COMPUTER CONTROL OF BROOKHAVEN 200 MeV LINAC*

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Abstract

A unified control system philosophy allows operation of the linac from a PDP-8 mini-computer with full supervisory control, data acquisition and the full computation capability of the PDP-10 located at the AGS. Interface hardware for diagnostic monitoring equipment and operational control equipment is described. Failure of any link in the control system does not necessitate shut down of the linac, only a diminished control capability results.

Introduction

The 200 MeV linac at Brookhaven has operated under computer control for more than a year. The control system philosophy that was adhered to from initial conception was that of automatic control at the equipment level. That is, all sub-systems are completely independent in their operation, all interlocking and protective circuits are within the sub-system and the only external connections are for services (i.e. power, water, etc.) operational control (power ON-OFF, parameter references, etc.) and parameter measurements.

All sub-systems are tied back through a Local Control Station (LCS) to the Injector Control Room (ICR) where machine operation can be controlled manually. A PDP-8 mini-computer with an 800K word disk is used to afford full supervisory control of all linac systems. A teletype and a graphic display terminal in the ICR are the operator interface devices.

The operating system is based on supervisory control from the input devices, the primary one being a PDP-10 computer located a quarter mile away in the AGS Main Control Room. However, there is minimum dependence upon the PDP-10 for operation.

The primary advantage of this arrangement is that the full capability of the PDP-10 is available for computation while the real time speed of the PDP-8 is used for operational control and monitoring. Operating programs run on the PDP-8, with the PDP-10 being called upon by the PDP-8 to do computation when needed. Under normal operating procedures the operators in the Main Control Room at the AGS determine the operating programs in the PDP-8 by means of the PDP-10. Figure 1 is a block diagram of the overall control system at the linac.

There are manual override controls on all systems up to the level of the PDP-8 interface buffer. This insures continued operation in the event of any type of computer failure. Malfunction of any of the lower level systems is tolerated by controlling the affected system from a level below the failure.

Operating Systems

AC (Power) Controls

The ac controls[1] are a self-sufficient means for turn-on - turn-off and interlock protection for the major equipment of the linac. As described in ref. 1, below any number of control points can be "Daisy-chained". The diagram in Fig. 2 shows how the computer is able to control this system by means of the "DACADS"[2] Binary Function Control Unit. The ability to lock off the power from any point in the chain is strictly adhered to for personnel safety.† When LOCK-OFF is done at any station, no other station can turn the equipment ON until the system is released by the station that locked the system OFF. Upon release by that station, any other station or the computer can turn the system ON.

Parameter Controls

The DACADS is used to control the reference levels of up to 1000 channels of data. The data is input through one of the four DACADS Manual Control Units in the ICR, the DACADS-computer interface, or one of the DACADS Manual Control Units located in a LCS. The data is moved about the system as 12 bit BCD digital data. At each of the DACADS Memory-Multiplex Units the digital data is converted to analog data and distributed to the local systems which use these references. At each of the ten Memory Multiplex Units, 100 channels of video or dc data may be multiplexed into a single line and sent back to the ICR via a video cable. The selected data may also be analog to digital converted and returned in digital form through a DACADS digital channel.

Binary control i.e. ON-OFF control of 54 lines (expandable to many hundreds) is available from DACADS through the Binary Function Control Unit. These channels are presently being used to control rf pulsing of the linac so that pulses of differing proton energies may be made available to different users. Operation of the ac controls, steering magnets and other necessary operating parameters are being connected into the system at this time.

Machine Diagnostics

A device called the Computer Video Switching Interface connects to the ten DACADS multiplexer video lines. By suitable program instructions two of the ten lines can be selected for amplification and transmission to the AGS Main Control Room. Thus, by programmed instructions to DACADS one out of 100 video channels can be selected from each LCS and by a second set of instructions two of these ten can be displayed in either control room. The Computer Video Switching Interface allows simultaneous sample and hold for each of the ten lines. Then multiplexing and A/D conversion for direct use of data in the computer.

Beam Diagnostics

At present a temporary device exists which connects either the Secondary Emission Monitors (Beam profile and position) or emittance measuring electronics to the computer. This interface supplies the necessary signals to advance equipment stepping motors, the multiplexer and the A/D conversion required for input to the computer.

