Hardware Controls for the STAR Experiment at RHIC

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Abstract

A hardware controls system has been implemented for the STAR experiment at RHIC. Approximately 10000 parameters governing experiment operation are currently controlled and monitored.

The system is based on the Experimental Physics and Industrial Control System (EPICS). The architecture of STAR hardware controls will be presented as well as the results of operation of the integrated baseline system. Novel features of the system include a specialized field bus (High-level Data Link Control – HDLC), new EPICS record support, Control DEVice (CDEV) interfaces to accelerator and magnet control systems, and C++ based communication between STAR online and Hardware Controls and their associated databases.

I. INTRODUCTION

The Solenoidal Tracker At RHIC (STAR) experiment uses a large Time Projection Chamber (TPC) for the study of ultra-relativistic heavy ion collisions. The baseline subsystems of the STAR experiment are the time projection chamber, data acquisition (DAQ), trigger, online computing and magnet. The first STAR commissioning run began in June, 1999. The first collision at the Relativistic Heavy Ion Collider (RHIC) for physics studies is scheduled for Spring 2000 [1].

The main tracking device in STAR is a cylindrical Time Projection Chamber (TPC), 4.18 meters in length with inner and outer radii of 0.5 m and 2 m respectively [2].

The STAR Hardware Controls system sets, monitors and controls all subsystems. In addition, Hardware Controls can generate and display alarms and warnings for each subsystem. A real-time VxWorks environment is utilized for this purpose and a controls software package, EPICS, is used to provide a common interface to all subsystems.

II. STAR HARDWARE CONTROLS INTEGRATION

The baseline STAR detector consists of various time projection chamber subsystems (anode high voltage, cathode field cage, gating grid, front-end electronics power supply, HDLC link, gas, laser, interlocks, and VME-crate control), mechanisms for the exchange of information with the STAR trigger and online as well as external magnet and accelerator systems. The relationship of the STAR Hardware Controls to other systems is shown in figure 1.

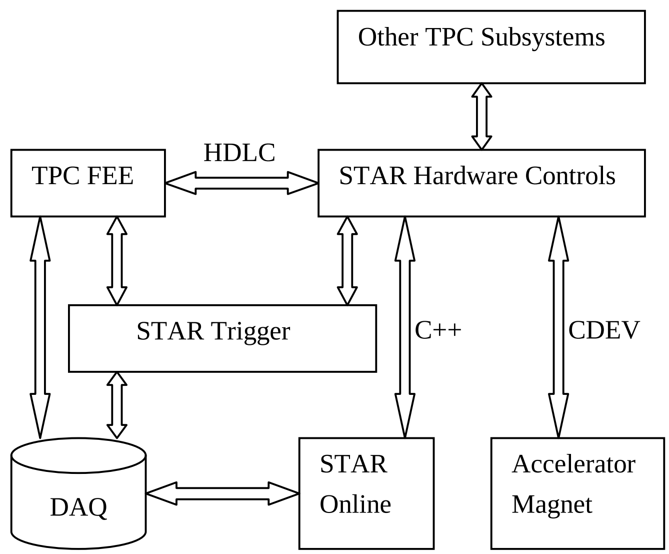

Fig. 1 STAR Real-Time Systems.

The high-voltage supply for the TPC anode wires creates high electric field regions near the TPC endcaps. Here the charge avalanches occur due to the electrons from the ionized gas in the main TPC volume. The anode high-voltage system controls an Arcnet connection to the LeCroy 1458 power supplies. The voltage and current are ramped, set and monitored using EPICS sequencer programs.

The cathode and field cage create a uniform electric field in the TPC. The voltage gradients are set up using four resistor chains. Any changes in the gas temperature, pressure and composition can vary the drift velocity. Detection and feedback mechanisms have been implemented to maintain a constant drift velocity. A Glassman high-voltage power supply provides the high voltage at the cathode central membrane and center of the field cage. New EPICS driver support has been written for four VMIC modules: a 64-bit differential digital input board (1111), a 32-channel relay output board (2232), an analog to digital converter (3122) and a digital to analog converter (4116). In addition, precision measurements are made of the voltage drops and current through the final two resistors (region nearest the endcaps) of the field cage chains. These are monitored using a new EPICS driver providing a GPIB connection to a Keithley electrometer.

A bipolar gating grid is located 10 mm from the anode-wire plane. The gating grid separates the drift volume from the amplification region. It controls the passage of electrons from the drift volume into the amplification region and also prevents ions created in the amplification process from entering the drift volume. The potentials on the wires of the gating grid can be regulated to make the grid opaque or transparent to the drifting electrons while being completely opaque to ions. This is achieved because the drift velocity of electrons is about 1000 times larger than the drift velocity of ions. Specialized control electronics were developed for STAR. The control cards for the gating grid reside in a VME crate on the electronics platform. EPICS drivers have been written to control the potentials on the gating grid and to monitor its status.

