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# MAGNET POWER SUPPLIES FOR ALS-U*

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*Abstract*

The ALS-U project is an upgrade to the existing Advanced Light Source at Lawrence Berkeley Laboratory to a diffraction limited light source. To be able to achieve the small horizontal emittance of the ALS-U, the three bend achromats in the ALS will be replaced with nine bend achromats. Because the lifetime of the ALS-U beam will be significantly reduced, the plan is to use a swap out injection scheme between the storage ring and a new accumulator ring. The present plan is to use individual power supplies for each magnet in the storage ring, and series connected magnet strings for the accumulator ring. The sheer number of supplies needed, along with the tighter stability requirements for the ALS-U, is demanding in terms of the power supply requirements for stability and reliability. This paper will discuss the ALS-U magnet power supply requirements, and possible options to meet them.

## BACKGROUND

The ALS-U is shown pictorially in Fig. 1.While Fig. 2 shows one arc sector of the storage ring [1].

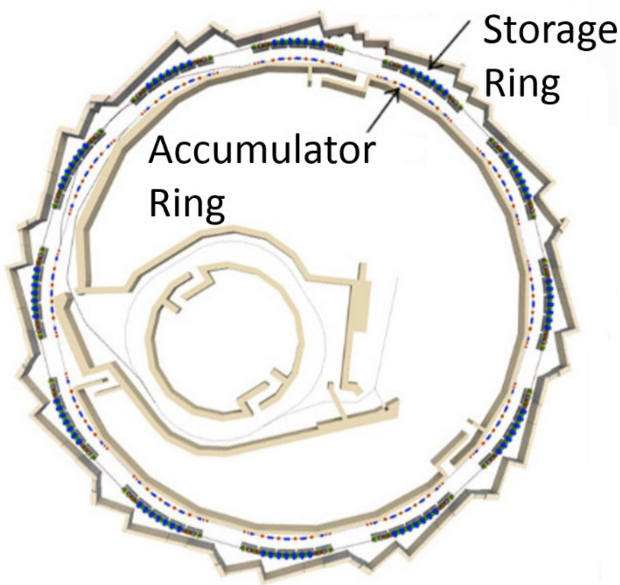


Figure 1: Layout of the ALS-U.

All the storage ring magnets [2] are planned to be powered by individual supplies to allow for greater flexibility in machine tuning, while most magnets except for the quadrupole and some of the sextupole magnets in the accumulator ring will be powered in magnet strings. The magnets the transfer lines are planned to be individually powered.

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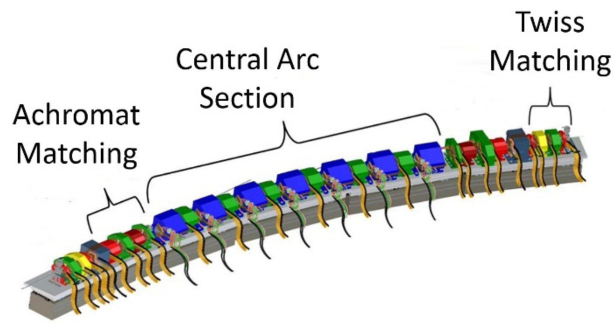


Figure 2: Drawing of an ALS-U arc sector.

## POWER SUPPLY REQUIREMENTS

Table 1 lists the storage ring magnets and the requirements for power supplies to power them. Table 2 list the requirements for the accumulator ring. In the tables, the current listed is the nominal current for the given magnet, while the voltage is the sum of the magnet terminal voltages, the cable drops, and the magnet and cable di/dt voltage when ramping to the nominal current. Some of the magnet designs currently use a single turn, resulting in very low magnet terminal voltages, which have been rounded up to 5 V in the tables. We are currently working with the magnet designers to reach a compromise between efficient magnet designs and power supply requirements.

Stability defined in the tables is for both long term (8 hours) and ripple, where the ripple frequencies are calculated from the magnet and cable impedances and attenuation of a round copper chamber 13 mm diameter and 1 mm thick. This simplistic analysis results in a ripple frequency bandwidth of concern from DC to 3 kHz and is currently being investigated in more detail. The requirement seems conservative, however more attention need to be paid to power line frequency ripple that could be coherent for most supplies. The bandwidth of the harmonic sextupole is 1 kHz.

