements and applications prototype testing beginning in April of 1998.

7 Conclusion

Over the next year about 100 FECs with about 1,400 VME modules and tens of thousands of connections to accelerator equipment must be installed and checked out from controls programs. While this work is going on there will still be development work to be done at various levels of the control system. At the same time controls will have to support various subsystems coming on line. Each of the individual technical task are understood and well in hand but accomplishing of all the tasks that need to be done over the next year will be a challenge.

The demands on a control system are very great at commissioning time when workers are trying to get subsystems to work reliably in a production setting. It will be a considerable challenge to have an operational control system ready to support the commissioning effort in 1999.

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