DIGITAL CRYOGENIC CONTROL SYSTEM FOR SUPERCONDUCTING RF CAVITIES IN CESR*

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Abstract

Effective cryomodule control and monitoring are essential components to successful operation of CESR (Cornell Electron Storage Ring). The ability to quickly diagnose system problems can have a dramatic effect on machine down time. The CESR SRF Digital Cryomodule control system, employing a PC and a commercial PLC and user interface, is presented. With these tools, system status is available at a glance or, if needed, detailed system information can be displayed. Straightforward configuration of PID (Proportional Integral Derivative) control loops, safety interlocks, signal display, and data acquisition is the main feature of the system. The SRF cryomodules have several modes of operation. For example, under normal machine running conditions, liquid helium level is regulated using a liquid- level signal as the process variable (PV). For cryostat cool-down, the flow rate of cold helium gas returning to the refrigerator directly reflects cryomodule cooling rate and is a more useful process variable. Both these operational modes use the same control variable (CV): the liquid helium supply valve control signal. Other operational modes include warm-up and RF processing. This control system can be reconfigured quickly to meet the conditions of different operational modes.

INTRODUCTION

Previous SRF cryomodule monitoring and control at Cornell's Laboratory for Elementary-Particle Physics (LEPP) [1] has been implemented using discrete controllers for each loop. All control settings were entered at the front panel and loop behavior was also monitored there. The computer interface for these controllers was via RS232 computer interface at a one-minute data rate. Vacuum and cryogenic temperature monitoring was done with commercial vacuum controllers and in-house built signal processing printed circuit cards. Interlocks were implemented with a combination of fast switching circuitry and hardware relay logic.

This discrete module control system was failure prone and lacked full remote capability. It has been replaced with a programmable logic controller (PLC) crate with ten modules, described in Table 1.

Before SRF cryomodules are installed in CESR, they are tested in the high power test area. Because much experience has been gained cooling down and warming up CESR cryomodules in this test area, it was chosen as a good place to revamp the cryogenic control system. PLCs are widely used for industrial applications and have proved to be reliable for controlling CESR Klystron HV power supplies.

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Table 1: CESR's ControlLogix Crate

Slot	Module	Part #	Description
0	Logix5550 Processor	1756-L1M1	512KB Memory
1	Ethernet	1756-ENET/B	Ethernet Bridge
2-5	Analog Input	1756-IF16	16 Channel Non-Isolated Voltage/Current Analog Input
6	Analog Output	1756-OF8	8 Channel Non-Isolated Voltage/Current Analog Output
7	Relay Output	1756-OX8I	8Point 10V-265V AC, 5V-150V DC Isolated Relay N.O./N.C.
8-9	Digital Input	1756-IB16I	16 Channel 10V-30V DC Isolated Input, Sink/Source

HARDWARE

Break-Out Box

The cryomodule break-out box serves as the interface between the module and the control rack. The box houses DC power supplies for all cryomodule signal processors. It also houses the signal processors for cryogenic linear temperature sensors (CLTS), thermocouples, water flow, and linear variable displacement transducers (LVDT), as well as housing differential amplifiers. All but a few signals port through the break-out box. Standard twisted pair and coaxial cables link the break-out box with the control rack.

Programmable Logic Controller (PLC)

The hardware interface of the digital control is the Allen Bradley ControlLogix PLC [2]. The PLC crate has 10 slots for modules. ControlLogix crates also require an attached power supply.

The computer network portion of the system uses the Ethernet protocol and is set up as an independent subnetwork for RF cryogenic control. This network is referred to as a Virtual Local Area Network (VLAN), and the network architecture provides a means for qualified PCs to communicate while isolated from non-RF system computers but maintains administrator-level access to the VLAN.

Each signal is processed before it reaches the PLC. All system connections with the exception of vacuum pump power supplies and some RF field signals are made through a break-in panel with pluggable connectors. From the break-in panel, vacuum and liquid helium signals go to their respective commercial controllers for processing. The analog outputs for these, along with the signals that are processed by the break-out box, are then routed to a series of multilevel terminal blocks. These terminal blocks serve as an intermediate distribution point between the PLC modules and the rest of the system.