There will a total of 52 magnets for the transfer lines that have yet to be designed. The total number of magnet power supplies for the ALS-U will be 1204. Once the magnet designs have been finalized for all supplies, margins will be added. It appears that many of the magnet power supplies will have similar requirements and can be powered by identical supplies used elsewhere in ALS-U. This should reduce the procurement cost, and the number of different spares needed.

## BASELINE DESIGNS

The gradient dipole and QFA power supplies for the accumulator ring will likely be 12-pulse pre-regulators followed by either a linear regulator or an H-bridge DC-DC

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Table 1: Magnet Power Supply Requirements for the ALS-U Storage Ring

| SR Magnet | Polarity | Voltage | Current | Stability (Ripple/8hr PPM) | # in Ring |
|---|---|---|---|---|---|
| BEND1 Gradient Dipole | Unipolar | 15 | 165 | 10/10 | 24 |
| BEND2 Main Coil | Unipolar | 15 | 180 | 10/10 | 24 |
| BEND2 Corr. Coil | Bipolar | 5 | 28 | 100/100 | 24 |
| BEND3 Main Coil | Unipolar | 15 | 180 | 10/10 | 54 |
| BEND3 Corr. Coil | Bipolar | 5 | 29 | 100/100 | 54 |
| Super Bend | Unipolar | 5 | 1000 | 10/10 | 6 |
| QD1 Main Coil | Unipolar | 10 | 220 | 10/10 | 24 |
| QD2 Main Coil | Unipolar | 15 | 250 | 10/10 | 12 |
| QF1 Main Coil | Unipolar | 9 | 228 | 10/10 | 24 |
| QF2&3 Main Coil | Unipolar | 6 | 169 | 10/10 | 48 |
| QF3 Bx Corr. | Bipolar | 5 | 80 | 100/100 | 24 |
| QF3 By Corr. | Bipolar | 5 | 80 | 100/100 | 24 |
| QF4 Main Coil | Unipolar | 15 | 260 | 10/10 | 24 |
| QF4 Bx Corr. | Bipolar | 5 | 42 | 100/100 | 24 |
| QF4 By Corr. | Bipolar | 5 | 42 | 100/100 | 24 |
| QF5 Main Coil | Unipolar | 15 | 271 | 10/10 | 24 |
| QF5 Bx Corr. | Bipolar | 5 | 42 | 100/100 | 24 |
| QF5 By Corr. | Bipolar | 5 | 42 | 100/100 | 24 |
| QF6 Main Coil | Unipolar | 15 | 269 | 10/10 | 18 |
| QF6 Bx Corr. | Bipolar | 5 | 42 | 100/100 | 18 |
| QF6 By Corr. | Bipolar | 5 | 42 | 100/100 | 18 |
| QF7&8 Main Coil | Unipolar | 15 | 273 | 10/10 | 12 |
| QF7&8 Bx Corr. | Bipolar | 5 | 35 | 100/100 | 12 |
| QF7&8 By Corr. | Bipolar | 5 | 35 | 100/100 | 12 |
| SF1 Main Coil | Unipolar | 9 | 179 | 100/100 | 24 |
| SF1 Bx Corr. | Bipolar | 5 | 45 | 100/100 | 24 |
| SF1 By Corr. | Bipolar | 5 | 50 | 100/100 | 24 |
| SF1 Skew Quad | Bipolar | 5 | 65 | 100/100 | 24 |
| SD1 Main Coil | Unipolar | 6 | 140 | 100/100 | 24 |
| SD1 Bx Corr. | Bipolar | 5 | 45 | 100/100 | 24 |
| SD1 By Corr. | Bipolar | 5 | 50 | 100/100 | 24 |
| SD1 Skew Quad | Bipolar | 5 | 65 | 100/100 | 24 |
| SH1&2 Main Coil | Bipolar | 11 | 165 | 100/100 | 48 |
| SH1&2 Bx Corr. | Bipolar | 9 | 55 | 100/100 | 48 |
| SH1&2 By Corr. | Bipolar | 6 | 55 | 100/100 | 48 |
| SH1&2 Skew Quad | Bipolar | 7 | 28 | 100/100 | 48 |

converter. All other supplies are planned to be commercially available, but many will require an external regulator and DCCT to meet the stability requirement. The baseline topology for these supplies is shown in Figure 3, and is similar to what other accelerator laboratories have used [3].

