ELECTRICAL INTEGRATION OF THE ALS-U STORAGE RING MODULES

A. Talon, R. Bloemhard, A. Can Atmaca, M. Castillo Sosa, Ch. De La Jolla, M. Erdmann, D. Gudkov, P. Gupta, M. Holmes, M. Leitner, D. Leitner, D. Li, F. Matichard, S. Myers, E. Newman, S. Omolayo, A. Ratti, D. Rice, J. Shaw, H. Singhal, C. Steier, A. Stewart, Ch. Sun, Ch. Swenson, Lawrence Berkeley National Laboratory, Berkeley, USA

Abstract

The ALS-U (Advanced Light Source Upgrade) project is an upgrade to the ALS at the Lawrence Berkeley National Laboratory.

The new multibend achromat SR (Storage Ring) will be installed during Dark Time when the ring is not used by the scientists due to installation work. Dark Time is currently scheduled to start in the middle of 2027 and will last at least 2 years. To meet the tight schedule and space constraints, the 48 modules of magnets are prestaged and aligned in advance.

Prestaging is the phase when the module is built in advance before it is transported to the tunnel. All local electrical wiring is prestaged to reduce the installation time in the tunnel.

Electrical work includes cabling for grounding, thermocouples, MPS (Machine Protection System), magnet power and correctors, vacuum, beamline feedback (diagnostics) and AC cables, all arranged to minimize heat buildup. Key challenges include module transport requirements and managing the overall routing as well as future upgrades in the tightly packed lattice arrangement.

This paper describes the electrical integration on the module during prestaging in detail. It further outlines the testing activities and the prototype modules developed to validate and optimize installation procedures. It details the schematics, cable and material management for the 48 modules, as well as the ALS-U configuration management system and databases used for electrical routing.

INTRODUCTION

The ALS-U Project is an ongoing upgrade of the Advanced Light Source (ALS) at Berkeley Lab that will provide a soft X-ray source that is up to 1,000 times brighter than today's capabilities, whilst generating a significantly higher fraction of coherent light in the soft X-ray region than currently available at the ALS [1].

To achieve this performance, the ALS-U Project will replace the existing SR with a new nine bend-achromat ring that delivers ultra-low-emittance electron beams to generate fully diffraction-limited X-ray light. A full energy Accumulator Ring (AR) is also added (see Fig. 1). Transfer lines from the AR to the SR are added to deliver a high-quality beam to the new SR [2].

These 2 new rings and transfer lines significantly increase the number of magnets, vacuum and control equipment.

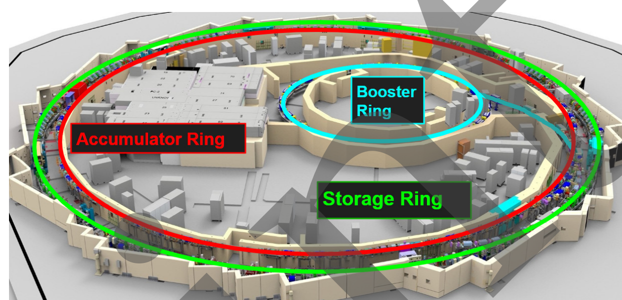

Figure 1: The rings that comprise the ALS complex: Booster Ring, Accumulator Ring (AR) and Storage Ring (SR).

Consequently, it also increases the number of cables, in a space that was originally designed to house only one ring. To facilitate the SR installation and reduce the Dark Time, the modules are prestaged. The ring is composed of 12 sectors. Every sector is made of 4 modules.

Prestaging the modules reduces the Dark Time duration [3]. The work is performed in a designated assembly space outside the ALS, to maximize beam time for users. All SR cables are separated in 2 categories:

- Short-haul cables are cables of various sizes in which both cable ends terminate on module mounted components. Short-haul cables will be prestaged. Having short-haul cables saves installation time. Furthermore, some short-haul cables would be difficult to install in the tunnel.
- Long-haul cables will be pulled in the tunnel once the modules are installed. These cables are pulled from the equipment racks (in the pit, which is the area circled by the ring that stores all of the racks, as well as the booster ring and the linear accelerator) to termination points on the modules in the tunnel.

The goal of this electrical integration activity is to plan and document all the cable routing to ensure a smooth installation during prestaging and in the tunnel.

This paper first describes the prototyping phase used to detect design issues early and solve them accordingly.

Secondly, it presents the documentation, testing procedures and work instructions that will be used during installation.

Finally, it describes the integration of electrical tasks within the overall project logistics.