There are over 4000 front-end boards in the endcap regions of the TPC for amplifying, shaping and digitizing signals from the TPC pad plane. These boards are powered by 144 low voltage Front-End Electronics (FEE) power supplies. Hardware Controls remotely controls power to the FEEs via six Acromag digital I/O boards that are connected to solid state relays. A new EPICS driver has been written for this purpose. FEE cards are connected to 144 readout boards also located on the TPC endcaps [3]. In order to have reliable links to the readout boards, easily identify any malfunctioning readout boards, communicate with a large bandwidth over a distance of about 30 meters under a strong magnet field and minimize cabling using a multi-drop topology, a High-level Data Link Control (HDLC) protocol (1 Mbit/s) was selected as the field bus for the experiment [4]. The HDLC link has been interfaced with the EPICS software from which a number of control and monitoring tasks can be performed [5]. The VME interface, a Radstone SBCC-1 board, supports up to four HDLC channels. Each HDLC channel communicates with six readout boards over an RS-485 link. A new EPICS record and related EPICS driver support have been written for this purpose. Using the HDLC link for testing, a bit pattern can be sent to a readout board to initiate the creation of an analog pulse. The FEE cards that are connected to the readout board will receive the pulse signal, then amplify and digitize it. By comparison of the output data with the original input, operation of the event memory buffer and the electronics can be examined. The HDLC link controls the routing of the digitized data to the buffer on the readout boards or directly to DAQ via a fiber optics link. If the data is sent to the buffer, it can be read back by Hardware Controls via the HDLC link. Data can also be sent from the buffer to DAQ. A comparison of the data between Hardware Controls and DAQ allows the integrity of the data acquisition and HDLC paths to be verified. In addition, voltages and temperatures on the readout boards can be monitored via the HDLC link. The EPICS-HDLC link enables monitoring and controlling of the readout boards, serves as an alternate access to the data, and makes the debugging of readout and FEE boards and cabling significantly easier. HDLC will also be used for four upgrade detector subsystems.

The gas system maintains a high-purity mixture of 90% argon and 10% methane in the drift volume of the TPC. The system can also purge the chamber with argon or nitrogen to avoid damage to the detector. The gas control program runs on a PC using the Windows NT operating system. Data is saved every 20 seconds on a cross-mounted disk which is accessed by Hardware Controls. The values are displayed in EPICS. This is the only subsystem with a front-end not under the direct control of an EPICS interface. The implementation of an EPICS front-end was not cost effective since the gas system was developed in Russia using interfaces developed specially for the STAR experiment [6].

A high-power laser is used to calibrate the TPC drift volume. Beam strength and polarization are controlled by a system using a half-wave plate and a Glan polarizer. Hardware Controls monitors and sets the laser status through a VMIC 32-channel relay output board.

The safety interlock system is controlled using an Allen-Bradley PLC system. This stand-alone system passes status information via TTL signals to a STAR front-end, an Acromag 948X digital I/O board. All required personnel and property protection is mandated to be independent of STAR Hardware Controls. Additional systems monitor temperatures, humidity and cooling water flow.

At STAR, EPICS front-end readout (IOC - input-output controller) programs are distributed among twelve VME processors (of the types MVME 147, 162, 167). STAR electronics controls are housed in eleven 6-u and three 9-u Wiener VME crates. Since during run time there is no access to the platform where these crates are physically located, remote control of the VME crates is required. This is achieved through a built-in VME-CANbus interface. The VME crate-control program controls the power status of the VME crate, sets the fan speed and monitors temperature. All the VME crates are daisy-chained with a unique crate address assigned to each [7]. To allow an orderly transition of the system during a power shutdown of short duration, uninterruptable power is supplied to the crate housing the CANbus interface as well as to the platform ethernet hub, terminal server and platform-based workstation. A second system oversees the 14 VME crates used for data acquisition.

A solenoidal magnet surrounds the TPC. It provides a 0.5-Tesla magnetic field, allowing for momentum measurements on the charged particles that pass through the TPC. The magnet is operated as part of the accelerator controls system. Magnet status information is obtained from the accelerator controls database using a Control DEVice (CDEV) client/server interface. Other accelerator information can be obtained in a similar manner. Beam scalar information, STAR experiment status and STAR measurements of the magnetic field can also be provided to the RHIC control group using CDEV.

Based on rapidly digitized distribution information for each RHIC beam crossing, the trigger system determines whether or not to initiate recording of a particular event. A LeCroy 1440 high-voltage power supply is used to provide high voltage to the phototubes inside the Central Trigger Barrel (CTB) detector. Hardware Controls monitors and sets the voltage on each channel of the LeCroy 1440 via an RS232 serial connection. Communication is accomplished using the subroutine records. New subroutine functions were written for this purpose. Additional support for VME access to STAR-specific CTB trigger boards has been written.

All of the Hardware Controls EPICS configurations will be set and monitored by the STAR Online Computing system as part of Run Control. The set of databases for a particular run configuration is maintained by Hardware Controls. The set of all possible run-time databases are stored as part of Online Computing. The appropriate set is transferred to Hardware Controls as Run Control transitions between various operating states. At present, this connection consists only of an interface between EPICS and Objectivity [8]. This connection will be completed by the Spring run. This will require a C++ program similar to that for the magnet system. In this case, however, Hardware Controls acts as both server and client. As a server, Hardware Controls sends the detector configurations to the online group. As a client, Hardware Controls receives new configurations from the online group and puts them into the EPICS database.

