CONTROL OF ION SOURCES FOR THE ZERO GRADIENT SYNCHROTRON (ZGS)*

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Summary

A controls' philosophy used during research, development, and operation of ion sources for the ZGS has been instituted. The total control design concept aids in the learning curve during research, development, and the turnover to the operational group. The system is designed for manual control, central computer control, and programmer computer control. The operational multiplicity is achieved by time sharing and priority interrupt assignments. Individual control console design varies with source complexity, but basic functions are similar.

Introduction

Most programs of research-development-operations evolve such that the three periods are not planned in a manner of each interrelating to one another. As such, rather than the program moving smoothly from transition point to transition point, continuity is lost. Programs continue but with costly expenses (time, money, moral, etc.). To improve on this situation, a plan is developed to provide a related controls' system from the program's inception. The program plan is defined with inputs from all related groups.

The supporting controls' effort frees the research period from the engineering of transducers, controls, and displays. The engineering areas mentioned are necessary but generally unimportant to the primary task. The developmental period benefits from the controls' support for the same reasons. The operating period benefits because questions are referenced to a common plane--the controls which the operations' group helped define at the program's inception.

Controls' Philosophy

Overall Approach

The controls must be built with the three periods in mind; some basic requirements for each period are

Research:

1. data taking (transducers),
2. manually operated controls (common panel),
3. defined timing functions (automatic),
4. displays,
5. contingency expansion of 1, 2, 3, and 4.

Development:

1. data logging (automatic),
2. semiautomatic controls,
3. contingency expansion of the research requirements.

Operational:

1. remote operation,
2. automatic control (computer),
3. contingency expansion of research and development (R&D) requirements.

A general block diagram of the controls' approach is shown in Fig. 1. The equipment located locally consists of the transducers, the multiplex/analog-to-digital converter (MPX/ADC), bistable controls, the distributor (a fanout device), and the data link. The remote equipment consists of the data link, the manual terminal (control and display), the computer terminal, and the programmer terminal. During the R&D periods, the controls are operated with the remote equipment located locally. This points out once more the common reference plane of controls for all the periods of the program.

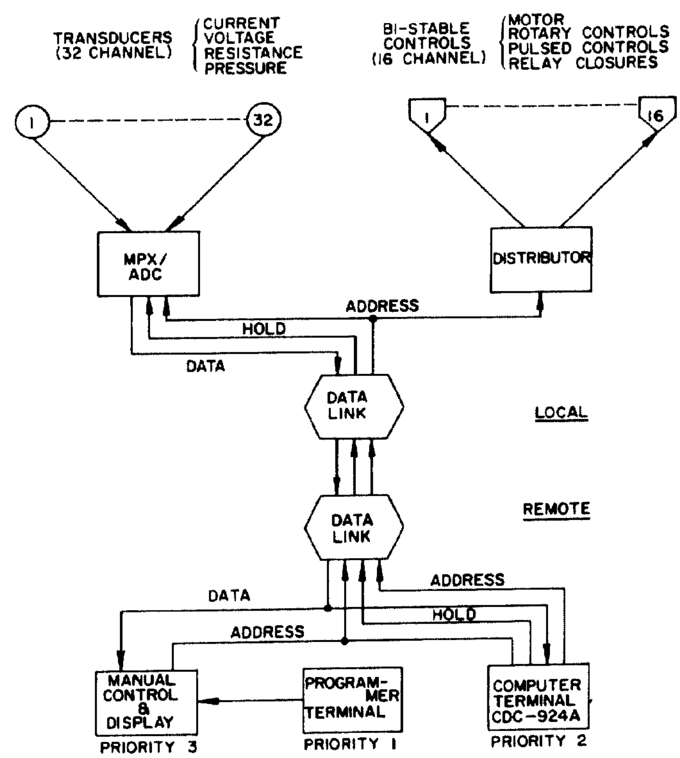

Fig. 1 Block Diagram of Ion Source Controls

The controls are predicated on using the minimum of cabling; and, thus, the three remote terminals time share the data link and cabling. The manual terminal is free running and asynchronous with the other two terminals, and this necessitates priority assignments and interrupts. The computer terminal is synchronized with the programmer terminal, and a software package eliminates conflicts. The computer and manual terminals have six-bit address capabilities; the programmer terminal has a timed pulse output.

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The terminals are integrated in a manner such that the programmer uses the manual terminal's addressing capability and has a priority interrupt over its normal data transmission. The computer terminal is integrated into the control system at the data link. The data link provides the final priority interrupt and the time sharing of its cabling. The data link treats the computer terminal as the highest priority and interrupts the manual terminal. The computer terminal has two addressing capabilities, one used for control and the second for data logging. Data is steered to the terminal requesting it and not the other. The total real time utilized by the functional capabilities of the programmer and computer terminals is < 1%.

Below is a table comparing the three terminals.

Addressing Technique

The three-wire system is capable of monitoring 32 transducers and controlling 16 bistable controls. One wire handles both the MPX and distributor addresses simultaneously, another sends serial data from the ADC, and the last handles the hold pulses.

The addressing is a six-bit binary code and assigned as:

1. binary codes 1, 3, 5...31 for monitoring control data (16 transducers monitoring controlled functions),
2. binary codes 0, 2, 4...30 for monitoring data (16 transducers for monitoring stand-alone functions),
3. binary codes 32, 33, 34...63 for operating 16 bistable controls.