Each PLC module is also fitted with a removable terminal block. This second group of terminal blocks can be bench-wired and then plugged into the front of their respective modules. Each removable terminal block and module can be manually keyed to insure a correct match. The manufacturer claims that removal and installation of these terminal blocks can be done under power, but they caution that if field side power is applied, this can cause arcing at the contact point, which can result in a build-up of contact resistance.

The control rack is designed to be completely portable, thus facilitating off-site rack fabrication and, if needed, installation following acceptance tests.

The PLC has the added advantage that it can run independently of the user interface should network or PC problems arise.

SOFTWARE

All programs in this system are running on a PC with a Windows 2000 operating system.

Ethernet

The Ethernet network interface was chosen for its speed, low cost, and broad applications to general computer system hardware throughout the commercial market.

Digital Interface and Control Software

Three principal sets of software are at work here: Allen Bradley's RSLogix 5000, Kepware's KepServerEX, [3] and National Instruments Lookout [4].

PLC Software

RSLogix 5000 is the programming software for the ControlLogix PLC. With this software one can configure the I/O modules and program the PLC with a ladder logic editor. Through a series of dialogue boxes, one can configure I/O modules for current or voltage, communication mode, data rate, fault reporting, among other things. Through the ladder logic editor, the user programs the PLC with familiar terminology. One can choose from a variety of instructions ranging from basic And/Or to complex mathematics, PID, and motion control. Once the program is complete, it can easily be verified prior to implementation. The program and configuration can then be downloaded to the PLC.

Some additional PLC software features include fault reporting for the crate controller and modules, and wire-off detection for the individual module channels.

OPC Server

Communication between the PLC and the network requires linking software. KepServerEX provides this link between the PLC and the user interface at the PC. This link is an industry open-specification standard, generally known as OPC (Object Linking and Embedding for Process Control), that was developed to provide a means for different manufactures of hardware and software to work together in a seamless manner [5]. Although Allen Bradley makes an application called RSLINX that provides similar connectivity, KepServerEX was chosen due to CESR's previous experience with it and its low cost.

National Instruments Lookout

For this system, Lookout is the user interface, commonly referred to as a human-machine interface (HMI) with supervisory control and data acquisition (SCADA) capabilities. Lookout is object based, that is, it uses object linking and embedding (OLE) to make connections to and from memory locations, which are referred to as tags. Once Lookout is able to communicate with the PLC, building the user interface is simple. Lookout connects to the PLC through an OPC client object. Once this object is created, all appropriate tags are visible in the Lookout object explorer. For example, to create a display for temperature, one opens the object explorer and moves down the file tree to the tag that will be displayed, then selects the item by right-clicking and dragging it to the area of display. Several display methods are available; in this case, one would use the default which is numeric display. This object can also be copied and morphed into another type of display, such as a potentiometer or bar graph.

The SRF cryogenic system status panel is the heart of the user interface, shown in Figure 1. From this panel, one can view the entire system and its health. Detailed system information that can be displayed encompasses: cryogenic system parameters, including liquid helium level, helium bath pressure, cryogenic and thermocouple temperatures in and on the cryomodule, cryogenic transfer line temperature and pressure; vacuum status, including cold cathode and Convectron (760 Torr to 1 mTorr); and system interlocks.

Another feature of Lookout is that rendered AutoCAD drawings arranged in layers provide a mechanically accurate path to view, for instance, historical data and alarms for system components.

