THE PSB EJECTION BUMPER SYSTEM FOR LHC

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1. INTRODUCTION

The LHC will be provided with protons from the injector chain Linac2 - PS Booster - PS - SPS. This injector chain is currently being upgraded to meet the stringent LHC beam parameter specifications [1]. In order to meet the beam brightness specification, the injection energy to the PS (and hence the ejection energy from the PS Booster) has been raised from 1GeV to 1.4GeV. This necessitated the upgrade, amongst other elements, of the PSB ejection bumper system.

Ejection of protons from the Booster follows a classical fast ejection scheme comprising three different magnetic systems:

i) a set of three slow bumpers (BE.BSW14L4, 15L1, 15L4) create a localised orbit deformation. The maximum field of the bumper is such that the particles still pass to the left of the septum magnet blade (zero-field region) and thus are not ejected.

ii) a fast kicker (BE.KFA14L1) provides the necessary additional deflection to move the particles into the septum's high-field region.

iii) a septum magnet (BE.SMH15L1) produces a large deflection to move the particles onto the transfer-line trajectory.

Each bumper pulse generator excites four vertically superimposed magnets.

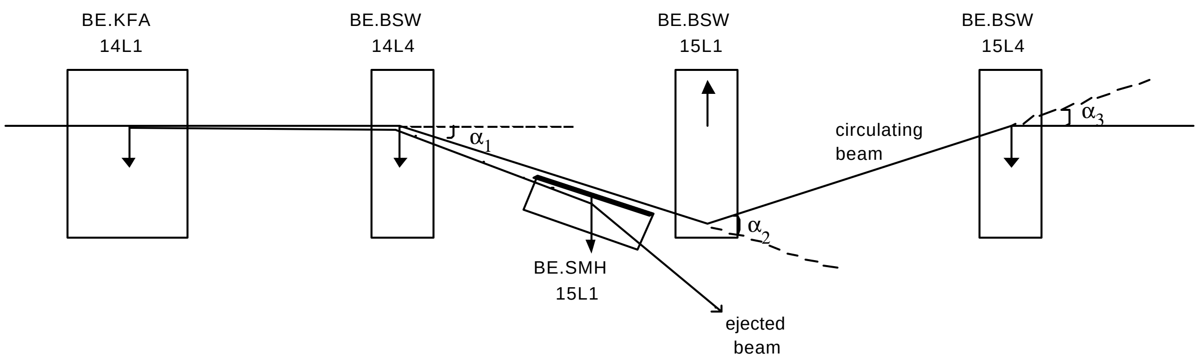

Figure 1. Schematic representation of the ejection system.

2. REQUIREMENTS

For ejection at 1.4GeV it was necessary to increase the field strength by a factor of approximately 26%; requiring an increase in the bumper magnet peak current from 500A to 630A. Whilst it was possible to conserve the existing magnets, their associated pulse generators were limited to 550A peak current. In addition, the bumpers would now be required to operate in ppm mode (between 1GeV and 1.4GeV). In view of these new operating conditions, and the necessity to interface to a new DSC-based control system, it was decided to completely replace the existing pulse generators.

3. DESIGN DETAILS

3.1 Magnets

The existing magnets, in use since 1972, were retained for use at 1.4GeV. BSW14L4 and BSW15L4 comprise Booster type 5 magnets, BSW15L1 comprises type 6 magnets. The magnets are connected in a series/parallel configuration which presents an effective impedance equivalent to that of a single magnet. The relevant parameters for the three magnet groups are listed below.

BSW	U_{max} (V)	I_{max} a),b) (A)	Aperture w x h (cm)	$\int B.dl_{max}$ (T.m)
14L4	500	765	14.6 x 14.4	0.095
15L1	500	845	14.6 x 7.2	0.134
15L4	500	765	14.6 x 14.4	0.095

a) Current per individual magnet. b) I_{max} is hardware limited to 690A for all magnets.

Table 1. BSW magnet main parameters.

3.2 Pulse Generator

An effort was made to use, to the fullest extent, similar chassis and components to those already in use in the kicker systems; this to facilitate maintenance and reduce design time and costs.

The operating principle is based on a resonant semi-sinusoidal current discharge into the bumper magnet with a free-wheel diode/inductor circuit providing a partial recharge of a primary capacitor.

