EFFICIENT AND EFFECTIVE OPERATION OF THE APS LINAC

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Abstract
The Advanced Photon Source (APS) linear accelerator (linac) utilizes two thermionic cathode rf guns and one photocathode rf gun. The thermionic guns are primarily for APS operations while the photocathode gun is used as a free-electron laser (FEL) driver. With each gun requiring a different lattice and timing configuration, the need to change quickly between guns and maintain the required equipment protection puts great demands on the Main Control Room (MCR) operators. This paper discusses how the APS staff has learned to deal with the frequent changes required by a newly upgraded equipment safety interlock system and how they have become familiar with the automated control system called [1, 2] Procedure Execution Manager (PEM). Our linac is controlled via the Experimental Physics and Industrial Control System (EPICS), but the lessons are applicable to any control system.

1. EQUIPMENT SAFETY SYSTEM

1.1 Interlock Support

Equipment protection interlocks are mandatory for all the linac subsystems. The original interlock chassis design consisted of a metal box enclosure containing 24 VDC relays, indicator lights, and terminal blocks that served as a hard-wired junction point between field sensors and the interlock chassis. This was a very robust and reliable interlock system until changes or additional interlocks were needed.

In the past two years components have been added to the linac that required upgrades not only to the interlock systems but also to the Motif Editor and Display Manager (MEDM), which consists of control screens used by the MCR operators. The hard-wired nature of the existing interlock system made it difficult to keep pace with these changes.

It was apparent that in order to support these changes and future project upgrades in an efficient and effective way, a new linac interlock system was needed. This was done using a programmable logic controller (PLC) (see Figure 1) with the following requirements in mind.

- The control logic should be flexible to accommodate frequent changes.
- The system must be highly reliable.
- The system must be physically compact due to space limitations.
- The system must have increased capability for complex interlock conditions.
- The system must provide enhanced information to MCR operators.

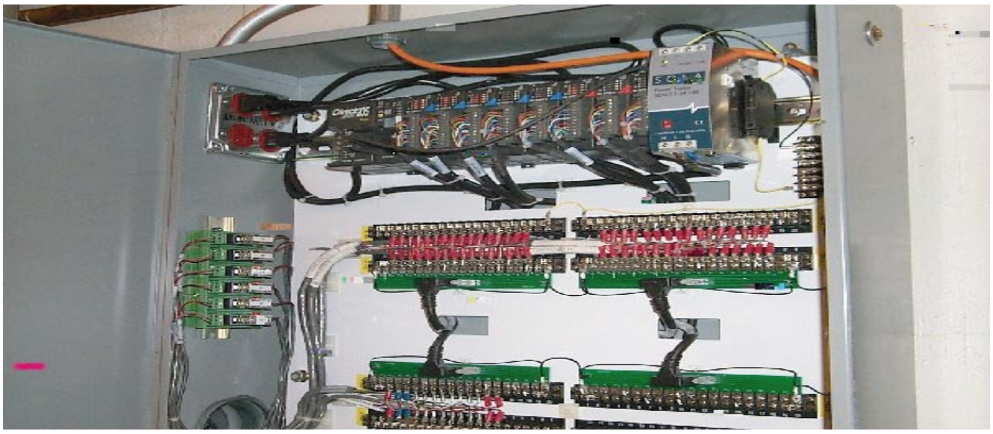

Fig. 1: New Interlock Control Chassis Cabinet

1.2 PLC Selection

A PLC-based system is particularly suitable for applications in which the requirements listed above are important. If system requirements call for flexibility for future growth, the programmable controller brings returns that outweigh any initial cost disadvantage relative to a relay-based system. Even if neither flexibility nor future expansion is required, the PLC-based system can provide tremendous benefits as a troubleshooting and maintenance aid, as well as providing detailed information to the MCR operators via MEDM screens.

The 205 Direct Logic Controller using a DL250 CPU was found to meet or exceed all our requirements. The DL250 CPU had the best system capacity, performance, programming, and diagnostic ability, which will save many hours of programming and debugging time. The DL250 also interfaces well with EPICS.

