CONDUCTING RESEARCH AND OPERATOR TRAINING WHILE MAINTAINING TOP-UP RELIABILITY USING THE ADVANCED PHOTON SOURCE LINEAR ACCELERATOR*

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Abstract

In recent years many changes have been made to the Advanced Photon Source (APS) linear accelerator (linac) to support multiple tasks. The primary purpose of the linac is to provide beam to fill the APS storage ring, which is done using thermionic cathode rf guns. At the same time we provide support for research projects, including a new facility that will be used for future operator training and testing of injector components. With each task requiring a different lattice and timing configuration, while at the same time using common rf systems, the complexity of operations has increased significantly with even greater demands being made on reliability and performance. In addition, personnel safety and equipment protection concerns have become more complex. We approached these challenges by developing three new subsystems: a highly automated linac operation using APS's Procedure Execution Manager (PEM) software; a new interlock system based on programmable logic controllers; and an automated S-band rf switching system. In this paper, we discuss how these developments have improved the flexibility and reliability of the APS linac, and how we intend to conduct operator training and test new injector components while maintaining storage ring injections.

INTRODUCTION

The Advanced Photon Source at Argonne National Laboratory is a high-brightness, third-generation synchrotron light source. It is operated in top-up mode 75% of the time, which entails injecting beam every two minutes to maintain a current of 102 mA to 1% tolerance. When top-up is not being performed, the ring is filled twice per day. In either mode, the APS linac is now configured to support multiple functions, accomplished by the addition of three new subsystems: an interlock system based on programmable logic controllers (PLCs), an automated S-band rf switching system, and a graphical user interface called the Procedure Execution Manager (PEM).

LINAC AUTOMATED OPERATIONS

The APS linac is made up of five modulators and klystrons, three SLEDs, three electron guns, and a complex diagnostic and lattice arrangement. In addition, there are subsystems, such as water, vacuum, and timing that are incorporated into operating screens that hold hundreds of read-backs and controls for every aspect of operation.

Originally, when making changes in the linac, the operators had to switch back and forth among many control screens and perform procedures from memory or with the aid of written procedures. To say the least, this was a very time-consuming and error-prone task.

The use of PEM software procedures [1,2] for equipment start-ups, lattice reconfigurations, and changes to the rf power system in the event of a failure has proven to be most beneficial. The main difference is that PEM has the ability to repeat steps faster, more consistently, and with less possibility of error.

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 the PEM's ability to execute steps in parallel can decrease the execution time and further enhance productivity. In addition, the PEM has error trapping and reporting to help machine managers and software developers diagnose and respond to errors.

As an example, a PEM would be used in the event of an rf system failure. Selecting the Linac_Switch Mode PEM from the operation dialog screen (Fig. 1) will automatically remove the failed rf source and, in parallel, switch to the back-up rf source. Prior to starting this procedure the operator is required to select a snapshot file that will be restored at the end of the switching mode change. A snapshot file (Fig. 2) is a database file that includes all the settings necessary to reproduce the conditions existing when the snapshot was recorded. Once executed, the PEM procedure opens another display window that shows each step as it occurs and reports procedure status (Fig. 3).

There are two principal difficulties with the PEM process. First, changes in the controls system or hardware can cause the 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

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machine time, which is in very high demand for storage ring top-up and experimental programs.

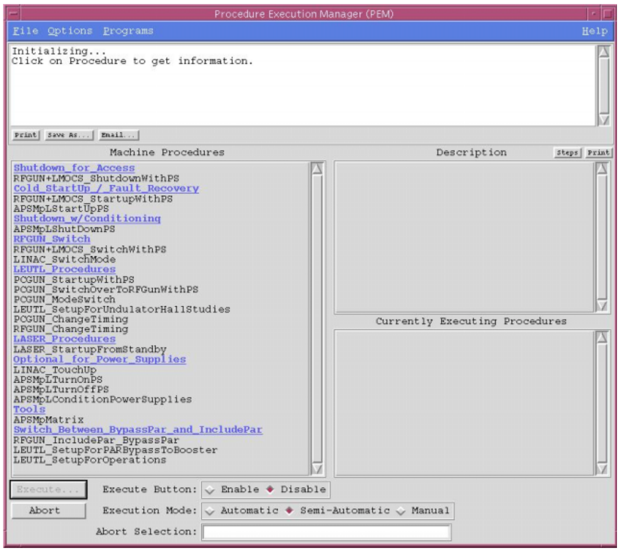

Figure 1: Procedure Execution Manager for the APS linac.

