

SEPTUM AND KICKER PULSERS FOR THE LNLS 500-MEV BOOSTER SYNCHROTRON

A.C. Lira*, F.C. Arroyo, E.K.C.S. Hayashi, LNLS, Campinas, Brazil

Abstract

Brazilian National Synchrotron Light Laboratory (LNLS) has commissioned its new 500-MeV booster synchrotron injector. In this paper we present an overview of the septum and kicker pulse circuits now in operation. Half-sine wave septum current pulses range from 6.1 kA to 7.3 kA with widths around 80 μ s. Injection and extraction kicker circuits are capable of delivering currents up to 650 A and 1.2 kA, with fall and rise times consistent with the booster revolution period of 112 ns

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 has successfully operated it since July 1997. Since then, injection into this storage ring has been made from a 120-MeV LINAC.

In 1998 the construction of a booster storage ring was proposed [2] to make injection into the 1.37-GeV synchrotron 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 a 0.17 Hz repetition rate.

With the insertion of the booster injector, a new set of septum and kicker pulsers had to be constructed for both the new injection and extraction into/from the booster. All pulsers were designed, developed and constructed by the Power Electronics Group at LNLS according to the requirements given by the Accelerator Physics Team.

2 SEPTUM PULSER TOPOLOGY

All septum pulse circuits are based on half-sine wave circuits. A capacitor bank is constantly and precisely charged to the specified voltage necessary to obtain the desired peak current. At the time the high-current pulse is to be generated a SCR discharges the capacitors into the septum magnet. Table 1 lists the main characteristics of the septum circuits.

All septum magnets have similar construction: ferrite window frame in vacuum. Ferrites are of type Mn-Zn ($\rho=150 \Omega \cdot m$) MN-67 from Magnet Ceramics.

Table 1: Electric characteristics of the septum pulsers.

Septum	Function	Maximum Capacitor Voltage (V)	Peak Current (kA)	Pulse Width (μ s)	Pulser Capacitance (μ F)	Magnet Inductance (μ H)
YSI03	thin injection into booster	430	7.5	52	300	0.51
XSI01	thin extraction from booster	470	6.13	64	300	1.03
XSG02	thick extraction from booster	530	6.13	75.8	300	1.54
XSG05A	thick injection into ring	550	7.1	64	300	1.03
XSG05B	thick injection into ring	550	7.1	64	300	1.03
XSI06	thin injection into ring	450	4.77	53.1	200	1.03

2.1 The Septum Pulse Generators

All the septum pulse generators have the same basic configuration (see Fig. 1). The number of energy-storage capacitors is changed according to the desired peak of current pulse, and respecting for the maximum peak current of the capacitors (800 A each).

A prototype of the chosen topology was put in operation for over 1 million pulses, without showing any failures, at a repetition rate of 1 Hz, which corresponds to an estimated time of operation of 5 years.

*lira@lnls.br

The type of capacitors used plays an important role in the pulser's expectancy of life. A first attempt to use polyester metallized capacitors failed after some hours of operation when some capacitors were damaged. A second and successful attempt was made using self-healing metallized polypropylene capacitors.

In applications with such a high peak current, distributed gate thyristors must be used. In our case we have exhaustively tested the Westcode's R305CH16-F2H0 thyristor which finally was put into operation in all septum pulsers.

A recovery circuit (Dr and Lr) was added in order to restore some of the energy present at the capacitor bank, which have an opposite (negative) voltage at the end of the half-sine wave current pulse. This helps reducing the

total loss and avoids the recovery be done via the septum magnet.

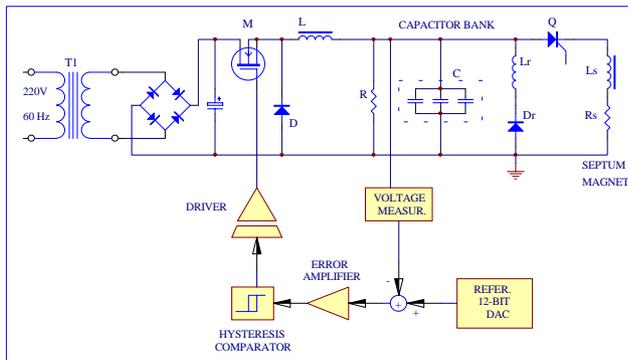


Figure 1: Basic topology of the septum pulser.

