POWER SUPPLIES FOR THE LNLS 500-MEV BOOSTER SYNCHROTRON

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Abstract

Brazilian National Synchrotron Light Laboratory (LNLS) has commissioned its 500-MeV booster synchrotron machine. In this paper we present an overview of the magnet power supply system comprised by precise (better than 10 ppm) current supplies ranging from 5 A to 300 A, with powers of a few watts to 126 kW, and current ripple of 0.02 to 0.1 % relative to the maximum current. As the booster operates also as a storage ring, a special ramped current power supply had to be designed for the dipole magnets in order to accomplish both requirements of fast ramping up (1.9 s) and precise DC operation.

1 INTRODUCTION

Brazilian National Synchrotron Light Laboratory (LNLS) [1] has constructed a 1.37-GeV storage-ring facility for research on UV and X-ray, and successfully operates it since July 1997. Injection into this storage ring had been made from a 120-MeV LINAC.

In 1998 the construction of a booster machine was proposed [2] to make injection into the 1.37-GeV storage ring at a higher level: 500 MeV, and since then the construction of the building blocks for this new accelerator has begun. Commissioning of the 500-MeV booster storage ring started in April 2001 [3].

With the insertion of the booster storage ring, a new set of high-stability current power supplies was constructed for both the new injection and extraction transport lines and the booster itself. All power supplies were designed, developed and constructed by the Power Electronics Group at LNLS, according to requirements given by the Accelerator Physics Team. Table 1 lists the power supplies main characteristics.

Additionally, spare power supplies were constructed for all the low-power supplies ranging from 5 to 20 A.

Table 1: Characteristics of the LNLS power supplies for the new booster and transport lines

Magnets	Load Current (A)	Max. Mean Out. Voltage (V)	Current Stability	Ripple (mA)	Number of power supplies
120-MeV Injection Transport Line					**09**
H-Correctors	± 10	10	10^{-5}	± 1	02
V-Correctors	± 10	10	10^{-5}	± 1	03
Quadrupoles	10	10	10^{-5}	± 1	03
Dipoles	20	50	10^{-6}	± 10	01
Booster					**28**
H-Correctors (8 mrad)	± 6	10	10^{-5}	± 1	03
H-Correctors (2.5 mrad)	± 5	10	10^{-5}	± 1	07
V-Correctors (1.5 mrad)	± 5	10	10^{-5}	± 1	06
Quadrupoles	10	21	10^{-5}	± 10	08
Skew Quadrupoles	10	21	10^{-5}	± 10	01
Sextupoles	10	26	10^{-5}	± 10	02
Dipoles	300	420	10^{-5}	± 60	01
500-MeV Extraction Transport Line					**11**
H-Correctors	± 10	10	10^{-5}	± 1	02
V-Correctors	± 6	10	10^{-5}	± 1	03
Quadrupoles	10	15	10^{-5}	± 1	05
Dipoles	250	50	10^{-6}	± 250	01

2 POWER SUPPLY TOPOLOGIES

Taking into account the developments in switched-mode power supplies (SMPS) we tried to use this topology whenever possible in order to reduce costs, size and weight of the final power supplies.

2.1 Correctors

For all the correctors and some of the low voltage quadrupole power supplies we use a topology which combines a very low-cost SMPS used in personal computers (PC) with a series-linear regulation stage.

Small circuit changes were introduced into the original PC power supplies to make them suitable for this

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application where a variable output voltage of the SMPS is required, according to the desired load current.

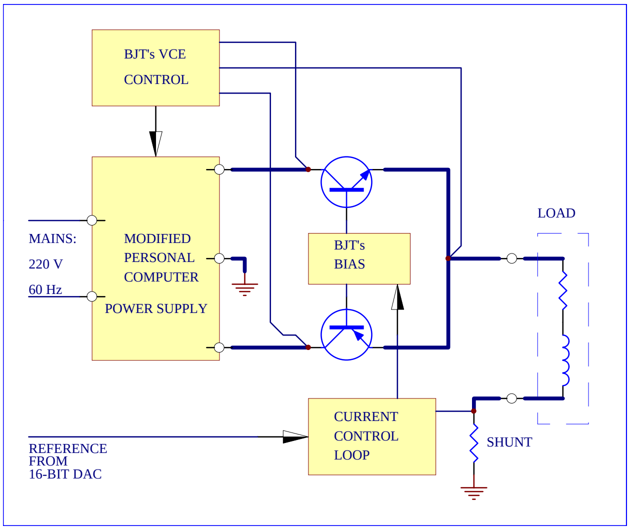

Figure 1: Block diagram of the corrector power supply.

