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A NEW CONTROL SYSTEM FOR AN OLD TANDEM

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In an effort to maintain the most flexible environment for accelerator-based atomic physics research at the Oak Ridge National Laboratory EN Tandem facility, a recirculating terminal stripper project has been in development. In the early stages of planning for this upgrade, the necessity for monitoring and control of various parameters in the accelerator terminal was considered. To provide proper flexibility and accuracy, telemetry via computer seemed to be the obvious route. Since the development of a robust system that would not be prone to upset from sparks was necessary, a phased development approach was taken. This involves first converting the accelerator's ground potential systems, then ion source (~100 kV) systems that can be easily accessed by merely running down high voltage supplies, and finally terminal potential systems that operate in high pressure gas at potentials exceeding 7 MV. Progress to date, including hardware arrangement and software development, is discussed.

1 Background

Over the past 35 years, systems for control of the ORNL EN Tandem evolved into a potpourri that included: variable voltage transformers, DC voltages controlled by various potentiometers one to twenty turn in resolution, and AC syncro-repeaters that were abandoned by the U.S. Navy before World War II. High voltage isolation was accomplished via insulating rods for control and TV cameras for remote readback. The high voltage supplies consisted primarily of oil-filled voltage-doubler types. While planning for installation of a recirculating terminal stripper system, it was realized that an overall upgrade and standardization of all accelerator systems control and monitoring, not just those in the accelerator terminal, would be necessary to realize the performance and efficiency improvements desired.

1.1 Initial Considerations

Factors in the process of selection of hardware, software, and configuration were (1) an absence of in-depth experience in control systems, (2) limited programming talent, (3) the various extreme conditions that the hardware must endure, (4) the wide scope of controls to eventually be included, (5) a very limited operating budget, and (6) limited personnel resources. Accelerator user input was sought and considered throughout the project.

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A large portion of the devices to be controlled and monitored by the system are not at ground potential, and all are remote from the control station. In addition, large EMF bursts from accelerator and ion source sparks tend to induce spikes in control and power lines. This would be very hard on digital electronics connected to hard-wired communications leads.

Another major consideration was the Man-Machine Interface (MMI). Based on personal experience with several computer-based accelerator control systems and review of other systems (many observed during SNEAP lab tours), a system arrangement was developed. That system would include the combination of assignable shaft encoders, or "virtual knobs," assignable analog meters, and computer graphics screens to produce the an intuitive interface for both experienced and unseasoned operators.

Most of our high-voltage optics supplies were over twenty-five years old, and not readily adaptable to remote programming. Luckily, my predecessor had purchased several remotely programmable supplies for an upgrade that he had not been able to complete. Electrostatic steering supplies would have to be purchased or constructed.

1.2 Control Hardware Selection

Several control system hardware arrangements were investigated. Industrial control systems are robust, well proven, dependable, and relatively easy to program. Their weaknesses are limited analog control capabilities, bulk, cost, and a lack of proven accelerator EMF environment hardening. To obtain the necessary voltage isolation, fiber-optic communication for these systems had to be added on.

The necessary hardware is available to construct a CAMAC-based system as used at the Holifield Radioactive Ion Beam Facility 25 URC tandem. Programming for such a system would be straightforward. Unfortunately, the hardware would be prohibitively expensive for this purpose.

Various PC board components are available to control GPIB, serial, and VXI instruments, but none were judged to have the flexibility or EMF immunity desired, and all were limited in communications abilities.

The hardware chosen was the ControlNet system by Group3 Technology Ltd. of Auckland, New Zealand. This system, designed for accelerator control, has built-in fiber-optic communications using inexpensive plastic single-strand fibers. ControlNet systems are comprised of a loop controller in the PC and Device Interfaces (DIs) located in the field. The loop controller handles communications and provides for the computer I/O. The DIs house the I/O boards, providing various services including communications, addressing, and error checking to the I/O boards. The Device Interface I/O boards provide the necessary I/O functions for hardware interfacing to power supplies, etc. Device Interface I/O boards are available for most accelerator control or monitoring tasks. The components were designed and hardened for the environment of high voltage accelerators. The physical dimensions are also attractive when planning installation into existing equipment and the accelerator terminal.

1.2 Control Software Selection

Due to price/performance, availability, and primarily personal experience, a rack-mount 100-MHz Pentium-based control computer was ordered. This permitted a wide range of programming languages for the system. Quick BASIC and Visual BASIC were considered. Several control system packages were reviewed and rejected for lack of adaptability to the application, or due to poor speed through use of DDE for all communications to hardware. A demo of LabVIEW from National Instruments was impressive in speed, graphics quality, and flexibility. LabVIEW has the added advantage of providing ready-made graphic controls and displays that are easily customized. A LabVIEW driver is available for the ControlNet system, but a driver could be written in any language that can address memory in the adapter area. Learning to program in LabVIEW involved a slow early progression while changing programming habits, followed by rapid progress and pleasing results.