CABLE ROUTING PROTOTYPING

To develop work instructions and determine the final cable routing, cooling water routing, and numerous installation details, the prestaging team used a mockup: a cost-effective prototype simulating the module at 1:1 scale (see Fig. 2). The magnet prototypes are made of wood. Some components like the BPMs (Beam Position Monitor) are 3D printed. The vacuum chamber is represented with a metal pipe. The cable and hoses are the actual ones (or equivalent in diameter, material and bending radii).

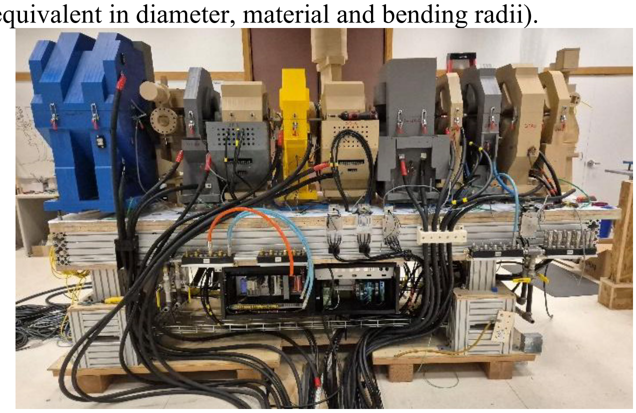

Figure 2: SR module mockup with mockup cabling in progress.

All cables and cable management hardware are routed and installed as it will be on the actual module. This mockup not only simulates the prestaging of a module, it also simulates the installation compatibility with the work performed later in the tunnel. Therefore, the long-haul cables that will be pulled later and occupy space on the module were also included on the mockup.

By using this prototype to test-fit cable routing, we verified installation feasibility and provided the necessary data for design, manufacturing and installation teams to update design documents and work instructions.

ISSUES AND RESOLUTIONS

The mockup helped us recognize issues in advance and solve them before assembling the first actual module. Below are the primary challenges identified, along with the design modifications incorporated to resolve them.

Magnet Power Cables Installation

During the installation on the mockup, we realized that the magnet power cables were really thick and rigid, therefore hard to handle. To mitigate this issue 3 main adjustments were made:

- One terminal block in the middle was replaced by 2 terminal blocks (see Fig. 3). It allowed applying larger bending radii and shorter cable routes.
- Strain relief brackets were added on both sides to reduce the constraints on these cables.
- Cables will be heated for easier bending during installation.

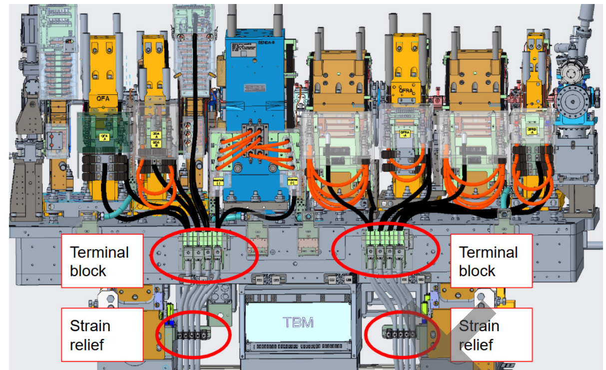

Figure 3: Magnet Short-haul and terminal block installation.

Vacuum TC Cables Space Integration

During the pulling of the vacuum TC cables, the length and space taken by the coiled TC cables was a concern since the cables must be coiled and stored on the module for transportation It increased the risk of damaging the cables.

It was decided to use junction boxes and 8 pairs TC cables instead of one pair TC cables for the TC connections. It reduced the amount of TC cables in the back trays from 20 to 3.

BPM Cable Thermal Resistance

The initially proposed BPM cables couldn’t withstand the bakeout heat (250°C) conducted by the vacuum chamber to the cables.

To solve this problem, intermediate heat resistant rigid cables were added. These rigid cables are directly connected to the BPM. They can withstand the heat, but are not flexible enough to reach the PTC (Pilot Tone Combiner) junction box. Moreover, the unit cost per foot for these cables is significantly higher than that of flexible cables.

Therefore, it was decided to use 2 cable types:

- The rigid cables connect BPM buttons to the intermediate patch panel fixed to the vacuum supports.
- The flexible cables are used between this panel and PTC junction box for cost efficiency and installation simplification.

This solution allowed the cabling to withstand the bake-out heat while being able to reach the PTC junction boxes in hard-to-reach places with flexible cabling.

