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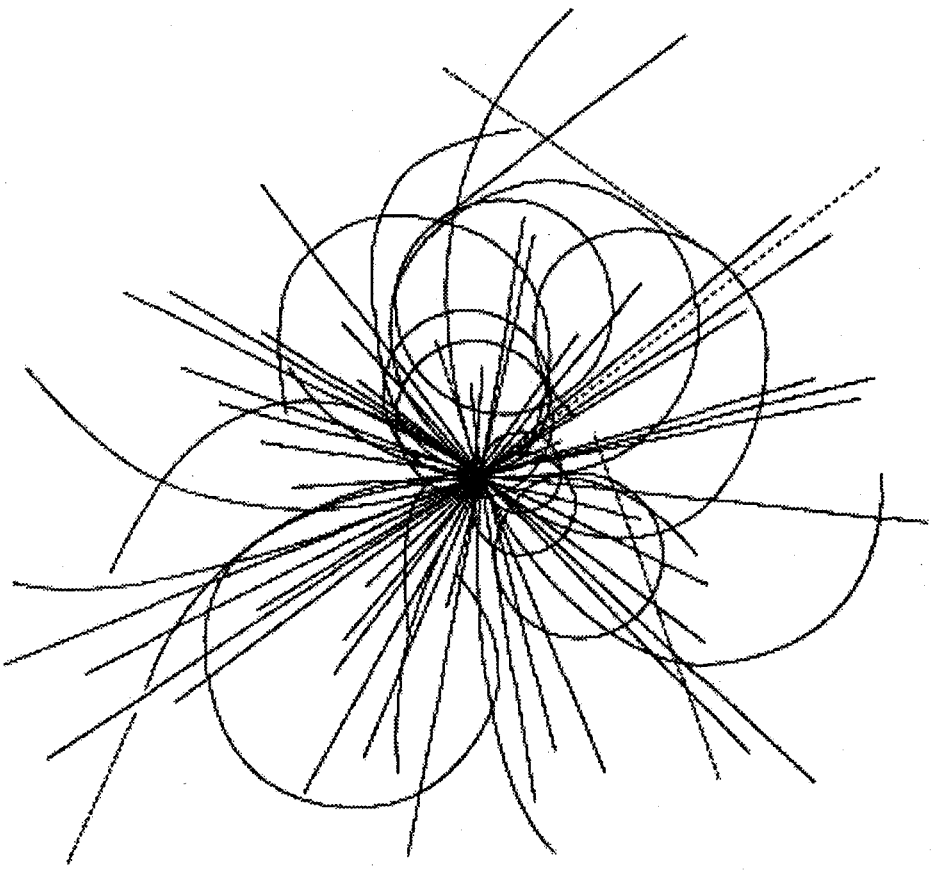

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DATA ACQUISITION AND CONTROLS FOR THE SSCL ACCELERATOR SYSTEMS STRING TEST PHASE I

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INTRODUCTION

The Accelerator Systems String Test (ASST) was a major milestone in SSCL R&D. Phase I demonstrated that the smallest repetitive sequence of bending magnets (a half cell) could be installed, leak checked, cooled to liquid helium temperatures, energized, and safely quenched. To support this activity, a control system had to be developed to operate and monitor cryogenic systems in the string, along with LCW and vacuum systems. Also, since this is a test facility, the magnet systems were heavily instrumented to provide sufficient data to confirm that design requirements were met, that the system was operating safely and as expected, and allow further design studies necessary for the construction of the SSC. This required the design and implementation of an acquisition system capable of collecting relatively large amounts of data, at various data rates, and presenting this data both to operations personnel and to a database for off-line analysis. In this paper, we describe the design, implementation, and operation of the data acquisition system and controls employed on the ASST.

SYSTEM REQUIREMENTS SUMMARY

The string components included a feed spool piece/recooler (HSPRF), five dipoles, a spool piece recooler (SPR), one quadrupole, and an end spool piece (HSPE). Instrumentation from these components included 120 cryogenic temperature sensors, 20 cryogenic pressure sensors, 24 vacuum gauges, 2 strain gauges, 3 linear position sensors, 32 accelerometers, 3 flow sensors, and 2 level sensors. Control devices included 2 immersion heaters, 6 on/off valves, 2 variable position valves, and 9 mass flow controllers. String electrical monitoring included 5 current transductors, 50 differential coil voltage taps, and 3 system voltages. The ASST specification dictated requirements for log data acquisition, transient data acquisition, and process controls to support this mix of instrumentation and

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control devices. The interface configuration of the instrumentation had to be flexible to support the special requirements of individual test requests to be performed on the ASST.

The transient data acquisition system presented a challenge with channel count and per channel sample size. A maximum of 256 transient event recording channels were required for the half cell configuration of the ASST. Synchronous recording of all transient channels is initiated on a triggered event, such as a signal from the magnet quench protection system. Sampling rate and sampling time requirements varied from 2000 samples per second for 30 seconds to 10 samples per second for 30 minutes. High sampling rates were required for the magnet power system, the string electrical signals, and the accelerometers. Medium sampling rates were required for cryogenic pressure and valve actuator signals. Lower rates were used for string temperatures.

Data Acquisition Electronics

To meet high accuracy measurement requirements, a sensor excitation and signal conditioning subsystem was designed and fabricated for the critical instrumentation. This subsystem is based on an 8-channel excitation and conditioning board packaged as a shielded 9U Eurocard module. An integrated backplane on a 19 inch rack mountable crate accommodates eight of the 8-channel modules and a single computer interface card. All analog, digital, and DC power supply I/O is accomplished through a crate backplane with rear access connectors. The front panels of the 8-channel modules have analog test points, excitation polarity switches, and gain setting displays for each channel.