2 Progress

2.1 Control Hardware Arrangement

The ground potential DIs, ion source elevated potential DIs, and terminal potential DIs communicate with the control PC via three separate fiber optic communications loops as shown in Fig. 1. Each loop has its own communication controller and shared memory area in the PC. The three loop controllers are contained on a single ISA bus PC card. This permits a phased installation and provides uninterrupted communications to any DIs that are powered.

In addition to the transorb suppression provided by the ControlNet signal conditioners, MOVs are added to all power lines, and all leads into and out of the shield boxes containing the DIs pass through ferrite suppression cores.

Signal conditioning not provided by the ControlNet hardware is achieved through either commercial conditioners (for thermocouple inputs), or simple locally made op-amp circuits.

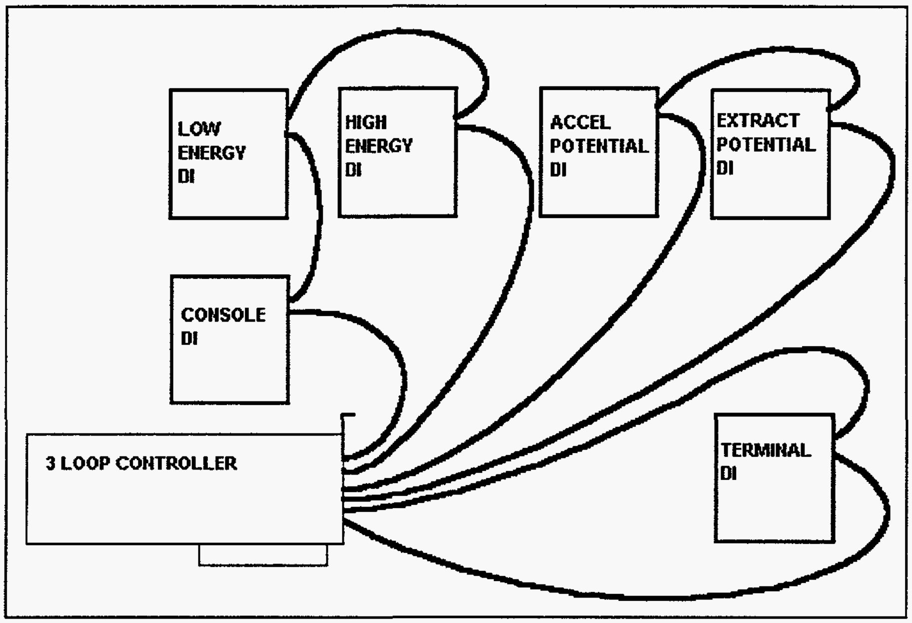

Figure 1: Control Hardware Arrangement.

Ground Potential Loop:

The Console DI provides four quadrature encoder inputs, eight analog outputs, and 24 digital I/O points for inputs from the "virtual knobs" and the Assign, Save, and Restore buttons, and for output to the analog meters. The DI also controls the locking of the control computer keyboard.

The Low Energy DI provides eight analog inputs (16 bit), eight analog outputs (14 bit), and twenty-four selectable digital I/O points for control of the Ion Source Accel voltage, Low Energy Steerers, and Einzel Lens #3.

The High Energy DI provides eight analog inputs, eight analog outputs, and two serial ports for control of the High Energy Steerers (magnetic), Magnetic Quadrupoles, and monitoring of selected vacuums.

Ion Source Potential Loop:

The Accel Potential DI provides eight analog inputs, eight analog outputs, and twenty-four selectable digital I/O points for control of the Ion Source Extract voltage, Ion Source X/Y Steerers, and Einzel Lens #1.

The Extract Potential DI provides eight analog inputs, eight analog outputs, and twenty-four selectable digital I/O points for control of the Ion Source Probe voltage, Ionizer current, Cesium Oven current, and monitoring of the Cesium Oven and Source Body temperatures.

Terminal Potential Loop:

The Terminal DI provides two analog inputs, one analog output, eight digital I/O points, and controls for four stepping motors including limit and course analog position inputs (8 bit) for control of the terminal stripper gas valve, foil stripper, turbo pump, and belt light, and to monitor the terminal stripper pressure.

2.2 Software Development

The software was written with several primary goals. Reliability was of highest priority. Controls should have obvious functions, and the system should promote an efficient flow of operator actions. Finally the software should remain flexible for continued improvement.