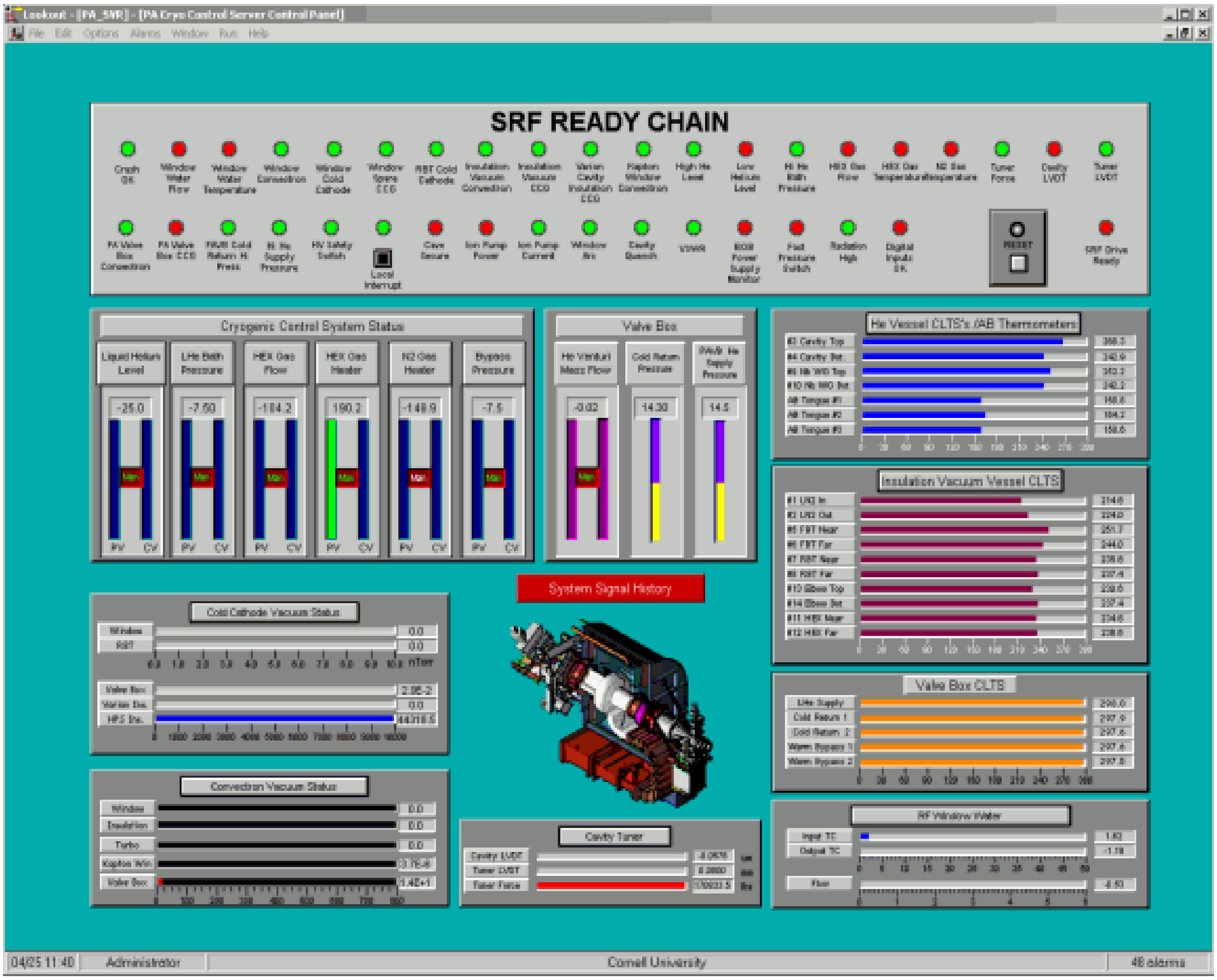

Figure 1: Cryomodule Root Control Panel

CONCLUSIONS

The digital cryogenic control system now being used at CESR has several advantages over its predecessor.

The small footprint of the hardware interface is convenient. Off-site assembly of the control rack and open access to test points makes for easy maintenance of the system. The layout of the multilevel terminal blocks allows ready access for trouble shooting and general testing. It also allows for any reconfiguration or modification of the system as CESR's superconducting program develops.

Once the developer becomes familiar with the software, building the user interface can be done in a timely manner. The HMI is an excellent tool to understand the status of the cryomodule because it allows the user to locate problem areas quickly. As the cryogenic system complexity increases, the graphical user interface provides visual information that is quickly comprehended by the experienced and by those less familiar with the SRF cryomodule.

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