THE KICKER SYSTEMS FOR THE PS MULTI-TURN EXTRACTION

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Abstract

A five-turn continuous extraction has up to now been used to transfer the proton beam from the CERN PS to the SPS. This extraction uses an electrostatic septum to cut the filament beam into five slices, causing losses of about 15 %. These losses would be an even greater drawback when the beam intensity is increased for the CERN Neutrinos to Gran Sasso (CNGS) facility. To overcome this a Multi-Turn Extraction (MTE) has been implemented, in which the beam is separated, prior to extraction, into a central beam core and four islands. Each beamlet is extracted using a set of kickers and a magnetic septum. For the kickers two new pulse generators have been built, each containing a lumped element Pulse Forming Network (PFN) of 12.5 Ω, 80 kV and 10.5 µs. For cost reasons existing 15 Ω transmission line kicker magnets are reused. The PFN characteristic impedance deliberately mismatches that of the magnets to allow a higher maximum kick. The PFN design has been optimised such that undesirable side-effects of the impedance mismatch on kick rise-time and flat-top remain within acceptable limits. The kicker systems put in place for the current first phase of MTE are presented.

INTRODUCTION

The new PS Multi-Turn extraction (MTE) scheme [1], which replaces the Continuous Transfer (CT), is based on a fast bump around the magnetic septum SMH16 (Fig. 1).

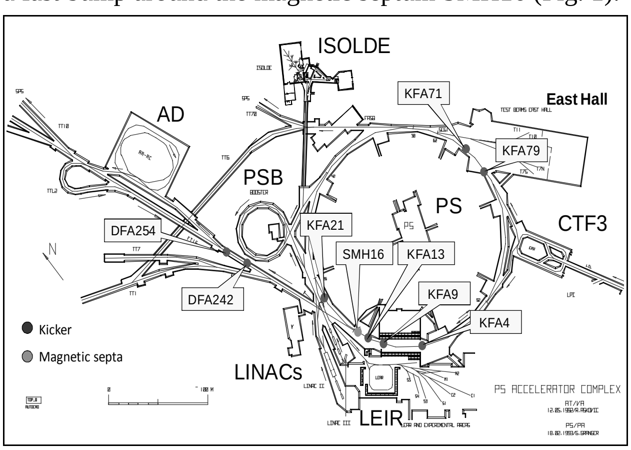

Figure 1: PS complex layout, indicating the location of the fast pulsed magnets employed in the MTE scheme.

Fast pulsed kicker magnets, located in straight sections (SS) 13 and 21 (KFA13 and KFA21), create a nearly closed bump for the beamlets in the first four turns. To close it perfectly, an existing kicker in SS9 (KFA9) is used. The core beam needs to be moved out by more than twice the distance of the other four beamlets. One additional kicker located in SS4 (KFA4) kicks out the core beam in the fifth turn, in conjunction with the existing fast extraction kicker KFA71-79 system. Two existing fast dipoles (DFAs) in the TT2 transfer line correct the trajectory of the beamlets to reduce the beam emittance in the SPS.

The system is being implemented in two phases. The first phase, completed in 2008, concerns the KFA13/21 and KFA4 subsystems, together with the existing KFA71-79 and KFA9 systems. Fig. 2 shows the new MTE kicker generators, with the blue Pulse Forming Networks (PFN) on the ground floor.

Figure 2: Kicker generators for KFA4 (right), 13 and 21.

SYSTEM DESCRIPTION

KFA4

KFA4 consists of a single terminated 15 Ω delay line magnet excited by the fast discharge of a SF_6 gas filled Pulse Forming Line (PFL). The system reuses an existing magnet, vacuum tank and pulse generator dedicated to lepton injection during the LEP era. The magnet has been slightly modified to connect smooth transition pieces between tank flanges and its outer ground plates. This kicker is dedicated to the core beam extraction only and therefore has a kick length of 2.1 µs which corresponds to one PS turn.

Fig. 3 shows the system layout and table 1 gives its main parameters.