Each channel has a fully independent excitation source. The excitation circuitry features computer controlled polarity switching, front panel polarity override switch, DIP switch programmable excitation values, and a 1K ohm 0.01% precision reference resistor. The reference voltage developed across the precision resistor is conditioned by a programmable gain instrumentation amplifier stage and routed to the crate backplane independently for each channel.

The signal conditioning for a sensor voltage input consists of an independent programmable gain instrumentation amplifier stage. The amplifier output for each channel is routed to the crate backplane. The amplifier gain setting is displayed using front panel LED and is also available for readout by the computer interface card.

The sensor signals from the excitation and conditioning subsystem are cabled to 64 channel VXI relay multiplexers. Pre-conditioned signals from flow controllers, vacuum process controllers, pressure sensors, and other devices are connected directly to VXI relay multiplexer inputs. A 5 1/2 digit VXI voltmeter module measures the voltage from the selected multiplexer channel.

A second set of multiplexers and a second voltmeter are provided for the conditioned excitation reference voltage outputs cabled from the excitation and conditioning subsystem. During sampling of a high accuracy channel, the conditioned sensor voltage is connected to one voltmeter and the conditioned excitation reference voltage is connected to the other voltmeter. The two voltmeters are armed and the VXI instrument trigger is used to initiate a simultaneous reading of the sensor voltage and reference. The excitation source for the high accuracy channel is then switched to the opposite polarity by the VXI controller, and after some settling time a second pair of simultaneous voltage readings are

taken. The positive and negative voltage readings taken from the sensor and the excitation reference are algebraically manipulated to eliminate offset voltages from thermoelectric effects, the instrumentation amplifier stage, and the voltmeter. A precise value for sensor resistance is then calculated from these results.

The ASST transient data acquisition requirements were met by the joint development of a specification for a VME module by the SSC Controls Department and Analytek, Ltd. of San Jose. Analytek then designed and built the modules (designated model 2032LC) for use in the ASST acquisition system. Eight of these 32-channel modules were connected to a single transient acquisition controller managing the configuration of the digitizers and the retrieval of sampled data at the completion of post-event sampling.

The VME and VXI crates associated with data acquisition are interconnected via ethernet to UNIX workstations. These computers act as file servers, database servers, man-machine interfaces, and data analysis stations.

Data Acquisition Software

Periodic data logging is performed at a sample rate of five minutes. This data is used in both the real-time monitoring of the condition of the string and for off-line data analysis of heat leak measurements and other slow processes.

Transient data recording captures the conditions and state changes of the string during a quench event or during a magnet current dump. In contrast to the periodic data logging, transient data is acquired at much higher sample rates for the same set of transducers, as well as additional transducers which record string voltages and currents developed during a quench event. Sample rates are assigned to individual transducers to meet specific instrumentation and data analysis requirements. Transient sample rates can be as high as 10kHz, and several thousand samples can be recorded for a given transducer during an event.

Data acquired for both the log and transient data acquisition is managed by and made available from a commercial Relational Database Management System (DBMS). Oracle was the DBMS selected for this purpose. The Application Programmers Interface of ORACLE was an important component in the implementation of our distributed Database access routines.

All Database access uses a library of routines written to provide application software distributed access to the information maintained by the database. Implemented using Remote Procedure Calls (RPC), these routines provide a set of function calls which allow configuration, log and transient data to be stored and retrieved from the database server. The calls were developed specifically for the data tables and data schema maintained by the DBMS.

These routines allow read and write access to channel configuration data, logged data, and transient data related to individual quenches. For each channel, the configuration database contains such channel attributes as its hardware address, its sampling rate, and engineering unit conversion data. The application software which runs in the real-time embedded systems uses the channel configuration information to set up the hardware and drive the real-time acquisition process.

The process of engineering unit conversion is implemented using an embedded RPN expression interpreter. This interpreter provides all standard math functions, as well as standard polynomial and Cheveychev polynomial evaluation of the Nth degree.

There were two major applications written to support the acquisition and recording of data for the log and transient data channels. The first is an application which manages the log data hardware and channels. This application, running in a Hewlett Packard Model 300 VXI system, configures and manages the multiplexers, digital multi-meters, parallel I/O cards, and counter card which comprise the hardware supporting log data acquisition. On request, this application reads the configuration of the log data channels from the DBMS for use in data acquisition, conversion and display.

The second major application of the data acquisition components of the system is the software which manages the transient data recorders. This software runs in a mode similar to the log data acquisition process described above, retrieving channel configuration information from the database, configuring and arming the Analytek recorder cards, and causing the data recorded in a triggered card to be written out to the database.

Data Analysis Software

The second major portion of this system are those components which are used by the operators and analyst to monitor and perform data analysis tasks on the logged data. It includes the DBMS described above; human interface which allows the user to select from the thousand or more channels maintained by the system some set onwhich they wish to operate; a trending and plotting package, and a commercial data analysis package (N!Power).

PROCESS CONTROLS SYSTEM

String cryogenics process control variables included power lead temperatures, recooler levels, shield temperatures, and valve positions. String vacuum process controls monitor 12 Convectron gauges and 12 cold cathode gauges. The LCW system included a cooling tower, a heat exchanger, a closed loop cooling water system, a deionization loop, and a backup water loop. LCW controls were programmed for supply pressure, temperature, and resistivity and for a full monitoring and alarm system with interlocks to the magnet power supply.

The string cryogenics, string vacuum, and LCW process control systems were implemented using TI (Siemens) model 545 programmable logic controllers (PLCs) and 505 series I/O modules. A separate PLC was programmed for each function. The string vacuum and LCW systems were configured in single 16-slot crates. The string cryogenics system required a second I/O crate with a remote base controller (RBC) to accommodate the number of I/O points involved. A TISTAR Model 20 system was used as a common operator interface for all three functions.