POWER SUPPLY SYSTEM OF THE PULSE BENDING MAGNET FOR THE LINEAR ACCELERATOR OPERATED AT THE MOSCOW MESON FACTORY

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Abstract

To ensure simultaneous operation of the linear accelerator in the experimental and isotope production systems, a pulse (kicker) magnet with its power supply system (pulse modulator) has been designed and manufactured in the D.V. Efremov Institute by an order of the INR RAS. The pulse magnet with its power supply system has been installed in the INR RAS and adjustment works have been performed. In the paper are described a schematic and principle of operation of the pulsed magnet and modulator deflecting a part of proton macropulses to the isotope production system. The results of the adjustment works performed are presented in the paper.

INTRODUCTION

To widen the potentialities of simultaneous operation with the beams produced by the linear accelerator operating at the Moscow Meson Factory (Troitsk town), a special pulse electromagnet(kicker magnet) with a supply system (pulsed modulator) has been designed and manufactured. The magnet pulsed at a repetition rate of 50 Hz allows a deflection of a 100-160 MeV beam of H^+ или H^- ions by 13º to a target intended for production of isotopes. The rest macropulses intended for physical experiments pass without distortion of their trajectories.

REQUIREMENTS FOR KICKER MAGNET

The kicker magnet is intended to replace the used permanent electromagnet, therefore, overall and setting dimensions should be kept the same. In addition, the magnet was supposed to operate both in the pulse and continuous modes, and a sufficiently high induction in the magnet yoke, 0.85 T, was chosen. The pulse of the current passing through the magnet is of a half-sinusoidal shape; the current pulse length is 12 ms. The pulse repetition rate is 50 Hz. When a pulse ceases, the residual magnetic field should be minimum so that the second macropulse can pass without a deflection. When a 200 ms macropulse is passing, the magnetic field non-uniformity at the half-sinusoid top is 0.05%. To keep stable 13º bending of a proton macropulse, the long-term pulse-to-pulse reproducibility of the magnetic field should not exceed this value.

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Table 1: Main Parameters of the Kicker Magnet

Parameters	Q-ty
Bending angle for 100-160 MeV proton beam	13º
Pole straight section length (uniform field), mm	350
Pole width (uniform field), mm	145
Gap height, mm	60
Magnet inductance, H	0.03
Magnetic half-sine pulse length, ms	12
Winding cooling	Water

PULSE MAGNET DESIGN

As the kicker magnet is pulsed at a repetition rate of 50 Hz, to reduce the eddy current heating of the magnet yoke it was assembled of 0.35 mm- thick laminations of electrotechnical steel 3413 previously thermally treated and with insulating coating [1]. Figure 1 shows the general view of the magnet.

Figure 1: The kicker magnet at a test facility.

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To reduce the edge effect along the beam axis, pole shimming is provided. To give a necessary shape to magnet poles, prior to assembly steel laminations have been milled in stacks, each of 5 sheets, at least. Thus the damage of the insulation between laminations was minimized. The direction of the electrotechnical steel rolling is perpendicular to the pole surface. All the laminations are glued with an epoxy compound under press and are tied with sheets of stainless steel.

The windings are divided into four separate coil sections. Two sections are fixed on the upper pole and other two are fixed on the lower pole. Each section is wound of a rectangular conductor 8×8 mm in cross-section; a circular channel is made inside the conductor through which the cooling water circulates.

POWER SUPPLY SYSTEM OF THE BENDING MAGNET

For the supply of the kicker magnet, a special pulse modulator has been designed and manufactured in the D.V. Efremov Institute. The output parameters of the modulator are given in Table 2. Figure 2 shows a functional diagram of the pulse modulator of the kicker magnet.

Table 2: Main parameters of the pulse modulator

Parameters	Q-ty
Magnet current maximum amplitude, A	430
Maximum amplitude of voltage across the magnet, V	3200
Power consumed by the modulator, W	36000
Recuperation current amplitude, A	3000
Pulse-to-pulse instability of the magnet current amplitude, not worse than, %	±0.05
Long-term instability of magnet current amplitude, not worse than, %	±0.05
Magnet current amplitude step, A	0.02
Pulse repetition rate, Hz	25-50
Modulator current pulse shape	Half-sine pulse
Modulator half-sinusoid pulse length, ms	12