1.3 Interlock Function and MEDM Displays

In EPICS, equipment is controlled from workstations that communicate over a network with local computers called input/output controllers (IOCs). All systems in the linac that require or use an interlock for equipment or personnel safety protection require a latching function independent of the IOCs. Once a latch has been made, operator intervention is required to reset the interlock.

A typical interlock example, shown in Figure 2, is provided by the linac rf systems. Each klystron requires a 400-watt power amplifier to provide rf input at sufficient levels to drive the klystron. Each amplifier is potentially inhibited by two signals. The first originates in the personnel safety system, known as the Access Control Interlock System (ACIS). The second signal, independent of the ACIS, is provided by the PLC Direct Logic system, which monitors the status of equipment, that must function in order to enable the klystron drive without the possibility of damaging the klystron or the equipment it powers. Examples of monitored equipment include waveguide, arc detectors, VSWR measurements, vacuum measurements, SF6 pressure, and water flow and temperature.

Using the PLC's ability to monitor each interlocked signal separately, the MEDM screen developer was able to design a thorough and robust display for operations and diagnostics. Figure 3 shows a typical MEDM screen that displays the status of interlocks for the sulfur hexafluoride (SF6) system and parts of the beam transport line. In the event of a trip, a quick glance at this screen shows the general source of the problem in an easily understood graphical fashion. Detail screens, like those shown in Figure 4, can then be consulted to determine the exact cause of the problem.

