Performance of the Elettra Injection System

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Abstract

A description of the Elettra injection system, which is composed by two Septum Magnets and four Kicker Magnets, is given. The two Septa are individually powered by a 9 kA peak current pulse, which is provided by discharging a capacitor by means of a thyristor switch. Each 8.35 kA pulse needed for the four Kickers is produced by four individual pulsers making use of a thyratron switch. The performances of the injection elements during the machine commissioning period are described and discussed.

1. INTRODUCTION

The injection of the electron beam into the Storage Ring takes place in the horizontal plane of the machine from the internal side of the ring. The system which performs this task is placed in a straight section and is composed by six pulsed magnets, four Kickers and two Septa [1], [5]. The Kicker Magnets operate in air, a ceramic vacuum chamber is placed inside the gap of each magnet in order to allow the magnetic field to penetrate through the chamber without distortion and attenuation; the Septum Magnets are enclosed in a suitable vacuum tank and operate in the same vacuum environment as the machine.

The injection magnets are supplied by dedicated capacitive discharge power pulsers able to produce current pulses with a total length of 5 μs for the Kickers, and a total length of 50 μs for the Septa; in both cases, it has been possible to reach up to 15 kA.

The trigger needed to fire the magnets is provided by the Timing System of the machine; a trigger signal called Pulsed Magnets Trigger is splitted into six signals by means of suitable delay boards: Fig. 1 shows the block diagram of the devices involved in the operations of each magnet.

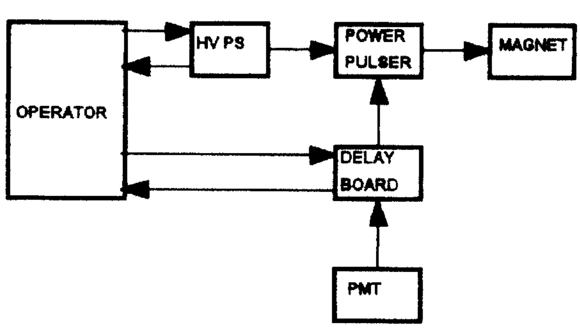

Fig. 1 - Typical pulsed magnet system block diagram

2. KICKER AND SEPTUM MAGNETS

The Kicker and the Septum Magnets are excited with current pulses.

The peak magnetic field required for the Kickers (0.22 T) is relatively high for this kind of magnet, but the use of a ferrite core it is still possible. Nevertheless the solution with laminated iron core has been preferred because of its simplicity and reliability; thanks to this, very compact, robust magnets with low sensitivity to mechanical stresses and shocks have been obtained.

On the other hand, the peak magnetic field required for the Septa (0.76 T) is too strong to allow the use of a ferrite magnetic core and therefore the laminated iron core solution was mandatory.

The cross sections of the Kicker and of the Septum Magnets are shown in Fig. 2 and fig. 3 respectively.

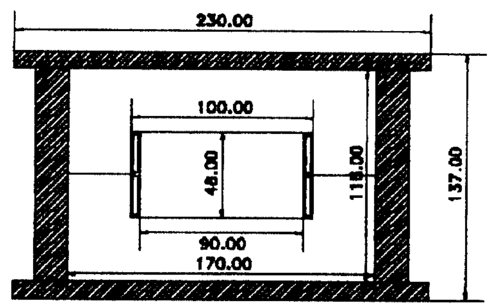

Fig. 2 Kicker Magnet cross section
(magnet core length 600 mm)

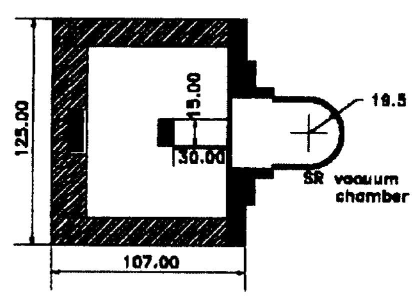

Fig. 3 Septum Magnet cross section
(magnet core length 720 mm)

Taking into account the skin effect in a ferromagnetic foil, the thickness of the laminations has been chosen in such a way to avoid the saturation of the magnetic core: the following commercial available laminations have been adopted for the construction.

Kicker Magnets	Septum Magnets
Permalloy C 0.1 mm	Silicon Iron 0.18 mm

The 0.1 mm laminations of the Kickers have been packed and glued together with Araldite F, in a stainless steel housing.