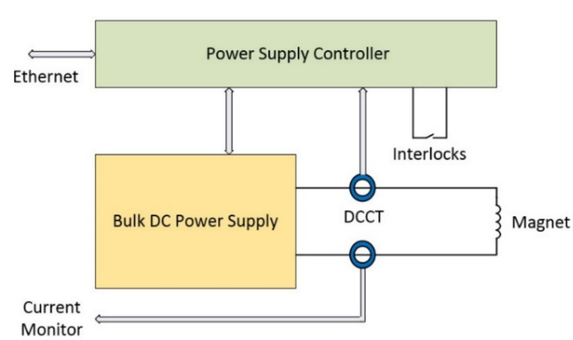


Figure 3: Baseline topology for high stability supplies.

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Table 2: Magnet Power Supply Requirements for the ALS-U Accumulator Ring

| AR Magnet | Polarity | Voltage | Current | Stability (Ripple/8hr PPM) | # in Ring/String |
|---|---|---|---|---|---|
| Gradient Dipole | Unipolar | 950 | 215 | 10/10 | 36/36 |
| QFA | Unipolar | 190 | 230 | 10/10 | 24/24 |
| QF | Unipolar | 6 | 192 | 10/10 | 24/1 |
| QD | Unipolar | 6 | 193 | 10/10 | 24/1 |
| SF Main Coil | Unipolar | 60 | 183 | 100/100 | 24/24 |
| SF By Corr. | Bipolar | 5 | 90 | 100/100 | 24/1 |
| SF&SD Skew Quad | Bipolar | 5 | 170 | 100/100 | 12/2 |
| SD Main Coil | Unipolar | 40 | 163 | 100/100 | 24/24 |
| SD Bx Corr. | Bipolar | 5 | 80 | 100/100 | 24/1 |
| SHF Main Coil | Unipolar | 5 | 125 | 100/100 | 24/24 |
| SHF&SHD Bx Corr. | Bipolar | 5 | 255 | 100/100 | 48/2 |
| SHF&SHD By Corr. | Bipolar | 5 | 148 | 100/100 | 48/2 |
| SHD Main Coil | Unipolar | 5 | 150 | 100/100 | 24/24 |

Other areas of concern besides stability are reliability due to the large number of supplies, and cost. Reliability could be improved by using redundant supplies, however, a transient generated when one supply fails and the redundant supply has to quickly go to full power will result in beam loss. Several options to limit the transient from one supply failing in a redundant system are being investigated. Using supplies with a very high bandwidth will limit the duration of the transient, while adding some energy storage such as series inductance will limit both the amplitude and bandwidth of the transient. A topology similar to that shown in Figure 4 which uses highly redundant DC-DC converters, a DC link from a large bulk, and interleaving of the PWMs could possibly address all three of the concerns, but will need and R&D effort.

## FACILITIES IMPACT

The magnet power supply design for ALS-U has several impacts on ALS infrastructure. AC power is distributed around the ALS by 150 kVA transformers, which will need to be upgraded to 225 kVA. Early installation of the accumulator ring while the ALS is operating, as is in the ALS-U baseline, also results in challenges for power distribution. The large number of cables needed to individually power each magnet will require additional penetrations of the accelerator enclosure. Physical space to locate ALS-U equipment does not appear to be major concern at this point, but along with the demand on the ALS LCW and chilled water, is being investigated.

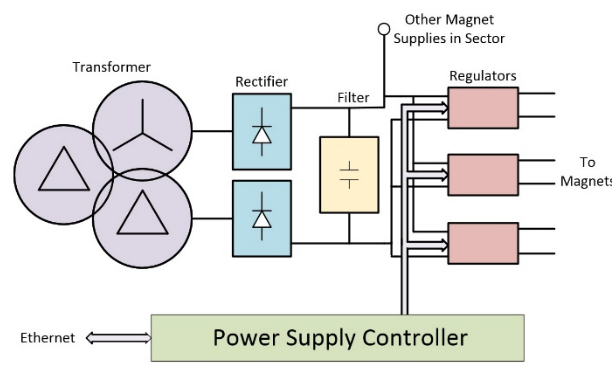


Figure 4: R&D topology to mitigate concerns with the baselne design.

## CONCLUSION

Requirements for ALS-U power supplies are presented with a baseline design which has been successfully adopted at other light sources. Concerns about the baseline design have been identified, and possibilities for mitigations. A number of impacts to the current ALS infrastructure have been identified, which are being addressed by the project.

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