Tray Organization For Code Compliance

It was found that multiple cables that were pulled through the basket tray should be separated from each other per NEC (National Electrical Code) standard. For example, the TC cables should not be next to high voltage Ion Pump cables.

It was decided to install dividers in the basket tray and in the plinth to keep these cables separated (see Fig. 4).

DESIGN DOCUMENTATION

Validation of Cable Fills Inside the Basket Trays and Plinths Penetrations

To validate the fills in the cable trays and in the module penetrations, cross-sections were drawn (see Fig.4). This allowed a clear understanding of the disposition of cables in the cable trays and in the penetrations.

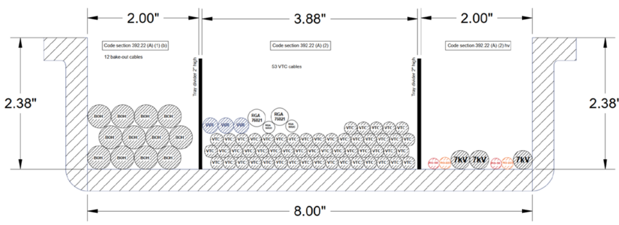

Figure 4: Basket-tray cross-section.

TC and TSWM Cables Schematic

Once the routing was validated thanks to the prototype, a whole collection of electrical drawings was created to be used for installation and for future maintenance.

Footprint Drawings

The electrical schematics contain all the electrical data and routing data. However, they don't have any visual representations of the lengths and positions of all of this data.
To help locate these elements on the module, footprint drawings were created for every module.

These footprint drawings describe magnet locations and the penetrations on the support module for cable routing from magnets to control electronics, cable trays and tunnel trench (see Fig. 5).

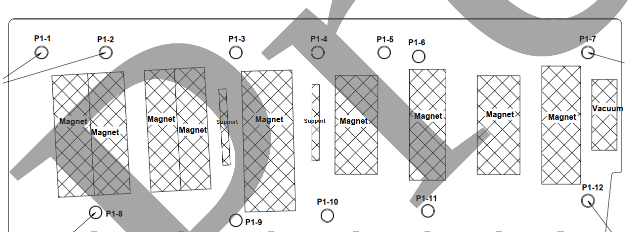

Figure 5: Module footprints top view.

ELECTRICAL WORK PLANNING

Electrical work must be planned in coordination with the mechanical installation and subsystem tasks on the prestaged module.

Module Installation Logistics

Electrical installation is synchronized with mechanical assembly. For example, electricians must install the grounding on the module before the vacuum bake-out (because the bake-out involves high voltage). Grounding is a prerequisite of vacuum bake-out.

Regarding the diagnostic cabling, installation must occur during the magnet splitting phase. This provides the necessary access for electricians to reach the vacuum chamber and install the BPMs.

All these electrical tasks are integrated into the mechanical assembly work. These tasks are interdependent, a delay in electrical work would slow down the entire assembly sequence [3].

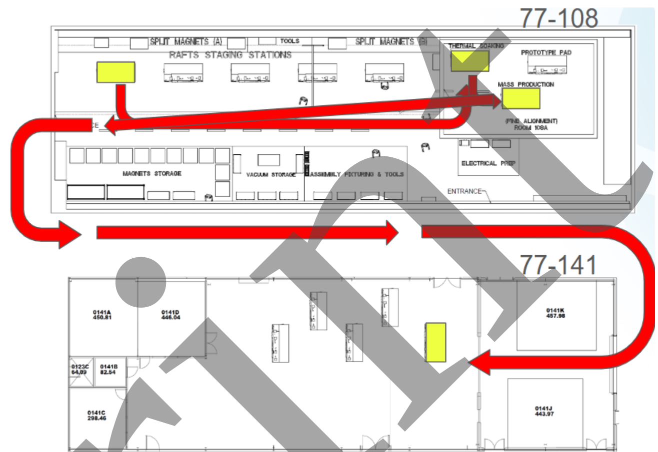

Figure 6: Module moving steps.

CONCLUSION

Electrical prestaging of the modules allows saving of installation time in the tunnel (during the Dark Time), and simplifies installation in tight spaces that would be impossible to do directly in the tunnel.

Using a 1:1 mockup, we developed solutions for BPM cabling, basket tray fills, grounding strategy, magnet power cabling and many other key details.

This preparatory work provides a documented framework: schematics, footprints and work instructions along with the CAD model. All this documentation provides support for long-term maintenance of the ALS.

This preparation work for electrical integration turned potential high-risk installation challenges into a validated, step-by-step workflow that is critical to the successful upgrade of the ALS.

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