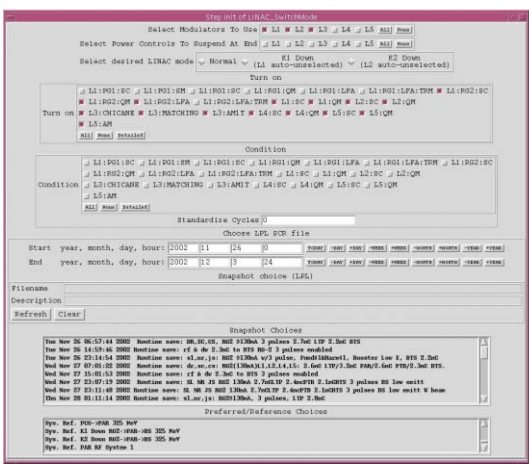
Figure 2: Initial dialog screen.

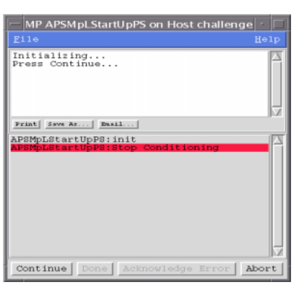

Figure 3: Status monitor.

NEW SUBSYSTEM INTERLOCKS

Interlock Support

New interlock systems have been designed to support various klystron operations. The main responsibility of the interlock system is to provide machine protection, which depends on vacuum, SF6 pressure and water flow to function properly. The interlock logic generates *Permit* signals specific to each subsystem (vacuum, pressure, and water flow.) These permits are connected in series to permit rf power to be generated from any one of five klystrons.

A milestone was reached in December of 2002 with the completion of the programmable logic controller (PLC)-based interlock protection system. The original interlock system for the linac was a hard-wired, relay-based one that was, for the most part, very reliable. However, adding new interlocks to the old system proved to be very time consuming, and it was unable to communicate with newer PLC-based systems.

PLC Selection

The 205 Direct Logic Controller, known as the world's most powerful micromodular PLC, was found to meet or exceed all our requirements. This Direct Logic Controller uses a remote master eight-slot I/O crate with a DL250 controller-processing unit. Using this type of system has saved money in equipment costs and many hours not only during the initial installation of the hardware but also in programming and debugging time. The DL250 was found to also interface very well with our EPICS system in that it provided additional diagnostic information to the control room via standard control screens.

Interlocks Interfaced with MEDM Displays

In EPICS, equipment is controlled from workstations that communicate over a network of local computers called input/output controllers (IOCs). All systems in the linac that require or use interlocks 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.

Using the PLC's ability to monitor each interlock signal separately, the MEDM screen developer is now able to design a thorough diagnostics display for operations and maintenance personnel. In the event of a trip or component failure, a quick glance at this screen shows the general source of the problem in an easily understood graphical fashion.

RF SWITCHING SYSTEM

As a result of top-up operation, the requirements for reliability and availability of the linac are even greater now than in the past**.** In addition, linac systems are under greater stress due to continuous operation, making failures more likely. The first part of the linac, consisting of the rf guns and four accelerating structures, requires two klystrons (designated K1 and K2) for normal operations. In the event of the failure of either K1 or K2, a third klystron (K3) would be used. Klystron three is also used to support experimental research equipment as well as a test stand. To do this, the system relies on S-band, electropolished switches, 340 pressurized waveguides, [3,4], and a PLC-based switching controller.