Voltage on the capacitor bank is stabilised via a Voltage Limit Control (VLC) that keeps this voltage swinging between two precise and fixed limits (100 mVpp) over the whole range of operation. This makes the capacitor bank voltage insensitive to variations in the mains voltage, since the MOSFET is turned on and off only to keep at a constant value the capacitor-bank mean voltage.

Due to the low repetition rate of the booster, the power dissipated in the septum coil is negligible.

Septum pulsers are placed as close as possible to the septum magnet in order to minimise stray fields and additional inductances. Connection between pulser and septum feed-through is made by a coaxial connection.

Figure 2 shows a typical waveform of a 8-kA peak current pulse.

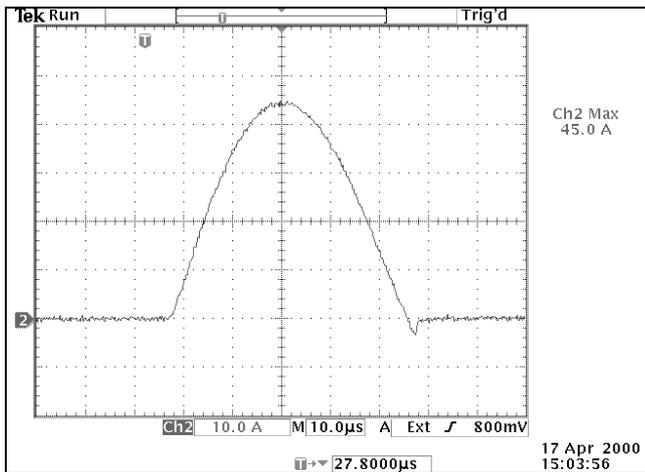


Figure 2: Typical current pulse of the septum circuits (1780 A/div).

3 KICKER PULSER CIRCUITS

Booster kicker circuits are based on the design of a Delay Line Pulser where the thyatron is electrically floating from the ground basis [4].

Because of the intrinsic inductances of the kickers we had to split magnet circuits in two halves, each one having its own pulser but the charging high-voltage remains the

same for both submodules, which are pulsed at the same time.

Kicker magnets are of the window-frame type inside a vacuum vessel. CMD-5005 high-frequency ferrites from Magnet Ceramics were used. Injection and extraction kicker mechanical design is the same and so are the topologies of the pulser circuits.

Table 2 lists the main parameters of operation for the injection and extraction kickers.

Table 2: Parameters of the kicker pulsers.

Parameters	Injection	Extraction
Max. PFN voltage	30 kV	30 kV
PFN impedance	25 Ω	12.5 Ω
Flat-top current	0.58 kA	1.11 kA
Rise-time (10% to 90%)	26.8 ns	40.2 ns
Flat-top duration	220 ns	152 ns
Fall-time (90 to 10%)	46.6 ns	85 ns

In order to reduce the rise time for the extraction kicker, a 500-pF peaking capacitor (C_p) was added on the design of this kicker pulser (see fig. 3). An overshoot of 10 % at the rising of the current at the extraction kicker seems to be tolerable and has an acceptable effect on the extracted beam, although a faster rise time would be desirable.

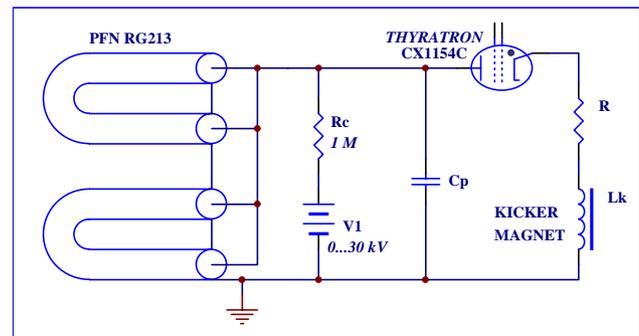


Figure 3: Kicker pulser diagram.

In the diagram, V1 is a high voltage regulated power supply from Glassman. Charging of the pulse-forming network (PFN) is made via a high resistance circuit R_c (1 MΩ) in order to avoid continuous conduction of the thyatron after a pulse has been produced. As the design pulse repetition rate is quite low: 0.2 Hz maximum, power losses on the resistive charging of the PFN is negligible.

Careful attention was taken during the mechanical design (see fig. 4) of the thyatron housing in order to reduce the EMI and provide for a low inductance circuit since the thyatron itself contributes greatly to the pulser's total stray inductance. A pipe of forced air makes the cooling of the thyatron directly to the cathode flange. Thermostat protection shuts-down auxiliary circuits and the high voltage power supply in case of overheating.