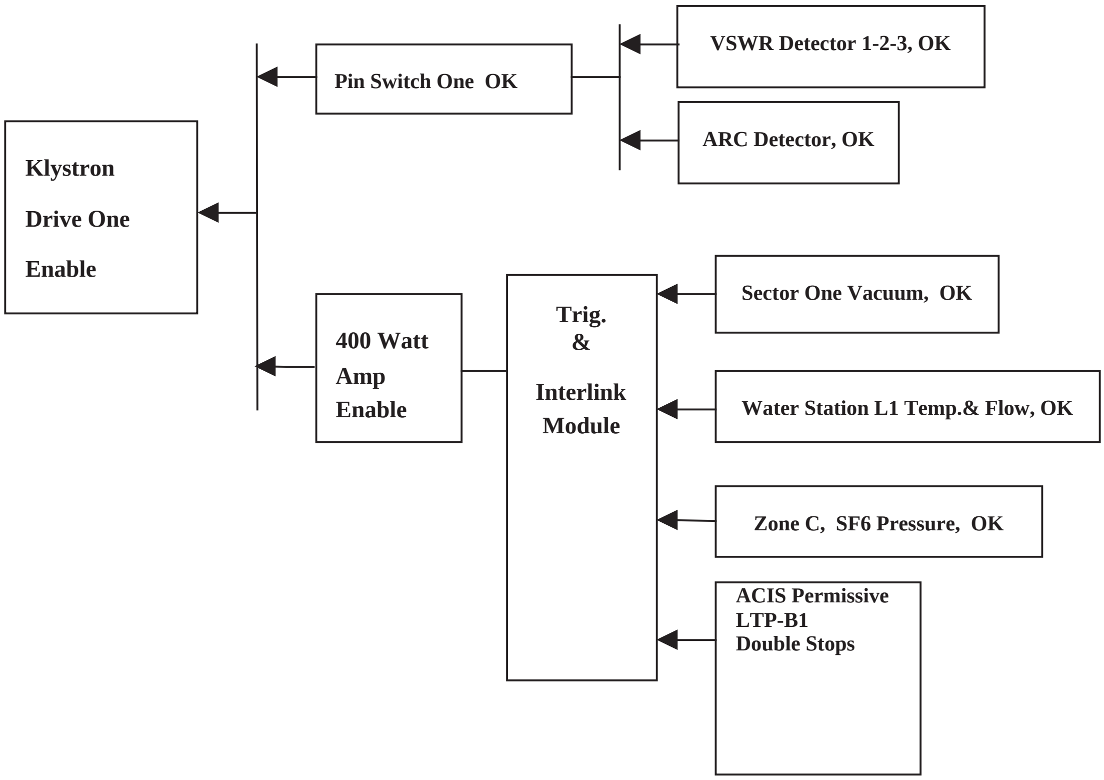

Fig. 2: Typical rf Interlock Logic

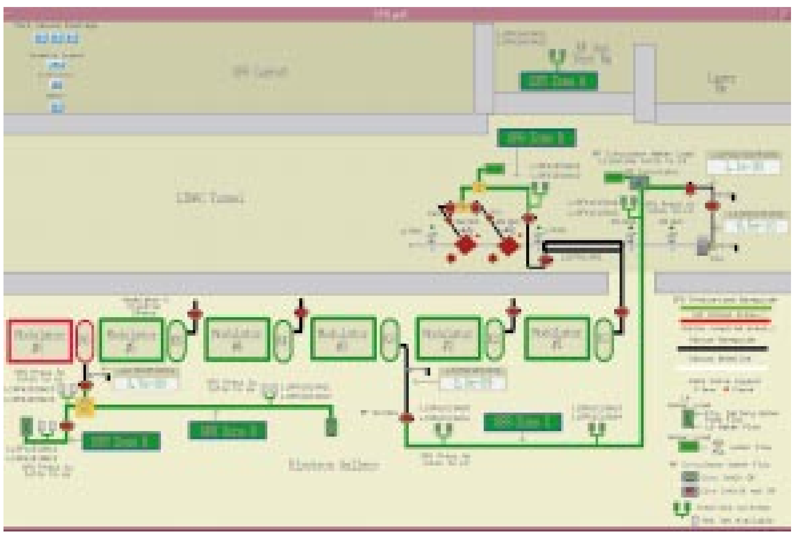

Fig. 3: Typical SF6 Interlock Logic MEDM Screen

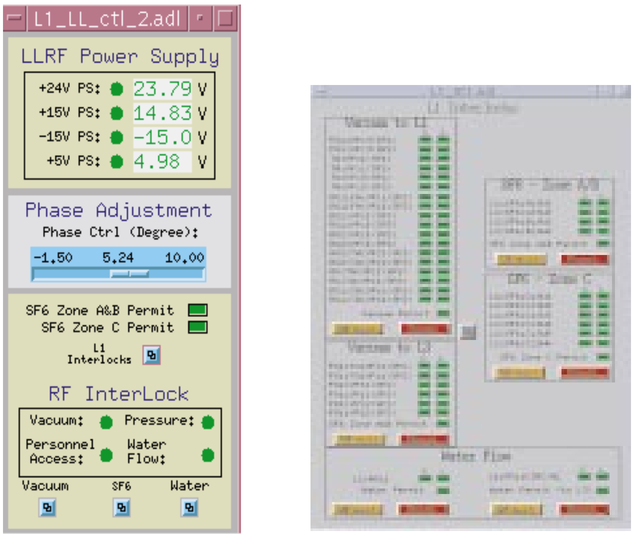

Fig. 4: Typical Interlock Detail MEDM Screens

2. LINAC AUTOMATED OPERATIONS

The APS linac comprises five modulators and klystrons; three electron guns; three dipole power supplies; 35 quadrupole power supplies; 48 steering magnet power supplies; 18 beam position monitors; 7 current monitors; and complex timing, water, and vacuum systems. There are literally thousands of controls and thousands of read-backs incorporated in a multitude of screens that control every aspect of operations. Originally, operators had to switch back and forth among many MEDM screens, performing procedures from memory or with the aid of a written document. In order to perform rapid changes in operating conditions, some Unix scripts were written to perform tasks automatically. Though the scripts worked well under ideal conditions, they could not always be counted on because equipment and operational procedure changes were often made without warning. Furthermore, these scripts were not regulated or source controlled and did not have much of an error checking ability, making them unreliable. Finally, the Unix scripts were slow and did not have a graphical user interface.