A new diagnostics monitoring system (see Fig. 2) is under construction which will have the capability

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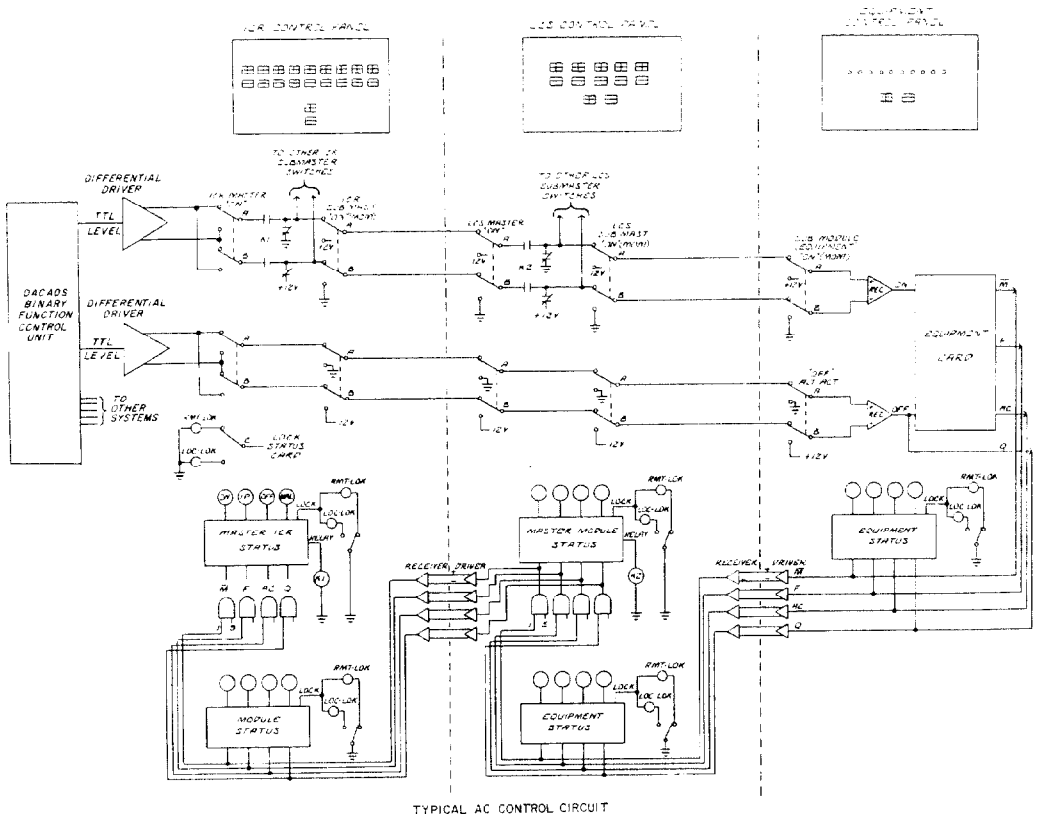
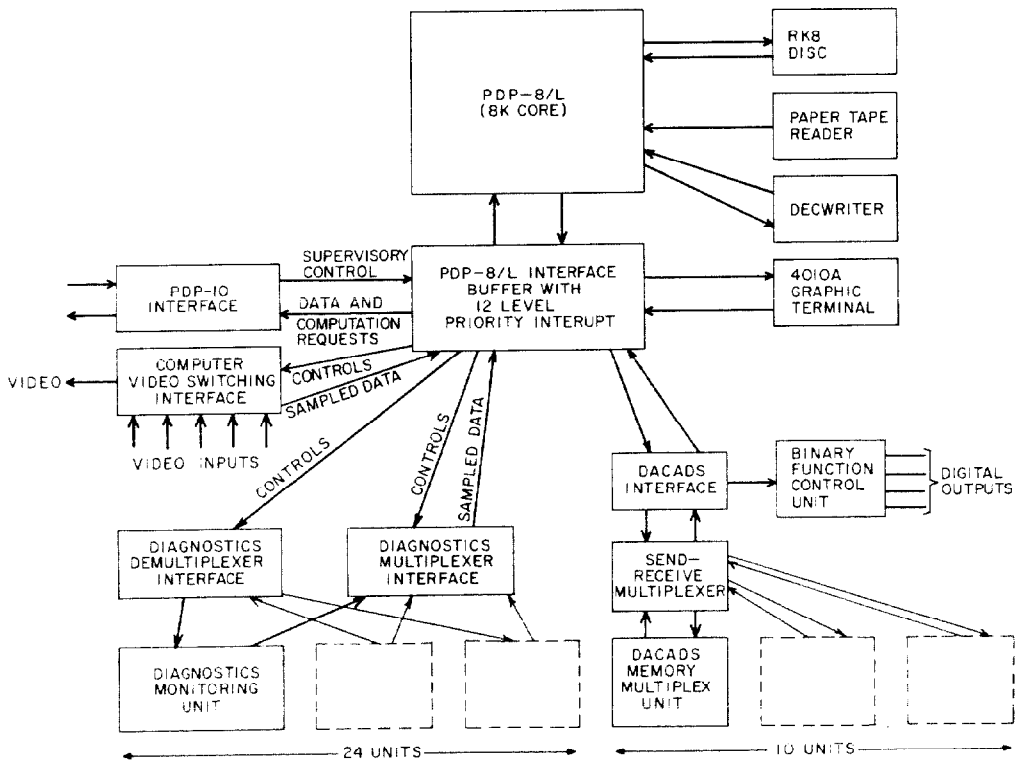
†Other positive safety devices are installed at the equipment.