On the other hand, the 0.18 mm lamination of the Septa have been cleaned with an ultrasonic procedure and simply packed into a stainless steel box. The materials used in the construction of the Septum Magnets have been carefully selected in order to limit the degassing process, due to the UHV operating environment [5]. The Septum screen, which shields the stored electron beam from the magnetic field of the Septum Magnet, has been made out of copper.

To achieve a safe operation with a simple construction, a single turn coil winding has been adopted for each magnet, resulting in the following inductance values:

Kicker Magnet	Septum Magnet
1.5 μH	2.0 μH

In both cases the current pulse has been obtained by discharging a capacitor into the magnet; the switch used to start the discharge process differs from Kickers to Septa depending on the value of the voltage needed to charge the capacitor. In the case of the Kickers it is necessary to reach over 15 kV and for this reason a thyratron switch has been used; in the case of the Septa, where the pulse is 10 times longer than that for the Kickers, only 1.5 kV are necessary and it has been possible to adopt a thyristor switch. The conceptual scheme of the power pulser is shown in Fig. 4.

Since the pulse forming network is based on a capacitive discharge process, the current waveform obtained is essentially a half sine wave. But the presence of a recovery network, which is different from Kickers to Septa, modifies the decay part of the current pulse [4], [2], [3].

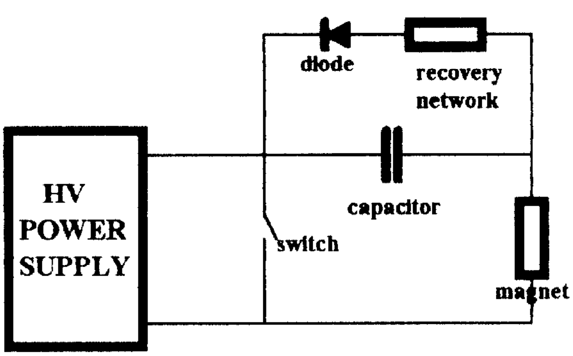

fig. 4 - Conceptual pulser scheme

The recovery network for the Kicker circuit is a pure resistance in order to have a damped oscillating behaviour of the current pulse [4]; Fig. 5 shows a typical waveform of the Kicker current pulse, acquired from a Pearson current transformer mod. 110 and digitized by an oscilloscope.

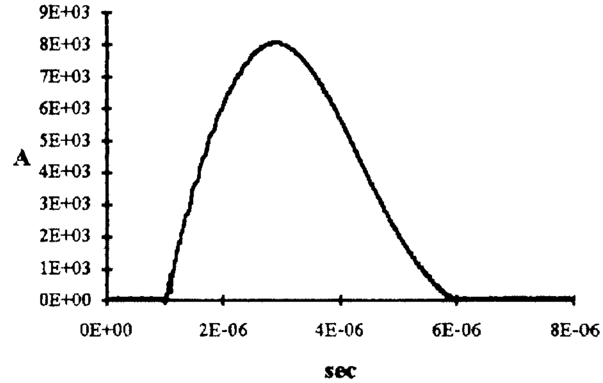

fig. 5 - 8 kA Kicker current pulse

It is very important to notice that it has been possible to obtain a current pulse with no negative values, whose presence would lead to adverse effects on the stored electron beam and, above all, on the thyratron lifetime.

In case of the Septum circuit the recovery network is an inductance, 10 times higher than the inductance of the magnet, allowing a recovery of the energy which is restored in the capacitor. Up to 90% of the starting voltage has been measured on the capacitor at the end of one cycle [2], [3]. Fig. 6 shows a typical waveform of the Septum current pulse obtained from a Pearson current transformer mod. 101 and digitized by an oscilloscope.

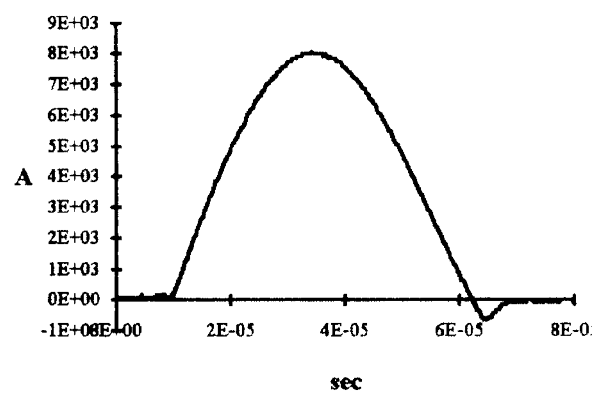

Fig. 6 - 8 kA Septum current pulse

The presence of the negative portion of the current pulse does not disturb the injected beam because the electron bunches coming from the linac go through the Septa only when the pulses reach their peak values; moreover it does not affect the lifetime of the thyristor because the relevant energy has been damped by a suitable snubber network in parallel with the thyristor.

