PERSONNEL PROTECTION SYSTEM UPGRADE FOR THE LCLS ELECTRON BEAM LINAC*

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Abstract

As facilities age and evolve, constant effort is needed in upgrading control system infrastructure. This applies to all aspects of an accelerator facility. Portions of the Personnel Protection System of the Linac Coherent Light Source are still relying on a 50 year old relay based Safety System. This presents a substantial risk to the facility's ability to reliably perform its mission. An upgrade is underway to modernize these systems using Siemens S7-300 Safety PLCs and Pilz PNOZMulti programmable controllers. The upgrade will be rolled out over multiple years requiring the implementation to be fully compatible with adjacent legacy system while setting the foundation for the new generation system. The solution is a modularized safety system which can be deployed in a short time (1 month) while being flexible enough to adapt to the evolving needs over the next 20 years. Once fully deployed, the upgraded PPS System will provide not only greater availability to users, but also a higher level of Personnel Safety than previously provided.

BACKGROUND

The 3 mile Linac has been in operation at SLAC National Accelerator Lab for more than 50 years. In that time many upgrades have been made to support successful operation of the facility into the future. In 2014, a multiyear project was begun to upgrade the Personnel Protection System for the section of Linac used for operation of the Linac Coherent Light Source (LCLS).

The Personnel Protection System (PPS) at SLAC is composed of a system of interlocks whose function is to prevent personnel from being exposed to radiation within the accelerator enclosures.[1] In the Linac this is done by controlling the ability of the Klystrons to produce RF for the accelerator waveguides. The SLAC Linac is composed of 30-100meter long sections. Pairs of these sectors are configured as 15 stand-alone PPS zone.

The system currently used is composed of telephone relays and has operated safely for many years. In order to continue to support the high level of facility uptime demanded by LCLS, a modern replacement is needed. The LCLS Linac is composed of the final 10 sectors. The new system will provide a substantial increase in diagnostic information available to the operations staff as well as new functional modes. These modes will reduce facility downtime following personnel access to the accelerator housing.

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Completing an upgrade of this size on an operational facility presents an additional level of difficulty. Annual maintenance down time is on the order of two months, with half of this time needed for recertification of all PPS installations. This only leaves four weeks to complete the removal, installation, and commissioning of a new system.

REQUIREMENTS

In addition to the standard requirements of a Personnel Safety System, this upgrade must meet two additional project specifics requirements. [2][3]

The first is the need for a personnel controlled access. Currently any access into the linear accelerator requires the operations staff to manually go into the tunnel and verify that no one is inside before closing the facility for beam operation. Depending on the number of sector pairs accessed this can take a substantial amount of time. Controlled Access will allow for trained personnel to enter the accelerator housing using a safety token and return the token once complete.[4] This eliminates the need for an operations search.

Secondly, due to the installation window time constraints, the upgrade must be deployed in phases. Each phase will be staged and modularly assembled while the facility is in operation and then deployed during a maintenance downtime.

DESIGN

The new system is composed of 3 separate PPS zones instead of the 5 sector pairs it's replacing. Each zone is deployed in a different annual maintenance down time. The three stages are listed in Table 1.

Table 1: Installation Stages

Zone	Controlled Access	Installation
Sectors 24 & 25	No	September 2014
Sectors 21-23	Sectors 21-25	September 2015
Sectors 26-30	Sectors 21-30	TBD 2016

Personnel Access to the accelerator regions is handled by three distinct access states at SLAC. No Access is the condition in which beam operation is allowed as long as the interlocks are met. Permitted Access allows free access to individuals to the PPS zone. This always requires an operations search of the region prior to machine recovery. Controlled Access allows for access without the need to search the PPS zone.