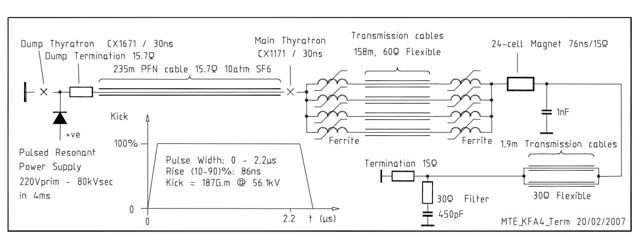

Figure 3: KFA4 system layout.

Thyratrons from E2V Technologies™ are used to discharge the PFL: a CX1171 for the main switch and a CX1671 for the dump switch. CMD5005 ferrite saturating inductor rings are inserted in the circuit to reduce the kick rise-time to a value close to that of KFA71-79. This helps to both steepen the current wave front after travelling through the 158 m long 60 Ω, RG220 like, transmission cables and to reduce the main switch thyratron pre-pulse current [2].

Table 1: KFA4 parameters

Item	Unit	Nominal	Achievable
Deflection angle at 14 GeV/*c*	mrad	0.400	0.571
Magnetic rigidity at 14 GeV/*c*	T.m	46.68	
∫Bdl	T.m	0.0187	0.0267
Magnet impedance	Ω	15.7	
Magnet aperture v × h	mm × mm	74 × 112	
Effective magnetic length	mm	615	
Kick duration	μs	2.1	2.2
PFN impedance	Ω	15.7	
PFN charging voltage	kV	56.1	80
Magnet current	A	1788	2576
Kick rise time (10 – 90) %	ns	86	

KFA9

KFA9 consists of a terminated lumped inductance magnet supplied by an 8.33 Ω PFN. The thyratron switch used to discharge the PFN is a CX1159. The system was built in 1975 [3] for the CERN PS to SPS CT which was used in parallel with MTE during its commissioning phase. This kicker is used to close perfectly the bump created by KFA13 and 21. The pulse duration is 10.5 μs minimum, which corresponds to five PS turns. Its rise time matches that of KFA13/21. The PFN charging voltage is pulse to pulse modulated between 29 kV (CT setting) and 7.2 kV (MTE setting). Fig. 4 shows the system layout and table 2 gives its main parameters.

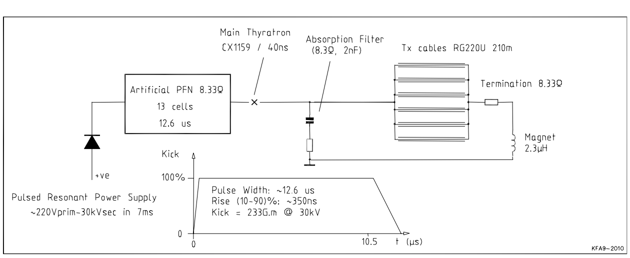

Figure 4: KFA9 system layout.

Table 2: KFA9 parameters

Item	Unit	Nominal	Achievable
Deflection angle at 14 GeV/*c*	mrad	0.120	0.499
∫Bdl	T.m	0.0056	0.0233
Magnet inductance	μH	2.3	
Magnet aperture v × h	mm × mm	52.5 × 158	
Effective magnetic length	mm	540	
Kick duration	μs	10.5	12.6
PFN impedance	Ω	8.33	
PFN charging voltage	kV	7.21	30
Magnet current	A	433	1800
Kick rise time (10 – 90) %	ns	350	350

KFA13 and 21

Both systems are identical except for the length of the transmission cables between generator and magnet. They consist of two parallel 25 Ω PFNs energizing three series connected 15 Ω delay line type magnets [4]. Fig. 5 shows the system layout and table 3 gives its main parameters.

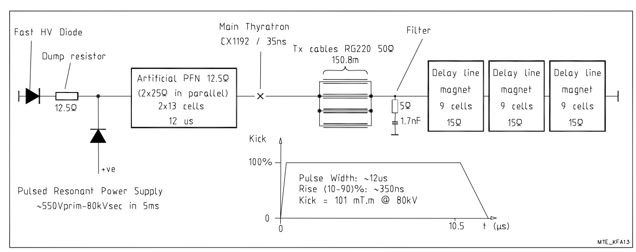

Figure 5: KFA13 system layout.