3. SYSTEM PERFORMANCES

Both the Kicker and Septa systems have been tested in laboratory for an entire week of continuous operation at 120% of the 2 GeV nominal parameters, and no faults or damages have been observed during this period.

For each magnet, calibration data have been collected in order to control all the magnets with suitable software from ELETTRA control room. Typical response curves are shown in Fig. 7 and in Fig. 8 respectively.

In Fig. 7 the peak value of the signal from a Pearson current transformer (CT) (0.01 V/A) is plotted vs. the high voltage applied to the Kicker circuit.

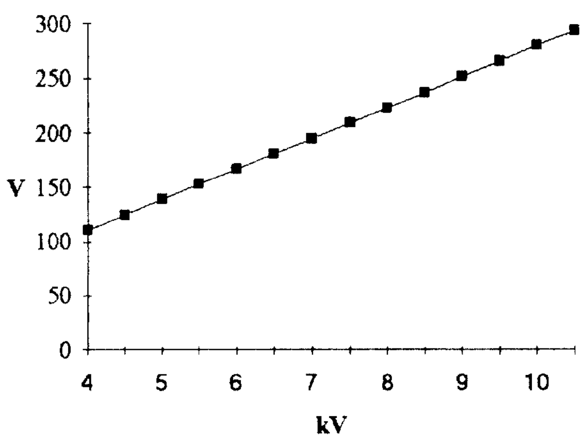

Fig.7 - Signal from Kicker CT vs. HV

In Fig. 8 the peak value of the signal from a Pearson current transformer (0.1 V/A) is plotted vs. the high voltage applied to the Septum circuit.

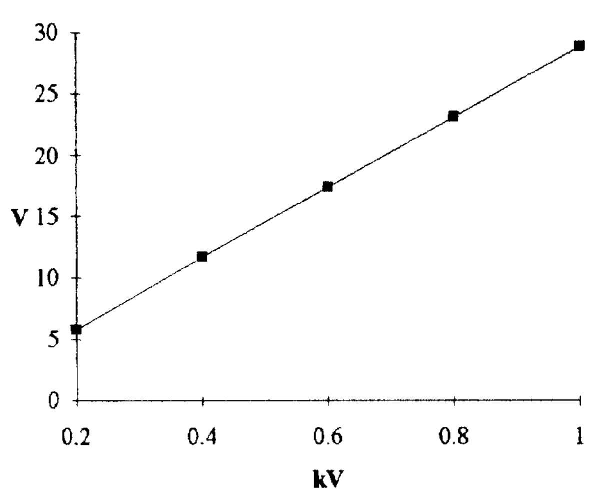

Fig. 8 - Signal from Septum CT vs. HV

During the machine operation the Kickers system did not show significant differences from what had been seen during the laboratory tests; in particular no false triggering and no missing pulses have been observed even if the system was operating 24 hours a day, especially during the period from October to December 1993.

It has to be mentioned that during all the commissioning operations, the filaments of all the four thyratrons have been always kept turned on for a total amount of 2200 (March 94) hours; on the other hand the trigger pulses have been enabled almost continuously during the first three months of commissioning and thereafter they have been enabled only when injection was required.

The Septa system, on the other hand, showed a positive drift in the peak values of the current pulses of both magnets, caused by a decrement of the inductance of the magnets. The increment of the peaks, in fact, is followed by a proportional decrement of the total length of the pulses.

The variation of the inductances, is due to the heating of the winding coils which results in a change of the geometry of the coils themselves. A compensation of the drift has been performed by chosing an injection time, on the injection pulse, where the amplitude remains constant in case of a thermal drift; then, acting on the delay boards of the Septa, the electron bunches have been synchronized in such a way to go through the magnets in this moment.

A software feedback system, based on a 10 bits acquisition of the Septa current pulses, is being implemented to control the stability of the peak values of the pulses.

4. CONCLUSIONS

After this first commissioning period the following conclusions can be made.

The whole injection systems showed the expected reliability, a feature which is mandatory not only for the injection efficiency, but for the correct operation of the machine itself.

Even if the Septum Magnets showed a small drift in the peak values of the current pulses, with the compensation technique mentioned before, it was possible, during routine operations, to reach up to 10 mA/s of injection rate, which is very close to the maximum theoretical value.

5. REFERENCES

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