Figure 2 shows a simplified electrical circuit for one bumper magnet group and its associated power supply. C1 is charged to a voltage V by a current source I1. When the semiconductor switch, SCR1, is triggered on, a resonance is excited between C1 and the magnet inductances L_ring1, L_ring2, L_ring3 and L_ring4. This lightly-damped sinusoidal current is interrupted by the opening of SCR1 at the instant of zero-crossing.

The free-wheel circuit comprising D1 and L_recovery begins to conduct when the voltage on C1 goes negative; a secondary resonance then occurs between L_recovery and C1 which ends when the current in D1 starts to become negative. This results in C1 completing the cycle with a positive charge, thereby reducing both the power losses and the post-cycle recharge period.

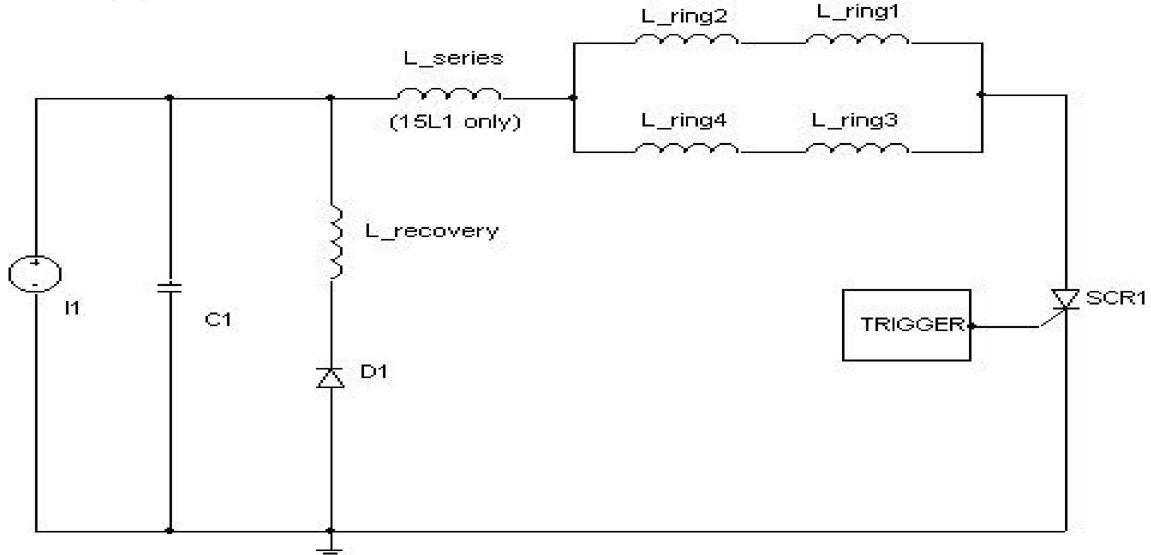

Figure 2. Simplified circuit diagram of one bumper.

The current source I1 is inhibited during the pulse period to protect it from the inverse voltage seen at its output terminals. This inhibit is lifted soon after the secondary resonance has stopped, at time t = 60ms. The recharge of the primary capacitor starts at this instant, and can be seen on the V_{C1} trace of Figure 3.

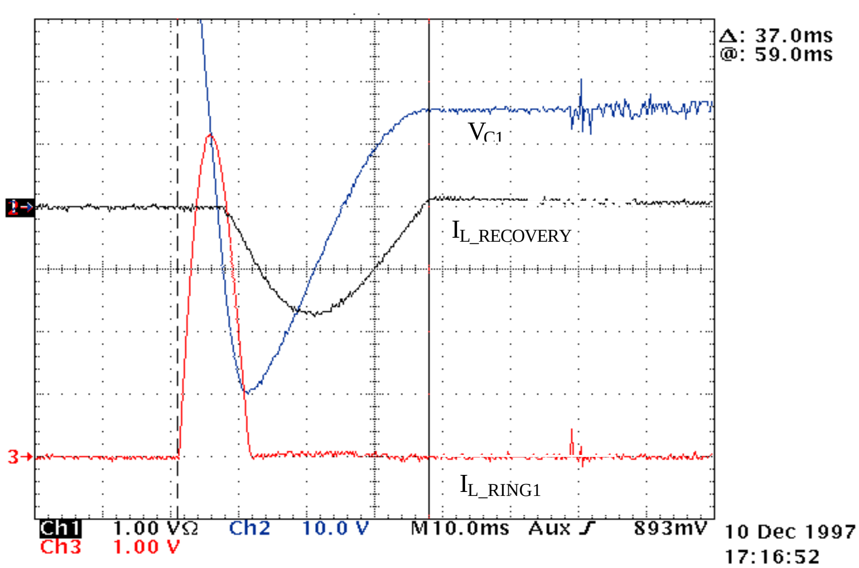

Figure 3. Representative waveforms of the power supply.