Switching System Description

The linac rf switching control system is responsible for monitoring and controlling eight rf switches connected to various waveguide sections in the low-energy section of the linac (sectors L1 through L3). The switches are used to reconfigure the operation of the linac, or mode change, with respect to gun operation and klystron sources. The switching system communicates to a variety of field devices including switch-mode interfaces, modulator interlocks, VSWR fault switching, sector interlocks, and Bitbus (via serial BUG).

In general, the switching system will monitor the rf switch position, command the switches to move when a mode or gun change is selected, and provide the proper handshaking signals to insure that no damage to equipment will occur due to an improper switch configuration or uncommanded switch motion. The switching system will also notify each individual sector interlock system of the switch configuration in order to route faults to the proper destination.

Modes

The following mode descriptions are used:

Mode 0 – K3 Down　　Mode 1 - K1 Down
Mode 2 - K2 Down　　Mode 3 - Test Room
Mode 4 - Normal

Using Mode 1 as an example, Figure 4 assumes klystron one (K1) has failed and is no longer able to support its normal operating functions. In this case, K1 Down Mode, when selected, reconfigures the switching system to direct klystron three (K3) output power to drive the selected load.

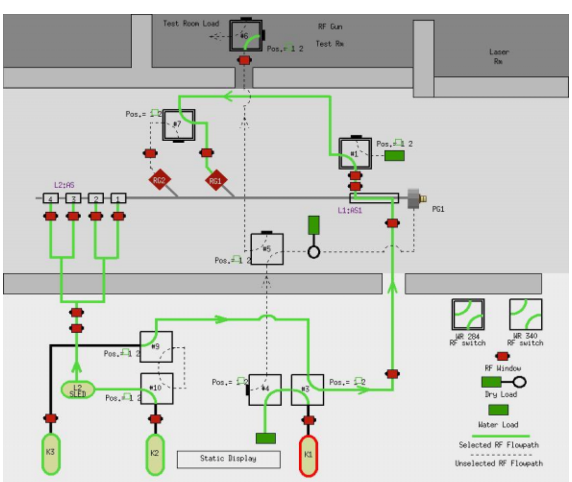

Figure 4: Mode 1 –K1 Down display.

LINAC TEST STAND AND OPERATOR TRAINING

The injector test stand was originally developed for the purpose of testing and commissioning new thermionic rf guns and injector components. Over time, the room evolved into a mini linear accelerator. The test stand holds similar components and in many ways mirrors the main linac injector. For example, control screens and machine protection systems are the same. As you might expect, having an area like this with similarities of the main injector would be ideal for operator training and testing, especially when the main injector is used 95% of the time for top-up operations.

Component Testing

To date, three new thermionic rf guns have been commissioned, and preparations are now being made to test a new gun, designed by John Lewellen, called the bunch ballistic compression (BBC) rf gun. This gun uses three independently powered and phased rf cavities, and either a thermionic cathode or a photocathode.

CONCLUSION

The new linac interlock upgrade and the use of the PEM procedures for equipment startup and configuration switching have proven to be very reliable, making the job of the control room operator much easier. In addition, this work has contributed significantly to the success of experimental programs component testing and will soon contribute to operator training.

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REFERENCES

[1] M. Borland, "The Procedure Execution Manager and its Application to Advanced Photon Source Operation," 1997 Particle Accelerator Conference, pp. 2410-2412 (1998).

[2] R. Soliday et al., "Automated Operation of the APS Linac using the Procedure Execution Manager," XX International Linac Conference, SLAC-R-561, pp. 524-526 (2001).

[3] A. Nassiri, A. Grelick, R. L. Kustom, M. White, "High Peak Power Test of S-band Waveguide Switches," 1997 Particle Accelerator Conference, pp. 3174-3176 (1998).

[4] A. E. Grelick et al., "Testing and Implementation Progress on the Advanced Photon Source Linear Accelerator High-Power S-Band Switching System," XX International Linac Conference, SLAC-R-561, pp. 983-985 (2001).