The graphics displays were designed with considerations of logical control groupings, as shown in Fig. 2. Attention was also given to the actual appearance of the controlled elements, and to displays the operators were already familiar with (in the case of our old CCTV system).

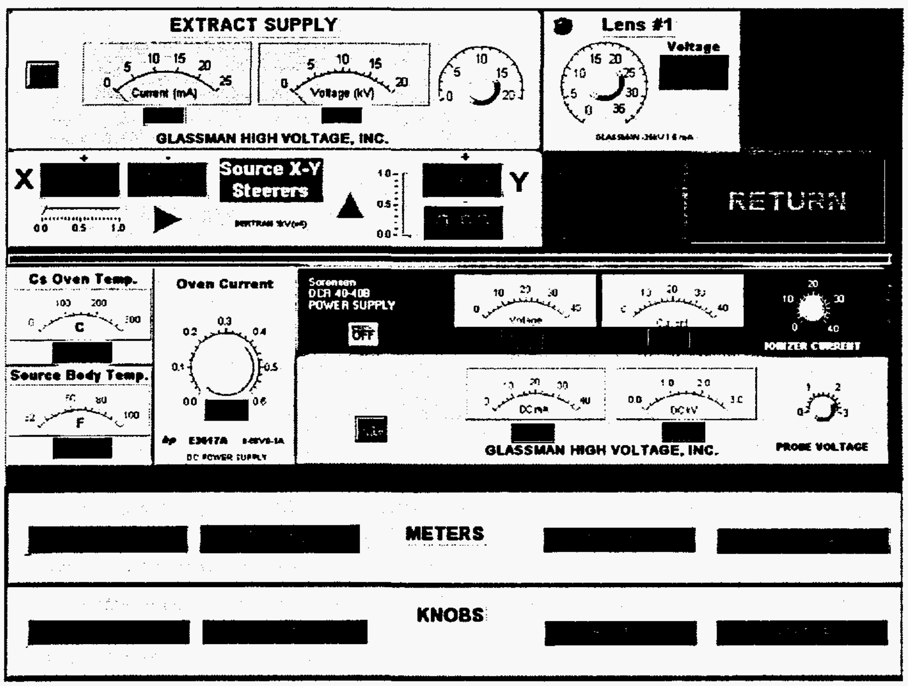

Figure 2: Screen capture of the Ion Source controls display.

A main "mimic buss" display of the overall facility layout with "hot spots" that can be "clicked" on to permit selection of desired control groupings first greets the operator. Also included is a button to run a program that calculates the NMR for the analyzing magnet. A twenty-inch 1024 x 768 pixel color monitor sets immediately above the panel that contains the assignable meters and shaft encoders. This presents an operating station that appears to the operator as one integrated unit as depicted in Fig. 3. A trackball is used for selection of assignable tasks and to control Boolean switches. The keyboard, stored on a slide-away holder, is used only for data entry while recording run settings and calculating the NMR. It is disabled at other times to increase program security.