TYPICAL AC CONTROL CIRCUIT

Fig. 1



LINAC COMPUTER CONTROL BLOCK DIAGRAM

Fig. 2

of multiplexing data and demultiplexing control signals for up to 64 different beam monitoring devices. Twenty-four devices will be installed initially. The basic equipment at a local monitoring point is called a Diagnostics Monitoring Unit and is comprised of 64 sample and hold circuits where data are multiplexed, buffered and sent as analog signals to the ICR. Logic to enable the sample process and then control the multiplexer is contained in this unit. The signals from the diagnostics monitoring unit are routed to the Diagnostics Multiplex Interface where they are amplified, multiplexed, and A/D converted for input to the computer.

The Diagnostics Demultiplexer Interface is controlled by the computer to send logic signals and clock pulses as required to operate the Diagnostics Monitoring Unit.

Operating Philosophy

Supervisory Control

Control of the operating software in the PDP-8 is accomplished by means of selecting a particular program to run on a foreground (interrupt-ON) or background (interrupt-OFF) job stack. When any of the keyboards or the link from the PDP-10 is exercised, an interrupt is initiated and the monitor interprets whether this is a command to add a job to the stack or a response to a previously started program. The operation of the Linac (PDP-8) monitor is identical regardless of where supervisory instructions are coming from (PDP-10 or keyboard).

The advantage of this approach is that new programs can be added to the system without consideration to the fact that there are many ways to call a program, including chaining from other programs. All hardware (displays, disk, etc.) including the link to the PDP-10 are driven by software handlers which are resident in core.

Multiple Operators

The system allows multiple operators to control any parameters they wish. The last command issued is the one which defines the status of the particular parameter. Although the opportunity for conflict exists, this has never been a problem. The usual coordination of operations personnel is such that the job assignments (i.e. preinjector, beam transport, etc.) preclude different operators from controlling the same parameters. In the event that two operators call for the same program or different programs which have conflicts a busy signal is sent to the second operator and his request is put on a queue. The request does not have to be repeated.

At present more real time monitoring equipment is available at the linac than at the AGS and therefore when a problem exists, control is done from the Injector Control Room.

Human Factors

The people who use the system fall into two categories a) Operators, who do no programming and b) Physicists and Engineers, who may do programming and usually operate primarily to incorporate new system equipment or do diagnostics to improve system performance.

Neither of these users groups should be burdened with the need to learn a programming language. The system should be relatively tolerant of typing errors and there should be sufficient opportunity for typing errors to be corrected before execution. All input coding to perform a given function should be the same no matter which terminal or control room is being used for operation. To enable operation from any terminal the operator merely types R LINAC. While a program is being executed the operator can return to the operating monitor control mode by typing CTRL/0. The operator can then start a new dialogue of instructions to the computer.

Program Sequence

An example of a sequence of instructions to run an emittance device and generate a display of the emittance ellipse follows:

1. Call up Emit Program.
2. Start motor drive to move pickup wire into beam.
3. When wire is in active area take data and store in computer buffer.
4. Motor returns wires automatically and signals end of data.
5. Program calls PDP-10 Handler which then ships to PDP-10 a program request (to compute the emittance and generate the ellipse) and instructs to return the results and plot at the ICR.
6. The PDP-10 program calls for the data, makes the computation, and flags the PDP-8 when ready then instructs the PDP-8 to plot the data.
7. This instruction is put on the PDP-8 job stack and when the data for plotting is in the PDP-8 the data is output on the graphic terminal.

Summary

A control system which places heavy emphasis on the human factors aspect of machine operation has been presented. It allows for continued operation in the event of control equipment failure. Portions of the system which have not as yet been installed will cause no disruption of presently operating equipment because of the supervisory nature of the control system.

References

1. D. Greenberg, "Linac Control System AC Turn On for 200 MeV Linac" Proc. 1970 Proton Linear Accel. Conf., NAL Sept.-Oct. 1970
2. I. Weitman and M. Brown, "Data Acquisition and Display System (DACADS) for the 200 MeV Linac at the AGS" ibid.