III. STAR HARDWARE CONTROLS SOFTWARE

EPICS was selected as the foundation for the STAR control software environment because it incorporates a standard means of sharing information and services, graphical display and control interfaces, and a robust, real-time operating system [9]. EPICS was designed and is maintained by Los Alamos National Laboratory and the Advanced Photon Source at Argonne National Laboratory as a development toolkit [10].

At STAR, EPICS is run on Sun workstations connected to VME processors running the VxWorks operating system. The EPICS run-time environment consists of several integrated components that share a standard communication layer. The components of EPICS used at STAR are:

- The Motif Editor and Display Manager (MEDM) is an operator interface that provides full-color, window-based screens that can mimic control panels.
- The Graphics Database Configuration Tool (GDCT) is the design tool for a distributed, run-time database that isolates the hardware characteristics of the I/O devices from the applications program and provides built-in, low-level control options.
- A sequencer that implements state-based control in order to support system automation.
- The Alarm Handler (ALH) that displays the alarm status hierarchically in real time.
- A data archiver which acquires and stores run-time data and retrieves the data in a graphical format for later analysis.
- An interface to a channel access program that establishes a network-wide standard for accessing the run-time database.

The backbone of EPICS readout control is a set of databases which will be loaded into the VME processors. At STAR, each database includes records written for monitoring and controlling parameters relating to a single subsystem. Users access these parameters through a Graphical User Interface (GUI) screen designed within MEDM. The State Notation Language adds more features to the database design, such as an I/O connection with the host machine and the flexibility of controlling the individual records within the database. The structure and software configuration of EPICS is shown in figure 2.

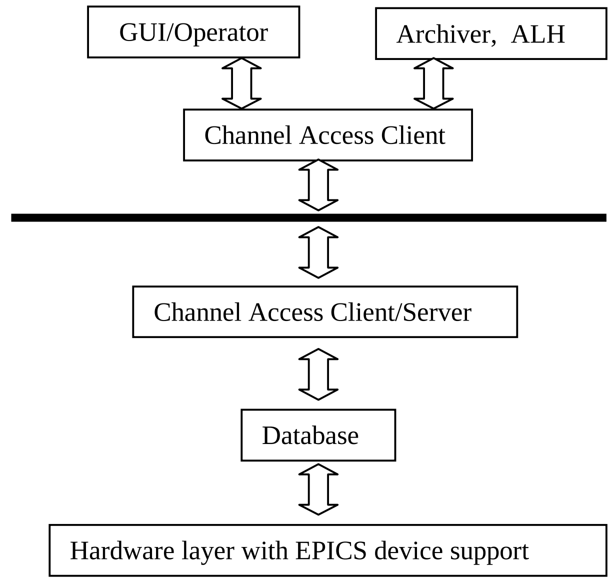

Fig. 2. Structure of EPICS with interface to hardware.

Between the RHIC controls system and STAR EPICS software, there is a software interface, a CDEV gateway service, which is used for exchange of information. There is a single network connection between the client and the gateway through which all CDEV requests are routed. This gateway receives a request from the client (STAR), establishes an appropriate connection to the actual service that is requested, and returns the results to the client Application Program Interface (API) [11]. There is also special CDEV GUI display software, CDEV MDEM, which is used to display the CDEV information obtained over the gateway.

The server contains a Device Definition Language (DDL) file which maps the RHIC information, such as magnet variables, to EPICS. On the client (Hardware Controls) side, there is a client DDL file that maps all the received data into the EPICS variables. The client API then uses the devices and instances defined in the both DDL files to fetch the data into EPICS. The schematic connection is shown in figure 3.

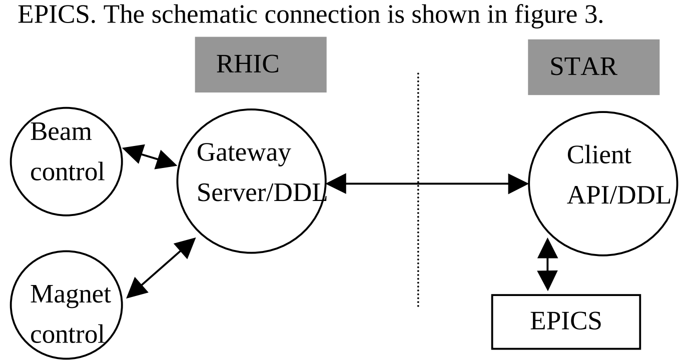

Fig. 3 Gateway service between RHIC and STAR

IV. SUMMARY

An EPICS-based control system has been developed for the STAR experiment at RHIC. The system developed contains a number of new EPICS implementations. HDLC provides the field bus used by the experiment for controls and as an alternate data path. Data transfer to and from external magnet and accelerator control systems is accomplished using CDEV. An interface between EPICS and an Objectivity database has been written. The system has begun operation as part of an engineering run during the summer of 1999. STAR Hardware Controls maintains the system-wide control of the STAR detector with its EPICS databases at the subsystem level.

V. ACKNOWLEDGMENTS

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