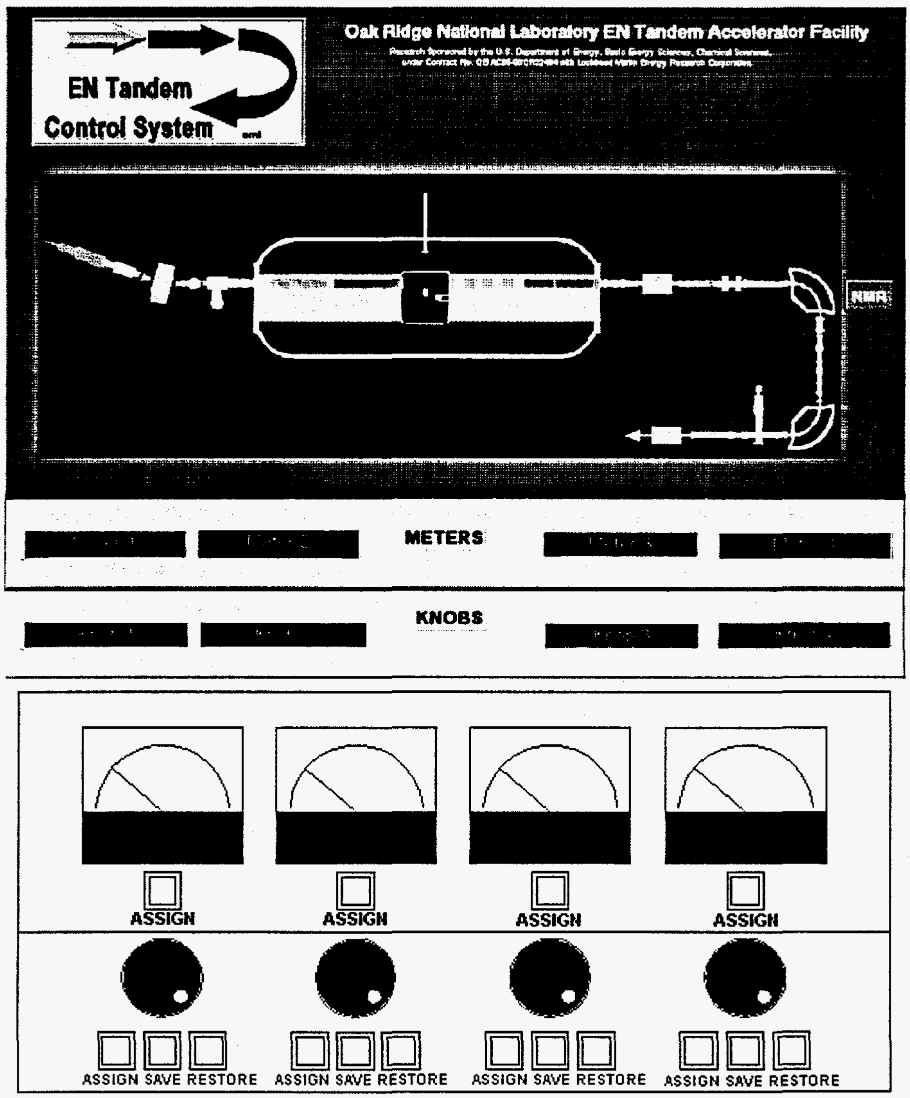

Figure 3: A screen capture of the opening mimic buss page and a drawing of the Meter and Knob panel. This depicts the integrated operating station presented to the operator.

The program makes extensive use of "global" variables, a programming taboo in LabVIEW that was necessary to provide the functionality needed. An element can be assigned to any shaft encoder by first pressing that encoder's associated "ASSIGN" push-button. This is indicated by the text "READY TO ASSIGN" in the encoder's associated assignment label on the screen. Next, the operator positions the trackball-controlled cursor over the image of the control for the desired element and "clicks" any of the trackball buttons, which assigns that control to the selected encoder. Individual control settings can be saved by pressing the assigned encoder's "SAVE" push-button, and if further tuning proves unproductive, that setting can be recalled by pressing the associated "RESTORE" push-button. Analog meters can be assigned in a similar manner to any displayed readout.

Each control's resolution was selected to provide adequate sensitivity for fine tuning without forcing the operator to waste efforts spinning an overly fine control to reach normal operating values. A feature that the users are looking forward to is a controlled rate-of-change for the ionizer current that will only permit the requested current to change at one amp per minute up to twenty-five amps, then one-half amp per minute beyond twenty-five amps. This will free the operator during ion source startup to do other tasks, while insuring a gentle ramping of the current. This feature has been installed and tested in software, and awaits installation of the Extract Potential hardware for implementation.

2.3 Steering Supplies

A potentially costly power supply replacement was for the electrostatic steerers. The Low Energy steerers consisted of two sets of vertical HV plates, powered by voltage-doubler type supplies and controlled by varying the 110 AC supply voltage with Variacs. The two sets provided a effective method to minimize offset and steering of the beam entering the accelerator. Toggle switches at the control console operated high-voltage relays to reverse the output polarities of the 1.5 kV supplies. The Ion Source steerers used similar supplies for the single sets of horizontal and vertical plates.

Photomultiplier tube supplies rated for 4 mA at 1 kV were obtained from Bertran High Voltage. These supplies feature remote voltage programming, remote voltage monitoring, and short circuit protection. A pair of positive and negative supplies are paired to drive the steerer plates via a high-voltage relay wired to reverse output polarity on switching. The power supplies and reversing relays are controlled by the new control system. Software interlocks prevent operation of the relays with high voltage applied.

3 Performance

The system was initially installed and tested in early August 1996 with only the Low Energy controls in service. The High Energy steerers were soon added to the system, followed by the Ion Source Accel Potential (~93 kV from ground) controls. In September, with a total of fifty-nine I/O points serviced by the new system, several experiment runs were conducted with the accelerator. Operator comments were all positive, and problems restricted to the failure of a used 24-volt power supply in one of the steerer supplies.

Installation of the remaining portions of the system will be governed by manpower, research program, and budgetary considerations. Programming for a logging program that would permit the recall of a previous run's settings was begun by Ken Friesen of Bethel College, Bethel, Kansas, while on a University of Tennessee/ORNL Summer Research Fellows Program. It is planned to fully implement this software improvement soon.

One of the goals that was successfully met by this system is for the controls to appear "real-time". There is no sensation of response lag, and the controls feel as if hard wired to potentiometers.

4 Acknowledgments

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