Load current bipolar regulation is accomplished by complementary bipolar-junction transistors (BJT) in series with the load. Vce voltage across these BJTs is kept constant at 2 Vcc depending on which BJT is conducting. In this way, internal power consumption is greatly reduced (see Fig. 1).

Current load is measured by means of a shunt. Current regulation is simply achieved via a proportional-integral (PI) control. Another feedback loop monitors the Vce voltage across the BJT under conduction and controls the duty-cycle of the PC power supply in order to keep the Vce voltage constant over the full range of current variation.

2.2 Quadrupoles, Sextupoles and Injection Transport Line Dipoles

Due to the requirements of high-stability, low ripple, fast response to the ramped reference and immunity from mains perturbations, we have chosen a topology (see Fig 2) that combines an off-line 45-kHz half-bridge DC/DC isolated converter followed by a rectifier and low-pass filter. The resulting isolated DC voltage is then applied to a chopper stage that finally controls the load current by means of a current limit modulation (CLM). In this way current ripple is kept constant for all the load current range.

The chopper duty cycle is easily monitored and another control loop modulates the pulse-width at the DC/DC converter in order to keep the mean duty-cycle of the chopper stage constant at 50 %, over the range of operation of these current power supplies.

In order to obtain a high degree of precision (better than 10 ppm), long-term stability and isolate the control electronics from the load, a DC Current Transformer (DCCT) is used to measure and to feed back load current value.

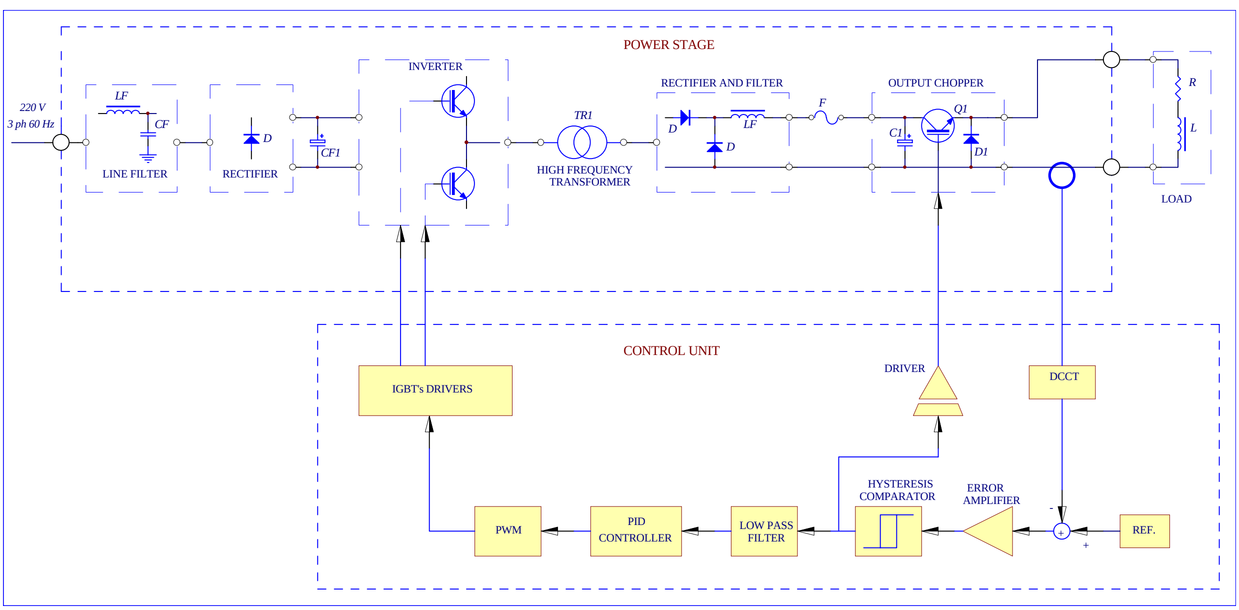

Figure 2: Block diagram of the quadrupole and sextupole power supplies.

2.3 Booster Dipoles

For the current and power involved, this power supply was the most challenged one to be designed and tested. As the booster machine operates also as a storage ring with a constant current of 300 A, we had to guarantee many conflicting aspects such as:

- Capacity of fast (1.9 s) ramping up from injection (57 A) to extraction (277 A) levels.
- Mean null tracking error during ramping up.
- High-stability on short and long-term operations.
- Low ripple ± 60 mA.
- Low fall-time for the load current at the end of the ramping up process.