The system reuses magnets and vacuum tanks built in the late seventies in the framework of the CERN multi-pulsing project. The magnets are terminated in a short-circuit in order to double their current. They have been slightly modified to include smooth transition pieces between tank walls and their outer ground plates. Reinforced contact fingers and vacuum feedthroughs have also replaced the old ones to withstand the magnet current increase. The PFN impedance has been deliberately chosen lower than that of the magnet in order to increase the available current. The effect of this mismatch on the kick waveform is negligible as it is compensated by a capacitive filter at the magnet input. The 80 kV cell capacitors have been manufactured by the Czech company ZEZ Silko™. The PFN is resonantly charged in 5 ms from a 600 V primary electrolytic capacitor bank via a Stangenes™ step-up transformer. It is discharged by a 3 gap 4.5" thyratron, type CX1192, rated at 100 kV and 6000 A. The PFN energy is dumped by an HVR™ carbon mass resistor disc assembly connected in series with a semi-conductor diode stack. The stack consists of ten series connected multi-chip diodes, type 5SDA27Z1353, from ABB™. Their current-voltage rating is 60 kA and 13.5 kV.

Table 3: KFA13/21 parameters

Item	Unit	Nominal	Achievable
Deflection angle at 14 GeV/*c*	mrad	1.897	2.16
∫Bdl	T.m	0.0886	0.101
Magnet impedance	Ω	15	
Magnet aperture v × h	mm × mm	53 × 147	
Magnet effective magnetic length	mm	255	
Number of magnets in series		3	
Kick duration	μs	10.5	12
PFN impedance	Ω	12.5	
PFN charging voltage	kV	70.3	80
Magnet current	A	5620	6400
Kick rise time (10 – 90) %	ns	350	350

The generator components are immersed in Midel™ 7131 ester oil for insulation and cooling purposes.

KFA71 and 79

These kickers were installed in the seventies in the PS machine and are used for the fast extraction of all PS beams [5]. For MTE, they are pulsed synchronously with KFA4 to provide additional kick to extract the core beam.

KFA71 and KFA79 vacuum tanks contain nine and three, respectively, 15 Ω delay line magnets. Each magnet is energized by the fast discharge of a SF_6 gas filled PFL. Fig. 6 shows one magnet-generator unit layout and table 4 gives the system main parameters. The layout is very similar to that of KFA4, except for rigid transmission cables which are SF_6 filled. The system is very flexible and a dedicated program computes, for each PS extracted beam type, the number of magnets to be energized and the current required to achieve the kick.

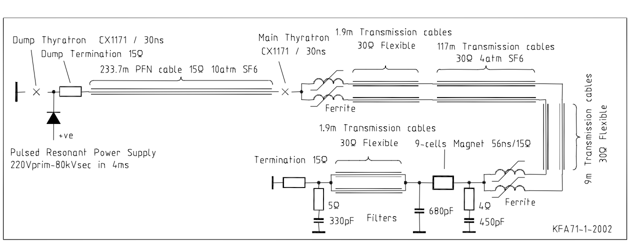

Figure 6: KFA71/79 unit layout.

Table 4: KFA71/79 parameters

Item	Unit	Nominal	Achievable
Deflection angle at 14 GeV/*c*	mrad	1.834	3.584
∫Bdl	T.m	0.0856	0.1673
Magnet impedance	Ω	15	
Magnet aperture v × h	mm × mm	53 × 147	
Magnet effective magnetic length	mm	255	
Number of magnets		9 + 3	
Kick duration	μs	2.1	2.2
PFN impedance	Ω	15	
PFN charging voltage	kV	41	80
Magnet current	A	1365	2650
Kick rise time (10 – 90) %	ns	56	

CONCLUSION

The kicker systems used for the MTE extraction from the PS have been presented. The systems are used since the MTE commissioning start in July 2008 and in full operation for physics production since the CNGS start-up in 2010.

REFERENCES

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