The magnetic section of 15L1 (type 6 magnet) differs from the other two bumpers (type 5 magnets) in that its vertical aperture is smaller. It also has fewer turns and consequently 15L1 has a lower inductance. Given that in the bumper scheme the temporal form of the magnetic fields needs to be identical in all three magnets (at least until the ejection point), additional reactance is needed in the circuit to conserve the same resonant frequency as the other two. To allow the use of similar primary capacitors in all three pulse-generating circuits an extra series inductance is added to the 15L1 circuit.

4. PERFORMANCE

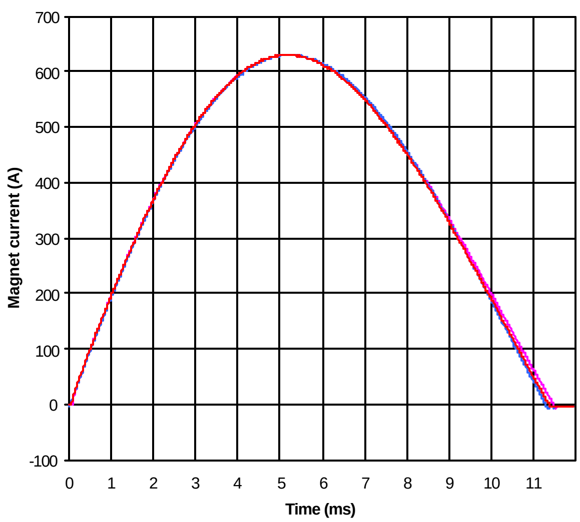

Figure 4. Current waveforms of the three bumpers.

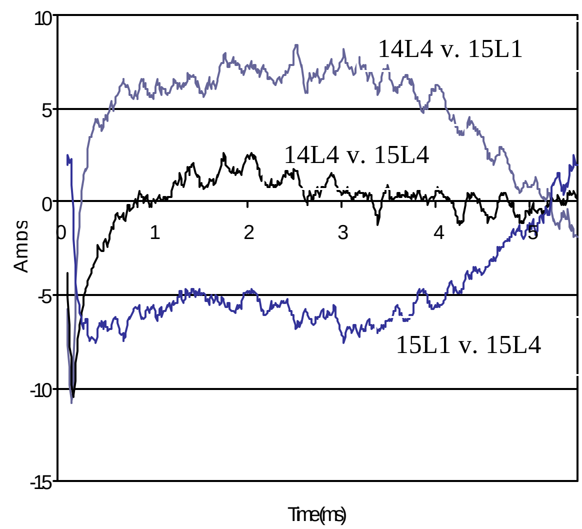

Figure 5. Current tracking error of the bumper pairs.

Figure 4 shows that peak current is reached in 5.25ms, and that the current tracking between the three bumpers is close until the ejection point at the peak of the semi-sinusoid. The current tracking error of the three bumpers is shown in figure 5. Both figure 4 and figure 5 were constructed from values sampled every 10us.

5. CONTROLS AND OPERATION

The pulse generators and associated controls are located in Building 361, BCER, Racks 108 to 113 inclusive. A local G64-based processor in each of the bumpers acts as an interface between the pulse generator and the DSC DPSBKSU2 of the PS control system (located in Rack 106). Communication between the DSC and the G64 crate is via RS232. The Command/Status protocol is the same as that used for the Ejection Kicker equipment.

Individual timing is sent to each pulse generator, namely BEX.WBSW14L4, BEX.WBSW15L1 and BEX.WBSW15L4. These are independently variable on the 10MHz train and arrive approximately 5.2ms before beam ejection.

To facilitate correct ppm operation an intermediate CCV value of 300A is sent for all cycles not having timing enabled and Kick On. This manifests itself as a voltage of 200V on the primary capacitor. The three bumpers have individual current control values. Typical current values for 1GeV and 1.4GeV and corresponding capacitor voltages are 500A, 330V and 630A, 400V respectively. A hardware interlock is set to occur for any CCV greater than 690A.

The current values shown on the local current measurement display indicate the total circuit current, i.e. twice the individual magnet branch currents.

6. REFERENCES

[1] K. Schindl, *The Injector Chain For The LHC*, CERN/PS 99-018 (DI)