This current power supply (see Fig. 3) is composed by a series association of a 6-pulse thyristor power supply and a SMPS with 12 chopper modules working in parallel. A similar scheme has been in operation with the 270 kW power supply that feeds the dipole magnets of the 1.37-GeV storage ring [4] but in that case with much less voltage (90 Vcc) at the chopper stage.

In the design we have built for the booster's dipole magnets power supply, 300 Vcc are present at the power modules that share the total current among them. Precise current regulation and tracking during the ramping up time is accomplished by the CLM method. Output voltage of the 6-pulse thyristor bridge is varied so as to keep a mean duty-cycle of 50 % at the SMPS stage.

SMPS modules are turned on and off sequentially 3.2 µs apart each other so as the dv/dt voltage applied to the load and cabling is kept at an acceptable level that does not generate enough EMI that would disturb other delicate equipments and instruments

During ramping up, the SMPS modules provide for the fast response of the power supply because of the voltage present at this stage, following the reference as long as the duty-cycle remains under control. The SMPS modules provide for the instantaneous voltage needed to encompass the reactive (1.56 H) power to the load.

After the end of the ramping up time and the electron beam is ejected from the booster, load current must decrease to its injection level as soon as possible. To overcome this problem, the DC switch (shown in fig. 3) opens and a resistive load of 2.2 Ω/22 kW is put in series with the dipoles in order to decrease the L/R constant of the load. In this way, repetitive cycles of a 5-second period have been achieved in booster operation.

2.4 Extraction Transport Line Dipoles

This power supply consists mainly of a SMPS working as a buck converter. Load current regulation is accomplished by the CLM method.

Six modules of IGBT-choppers working in parallel share the total load current. In order to reduce the dv/dt applied to the load, the IGBTs are turned on and off sequentially with a delay of 1us.

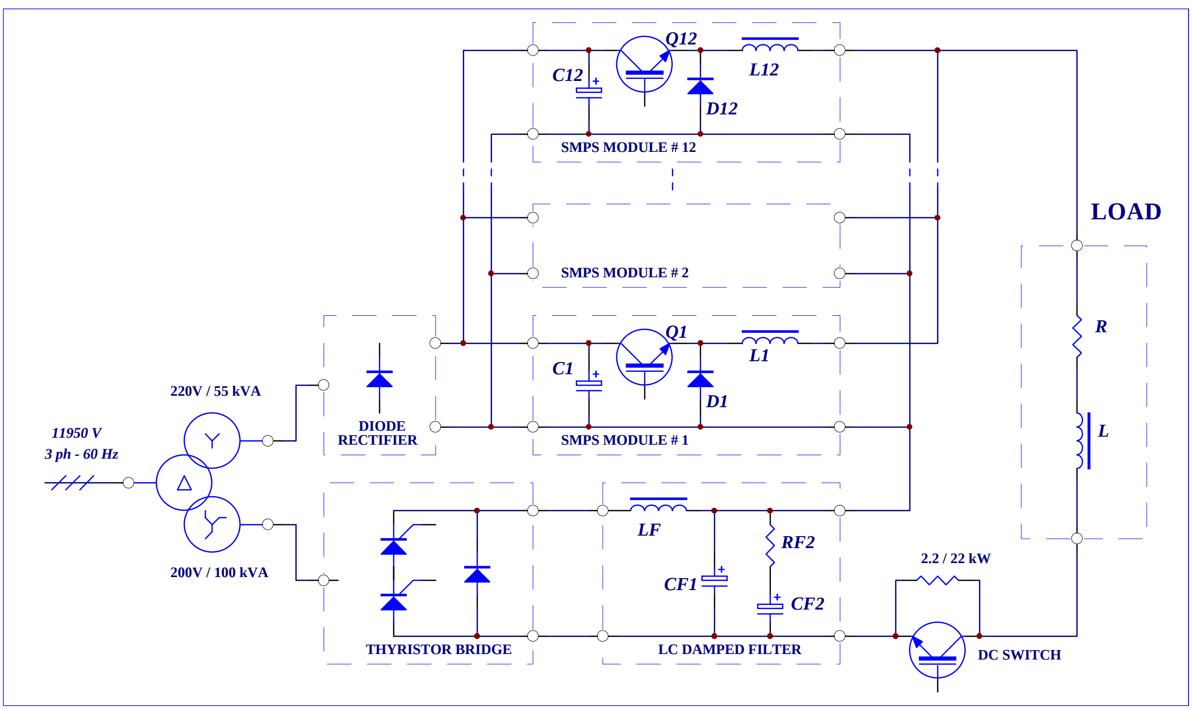

Figure 3: Basic configuration of the booster dipole power supply.

3 ACKNOWLEDGEMENTS

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4 REFERENCES

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