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There are two methods to access the Linac housing in sectors 21 through 30, a vertical ladder in each sector which requires fall protection equipment to be used and a stairwell located at Sector 24. Because of the need for additional equipment and training to use the vertical ladders, only the sector 24 stairwell is instrumented as a PPS Entry location. This means that a controlled access scheme requires the ability to move between the three zones without violating individual zone security and requiring an operations search of the area. The ladder located at each sector can still be used as entry point under permitted access conditions. Each stage is a stand-alone installation; the number of signals shared between zones is minimized to facilitate the staged deployment of the system. Controlled access was not fully implemented until the second stage at which point it provided an operational benefit. Controlled Access allows for the boundaries between the three zone to be opened without violating zone security as long as each zone is in controlled access and is secure

For each zone the PLC architecture used to implement the system is based on three PLCs as shown in Figure 1. Two Pilz PNOZMulti controllers are implemented as the safety interlock controllers. These handle all the safety critical sensors,

Figure 1: PLC architecture.

Emergency Off hardware and permits to radiation hazards. These communicate with a Siemens S7-315F processor over Profinet. This PLC is responsible for all non-safety critical functionality. This includes interfacing with the Experimental Physics and Industrial Control System (EPICS), controlling indicators throughout the region, and other non-safety critical functionality. EPICS is used to control and monitor all aspects of the PPS systems at SLAC. The individual status of all inputs as well as the ability to release safety tokens and grant access is done through EPICS. As an additional level of safety all PPS installations include a hardwired enable which is used at the PLC installation to gate all commands received over EPICS. If this signal is not present then the system ignores the control system request.

INSTALLATION

In order to meet the installation schedule, a large amount of staging and pre-assembly work was required.

New terminal cabinets and copper trunking were mounted and routed to the rack locations during LCLS Operation. These trunks were terminated in the rack once the rack hardware was upgraded. Because existing racks were repurposed, it wasn’t possible to pre-wire a new rack. Instead an assembly jig was constructed to allow the rack hardware to be prewired and then installed as a single unit in the repurposed rack. The upgraded rack assembly can be seen in Figure 2. This single rack installation replaces 4 racks in the case of Stage 1 and 6 racks in the case of Stage 2. At the completion of Stage 3 it is expected that 2 racks will replace 10 racks. Once the prewired assembly is installed in the rack, the copper trunks are terminated.

Figure 2: New Installation in repurposed racks.

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The existing zone wiring was removed and the conduit, inspected. New wire was pulled in the existing conduit and connected to the previously mounted terminal boxes. Field hardware was replaced at each entry way and throughout the tunnels. The sector 24 entry way was upgraded to support its new function as a controlled access point. Sector 24 entry before the upgrade and after can be seen in Figure 3.

Figure 3: Sector 24 entry way.

The legacy system uses redundant constant current loops which run the length of the Linac in order to sum the state of the individual subzones. Each zone is capable of breaking the continuity of these loops. There is a global PPS system which looks at these loops as well as other inputs and ultimately issues the hazard permits to the RF. The interface to this system is unchanged; the loops pass through dry-contact outputs on the respective Pilz Safety Processors. This allows for the upgraded and legacy installation to operate side-by-side without any intermediate solutions.

CONCLUSION

While completing the first two stages of this upgrade, a strong dependence on pre-planning and execution was necessary to deploy a large scale upgrade in a comparatively short amount of time. This project would not have been achievable without the strategies employed. When the third stage is executed, the project will benefit from the lessons learned to date and successful completion of a substantially larger geographical upgrade.

REFERENCES

[1] *Radiation Safety System Technical*, Basis Document SLAC-I-720-0A05Z-002-R004, SLAC National Accelerator Lab (2010).

[2] Linac Sectors 24-25 PPS Requirements Document CD-SS-PPS-02-11-18R1, Internal Document, SLAC National Accelerator Lab (July 2014).

[3] Linac Sectors 21-23 System Requirements Document CD-SS-PPS-02-11-21R1, Internal Document, SLAC National Accelerator Lab (June 2015).

[4] Linac Sectors 21-29 Controlled Access System Requirements Document CD-SS-PPS-02-11-22R1, Internal Document, SLAC National Accelerator Lab (June 2015).

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