Any address from 0-31 received at the data link is converted by the MPX/ADC only. Any address from 32-63 is converted and received by the distributor and the MPX/ADC. The MPX address is modified at the local data link so that the 32 bit is dropped and the 1 bit is added if it is not present. As an example, motor D is assigned the addresses:

38 for up,
39 for down, and
38 or 39 modified to
7 for its data.

A four-wire system is necessary for more complex systems. For instance, the controls for the new polarized proton ion source (PPIS) will have four wires and capabilities of monitoring 64 transducers and controlling 32 bistable controls. The address modification takes place in the remote date link but is the same coding technique.

Cabling

The cabling between the data links can be altered in length for whatever requirements are necessary. In the R&D periods, the cabling is only a 5-ft length. During the operation period, it is lengthened. In the case of an ion source operated in a high potential enclosure, the cabling is altered to light links for data transmission.

Typical Control System

A typical control system using the basic control philosophy is shown in Fig. 2. This system is used with the 30-Hz H^- source presently in its development period. The equipment on the left is local to the source; the equipment on the right is the remote operating equipment. During the R&D phases, the equipment is located as shown and operated from the monitor/control panel. When the equipment becomes operational, the local and remote sections are relocated and the data link cabling lengthened.

Human Engineering

An important aspect of a control system is the effort spent in consideration of the human interaction,

Terminal	Timing	Priority	Terminal Output	Terminal Input	Function
Manual	Asynchronous	#3 interrupted by #1 and/or #2	6-bit address (64 discrete codes)	14-bit serial data (accurate to 1 part in 10,000)	1. Capable of monitoring all transducers; display by exception. 2. Capable of controlling all bistable controls one at a time.
Programmer	Synced to the ZGS	#1	Single pulse/time (pulse converted to a 6-bit address by the manual terminal)	None	Timed functions (Source start, etc.)
Computer	Synced to the ZGS	#2 software timed to the programmer	6-bit address for bistable control	None	Capable of controlling all bistable controls each ZGS cycle.
			6-bit address for data logging	14-bit serial data	Capable of monitoring all transducers each ZGS cycle.

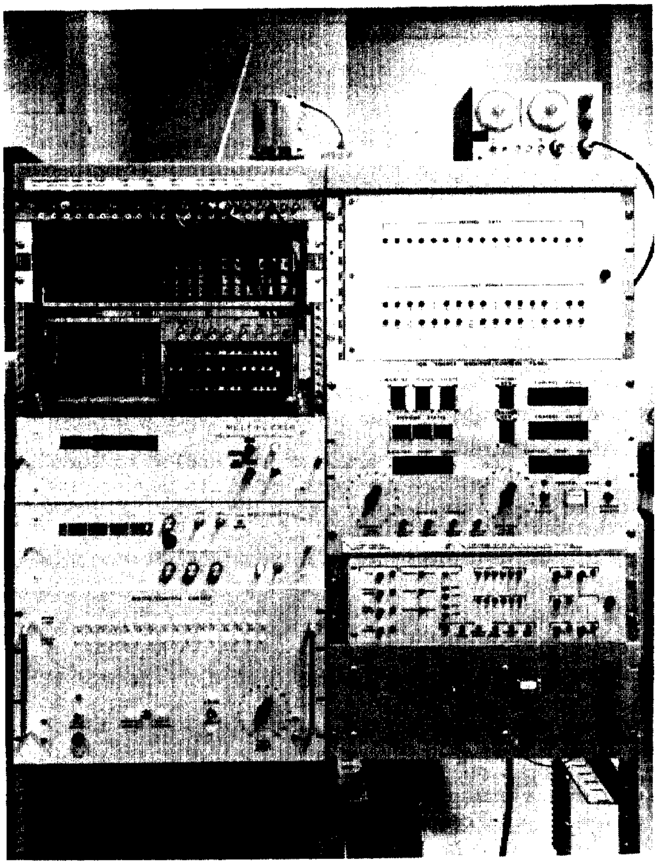

Fig. 2 30-Hz H^- Ion Source Controls

his ultimate acceptance of and ease in using it. The addressing technique, as described, ensures that operator interaction is based on a control-readout correspondence having no delay. The data is updated every 200 ms, which is about the normal human action-reaction response.

Another system consideration is how many displays are necessary for the human to effectively control the system. Certainly there is not a one-to-one correspondence, and display by exception can be utilized. In the H^- source, the correspondence is one display for every four data transducers. Each display can select any transducer.

In conjunction with the display is the advantage of digital readouts (DRO) over panel meters. The accuracy of a 14-bit digital converter is one part in 10,000; with panel meters it would be difficult to be accurate to one part in 100. Thus, data taking accuracy and repeatability of results are much easier to achieve using DRO's.

It is important that the local equipment can be operated locally when the remote equipment is relocated for the operational period. This provides the advantage of being able to adjust equipment or trouble shoot without remote assistance. The design of the parallel control feature is almost trivial to the existing controls.

At least one other consideration is the placement of the displays and the controls. Since most operators are righthanded, the controls should be right-side oriented. Selector switch-readout combinations should have, as closely as possible, visual correspondence. These types of considerations make the acceptance of control systems just a little easier.

Analog Data

This paper has been primarily interested in dc measurements. When a complete transient waveform is important, the system has to be expanded to greater than a three- or four-wire system. Here the problem for all practical purposes becomes a one-to-one correspondence of waveform vs. wire so long as the time constraints are uniform.

Conclusion

To date, two control systems using the basic system philosophy have been built and the PPIS system is being constructed. Excellent success has been achieved, and the response by the scientists and operators has been good. Of most benefit has been the defining of the goals and the ease of transition from phase to phase.

Acknowledgments

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