COMMISSIONING AND FIRST YEAR OPERATION OF THE LNLS MAGNET POWER SUPPLIES

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Abstract

We describe the commissioning and operation of over 100 power supplies used in the LNLS injector, transport line and storage ring. In particular, we discuss the power supply characteristics required for low energy injection and ramping as well as for high energy operation. Low current ripple and stability at injection energies as well as repeatability and performance at high beam energy are specially considered.

1 INTRODUCTION

The light source of the Laboratório Nacional de Luz Síncrotron (LNLS) [1], in Campinas, SP Brazil, includes an electron linear accelerator (linac), a transport line and a booster-storage ring. To achieve the characteristics of a high-quality light source, a total of 163 magnets are used. These magnets require 49 dc current power supplies for the storage ring, 26 for the transport line and 28 for the linac, adding up to 103 power supplies [2]. The LNLS accelerators were commissioned during the first semester of 1996 and the machine has been in normal operation since then.

Injection and electron current accumulation in the storage ring is done at low energy, 120 MeV. After accumulation, the current is ramped up to 1.37 GeV. This represents a very large dynamic range for the power supplies and special requirements on current repeatability. At initial energy, the magnet remnant magnetic field in the quadrupoles and dipoles is significant. Furthermore, operation at low energy is done with horizontal and vertical tunes which are very close to an integer [3], 2.09 $ß_{VER}$ and 5.05 $ß_{HOR}$. This requires that the power supply have a small ripple-to-mean-value ratio at low as well as at nominal current.

The final electron energy is limited by the saturation of the dipoles. The final current is 12 times the initial one, in particular the dipole power supply changes from 25 A at injection up to 300 A at final energy. To allow for different modes of operation of the storage ring, the magnets are split in to several families. The quadrupoles and sextupoles are arranged in 17 different power supply families. Thus, in order to guarantee that the six fold symmetry of the ring be preserved, the precision and repeatability of the power supply settings become important. During ramping, the power supplies track the 16-bit references along energy and tune space. At the same time, along the ramp the 12-bit orbit corrector power supply references are adjusted so that the orbit distortion is kept under control. At high energy, periodical adjustments of the steering magnet power supplies allow the orbit of the stored beam to be maintained within 30 μm of the specified trajectory.

2 POWER SUPPLY LAY OUT

A power supply room, next to the accelerator's control room, houses all linac, transport line and storage ring power supplies, with the exception of the storage ring steering magnet power supplies This arrangement allows measurements in the power supplies to be performed while the accelerators are in operation. The room is air conditioned with temperature and humidity control (25 ± 1 °C, 65 % relative humidity). The power supply' input and output cabling run under the removable floor, through cable trays along the underground linac tunnel and into the inside of the storage ring. To avoid unnecessarily long cables, the steering coil power supplies for the storage ring are placed in 6 racks around the inside perimeter of the ring. All power supplies have been developed and built in house. Many of these supplies have innovative topologies that allow for simple, reliable and precise operation [4, 5]. They have been designed to operate with high efficiency so that air cooling suffices to keep the cabinets' inside temperature and most sensitive electronic components below 40 °C. No water cooling is necessary in the power supply room. This has the additional advantage of avoiding any possible water leakage in to the cable bed. All power supplies have local and remote computer control options. In the second case, operation is possible using a PC. Remote control permits a power supply to be turned on and off, sets its current reference, reads the set current value and knows the status of the equipment operating conditions. Figure 1 shows the power supply room. The storage ring power supplies are arranged in three rows. The first two cabinets on the front left correspond to the 12-dipole supply, followed by several 2-quadrupole supplies. On to the right are the sextupole power supplies. At the back, to the left is the linac and to the right the transport line power supplies.