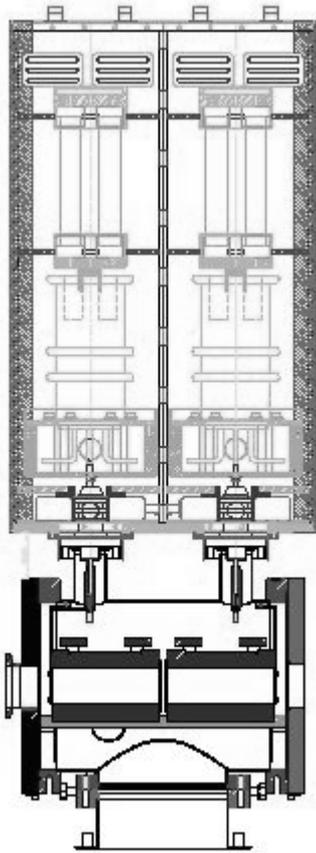


Figure 4: diagram of the thyatron housing and kicker.

During the production of the kicker pulses, the thyatron auxiliary circuits are isolated from the cathode potential by means of CMD-5005 ferrite rings in which five turns of the output auxiliary wires are coiled. This provides for an instantaneous high impedance circuit for the lasting of the pulse.

Auxiliary thyatron circuits for driving the grids, filament and reservoir power supplies were also developed and constructed by the Power Electronics Group at LNLS.

In order to reduce the reflected voltage applied to the thyatron at the end of the pulse duration and to match the PFN impedance 50Ω non-inductive resistors in parallel are used.

Figures 5 and 6 show the pulse current on the kicker circuits.

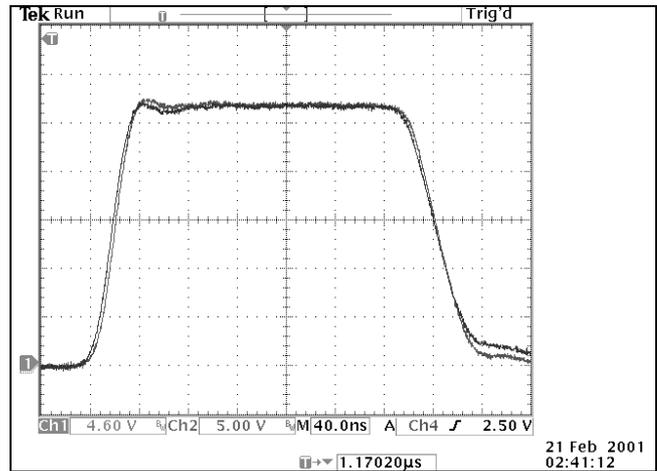


Figure 5: current pulses on the injection kicker magnets (110 A/div).

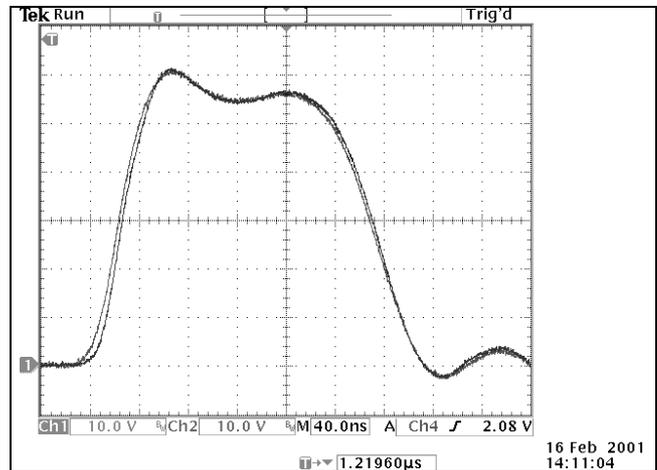


Figure 6: current pulses on the extraction kicker magnets (200 A/div).

4 REFERENCES

- [1] www.lnls.br
- [2] A.R.D. Rodrigues et al, "Design of a Booster for the Brazilian Synchrotron Light Source". EPAC98, Stockholm, Sweden.
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- [4] H.-D. Nuhn, R. Boyce, J. Cerino, T. Hosteler, "The SSRL Injector Kickers". SSRL ACD-Note # 101. June 1991.