The Procedure Execution Manager (PEM) has been used at the APS for several years to control long and complex tasks. PEM procedures, when configured properly, follow the same steps an operator would take during equipment start-ups and reconfiguration between injector lattices for user operations and experimental projects. The only difference is the PEM has the ability to repeat steps faster and with less possibility of error.

When using PEM procedures, the operator no longer has to open numerous MEDM screens and work on one task at a time. Rather, the PEM is able to efficiently use multitasking to alleviate the burden on the operators in what can often be a stressful situation. The operators can read corresponding descriptions and view the steps of a PEM procedure to become familiar with it. This is not intended to reduce operator training, but it does serve as an additional source of information that may be valuable to operators.

Complex PEM procedures are constructed by combining simpler PEM procedures in a series and/or parallel fashion. The PEM interface is expandable, simple, and consistent, so operators often do not need to learn anything new in order to correctly use a new procedure. Using PEM's ability to execute steps in parallel can decrease the execution time and further enhance productivity.

The dialog screen shown in Figure 5 for power supply start-up allows the operator to select a snapshot file to be restored at the end of a magnet conditioning. A snapshot file (see Figure 6) is a database file including all the settings necessary to reproduce the conditions existing when the snapshot was recorded. Once executed, the PEM procedure opens another display window, shown in Figure 7, that shows each step as it occurs and reports procedure status.

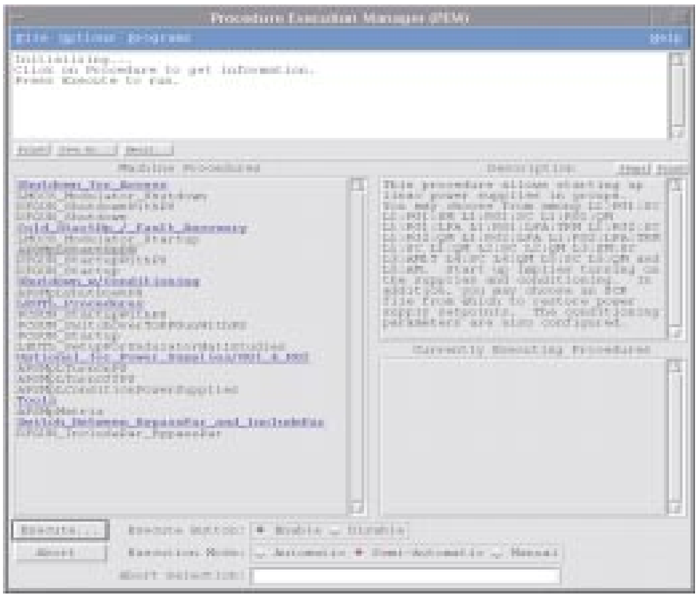

Fig. 5: Procedure Execution Manager

Fig. 6: Initial Dialog Screen

Fig. 7: Status Monitor

Prior to the use of PEM procedures for linac operation, reproducibility was difficult. Establishing and enforcing a uniform method for machine operation has resulted in a dramatic reduction in the time spent by the control room operator for accelerator tune-ups. Start-up and switch-over activities between experimental projects and daily injections have also benefited from the PEM program.

There are two principal difficulties with the PEM process. First, changes in the controls system or hardware can cause procedures to fail. This problem has been managed by the use of administrative controls and a device layer between the PEM procedures and EPICS. Second, thorough testing of these procedures requires machine time, which is in very high demand for experimental programs. This is perhaps the major factor slowing the development of these procedures.

3. CONCLUSION

The new linac interlock upgrade and the use of the PEM procedures have proven to be very reliable for switching between multiple operating modes. Without these tools, it would be difficult if not impossible to ensure equipment safety, improve reliability, and efficiently provide consistent beam. Switching between the operation modes safely with the assistance of the PEM has made the job of the control room operator much easier and has contributed to the success of experimental programs.

4. ACKNOWLEDGMENTS

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References

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