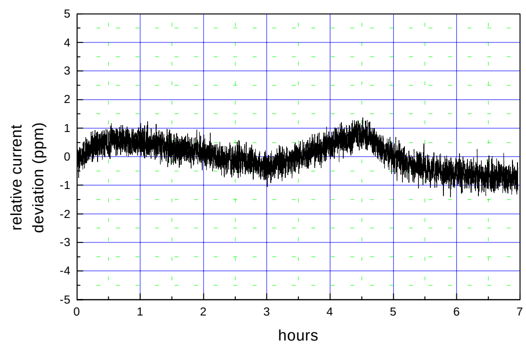
Figure 1: power supply room

3 POWER SUPPLY PERFORMANCE

The 12 storage ring dipoles are fed from a single power supply. It is an association of 2 converters: a 12-pulse SCR rectifier with 910 V maximum output in series with a switching Buck converter which uses 10 parallel connected IGBT [4]. The SCR converter supplies 90 % of the load power and the low power switching supply trims the current variations to the required ripple and stability values. Output current can vary from 3 to 300 A in 12 s with zero tracking error. The current ripple is determined by the DCCT sensibility and its frequency by the load characteristics. When operating with the 12-dipole load, the current is forced to oscillate around the mean value at about 2 kHz. This produces a magnetic field ripple of 0.1 G pp, equivalent to a 4.10^{-5} variation at injection energy and 3.10^{-6} at full energy. Communication with the control computer comprises 16-bit writing and reading analog signals, one turn on/off and 33 status digital signals.

The storage ring quadrupoles are divided in to 14 families involving 12 two-quadrupole families for the low-dispersion sections of the storage ring and 2 six-quadrupole families for the disperse sections. The splitting of the storage ring quadrupoles in so many families allows for several different modes of operation of the ring. The specification of the power supplies was done in order to accommodate those various high energy modes. The quadrupole power supplies are IGBT Buck converters, operating at 8 kHz @ 220 A, maximum current. This produces a 2.10^{-5} maximum variation in the magnetic field. Nevertheless, low-energy accumulation adds extra requirements to the quadrupole power supplies. The best operating conditions for low-energy accumulation are a combination of a large number of factors which were defined during the commissioning of the accelerators. In particular, it was found that for significant current accumulation in the machine, both vertical and horizontal fractional betatron tunes are very small. Correspondingly, the power supply ripple at low current must also be small to guarantee a magnetic gradient variation of $\pm$ 2.10^{-4}. Measurements indicated the need to modify the original design of the two-quadrupole family power supplies to reduce the magnetic field ripple when operating with 12 A, corresponding to injection energy. Consequently, an output damped LC filter was added to the 12 power supplies .This causes a 10-fold reduction in the current ripple and also in the switching frequency, which varies from 1 kHz @ 12 A up to 3 kHz @ 220 A.

The power supplies for the 6 quadrupole and sextupole families are 220 A, 50 V current sources constructed using a novel design developed at LNLS [5]. The new topology combines an SCR rectifier which supplies the power to the load and a two-switching transistor active filter which regulates the load current within specified limits. The novelty of the design is that the active filter handles not only a small fraction of the load power but also a very small current, less than 1 A @ 220 A load current. The active filter operates at 15 kHz and the ripple in the magnetic field gradient is 5 ppm. Figure 2 shows the measured mean current long-term stability for the 6 quadrupole supply and indicates a 2 ppm variation for a room temperature change of 5 °C.



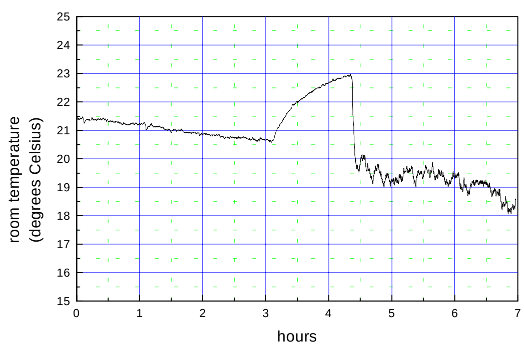


Figure 2: load current deviation (top) and room temperature (bottom) measured during a long time-stability test of the six-quadrupole power supply.

Calibration and operation of all these power supplies guarantee a maximum difference of 1 mV between written and read set point, which corresponds to 10^{-5} precision in the current repeatability.

The 30 storage ring steering magnet power supplies are bipolar, series-transistor controlled with ± 10 A, 10 V maximum output. The betatron tune set, needed for significant current accumulation at 120 MeV, and the high current orbit stability impose strong requirements on current stability and ripple for these supplies. The high energy orbit is adjusted between injections to 20 µm to comply to the beam line user needs. The steering coil supplies are stable to 0.1 % and the 180 Hz ripple is 2 mA, which corresponds to 1 bit of the 12-bit DAC.

4 CONCLUSIONS

The LNLS accelerator power supplies have been in operation for over 1 year. During this period, the actual operation parameters and conditions have been defined and the power supplies adjusted accordingly, when necessary. In particular, the injection and accumulation at low energy have demanded stringent new operating conditions for the power supplies, which were designed mainly according to high current specifications. At present, the system performance is adequate and reliable for all the needed types of operation of the accelerators: cycling, injection, low energy accumulation and storing.

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