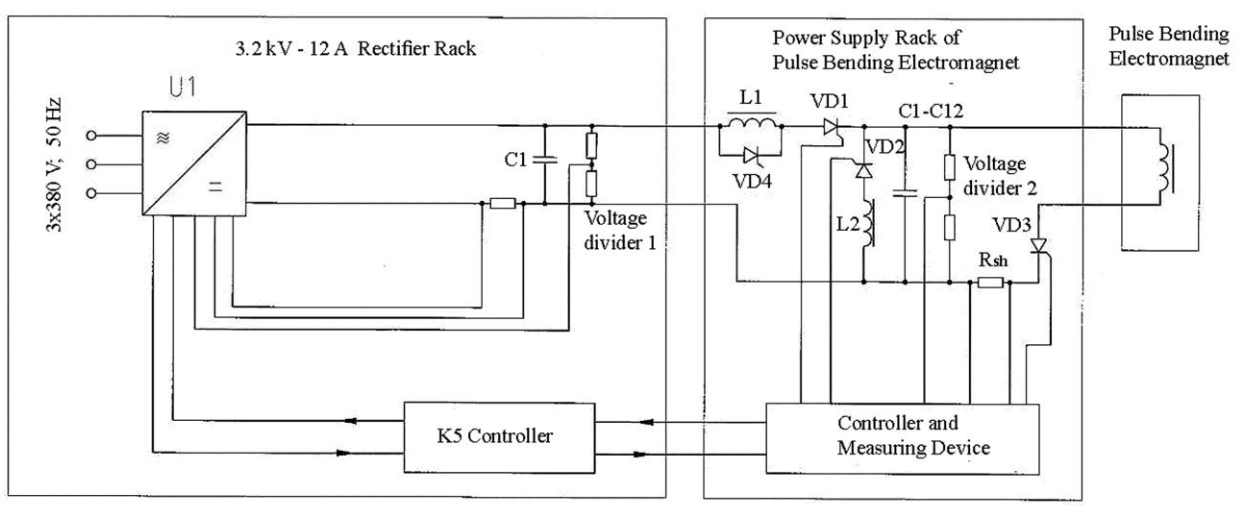

Figure 2: Functional diagram of the power supply system of the pulse bending electromagnet for the Moscow Meson Factory, the INR RAS

The pulse modulator consists of a high-voltage power supply rack-U_1 and a power supply rack of the magnet. The principle of operation of the pulse modulator is based on the discharge of a capacitor bank into a magnet inductance. Voltage for C1-C12 capacitors charging is supplied from the high-voltage power supply U1 through a charging resonant choke L1 and a unit of charging thyristors VD1. When a VD3 thyristor turns on, the magnet inductance is turned on in parallel with C1-C12 capacitors. A resonance circuit formed by these capacitors is tuned to a frequency of 42 Hz, which corresponds to the half-sinusoid length of 12 ms. On the half-period termination, capacitors recharge, the current decreases to zero and the VD3 thyristor turns off.

To recharge the capacitors, a recuperation choke L2 is turned on through a VD2 thyristor. Less than 2 minutes is sufficient to recharge the capacitors.

In response to a comparator signal, the charging choke is shunted by a VD4 thyristor. To ensure a necessary stability of the current pulse (0.05%), the pulse power supply system includes two current feedback loops.

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Figure 3 shows the pulse modulator installed in the hall housing the life-support systems of the accelerator.

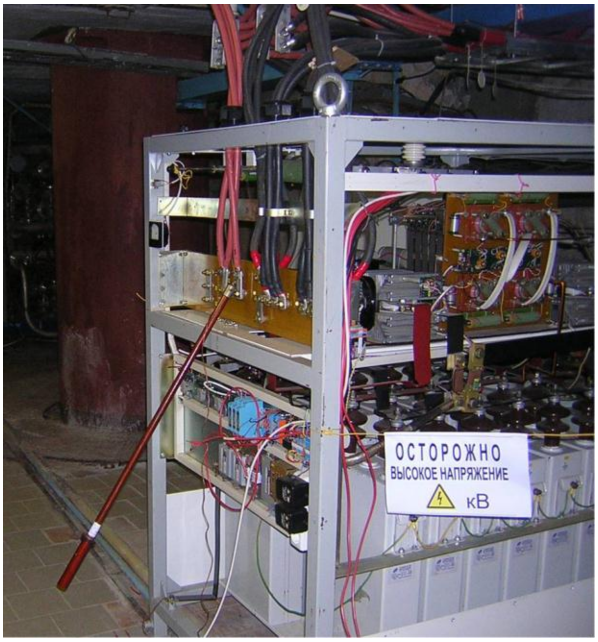

Figure 3: The power supply rack of the kicker magnet in the hall housing water and vacuum systems of the proton accelerator.

TESTS OF THE KICKER MAGNET WITH PULSE MODULATOR

The IM.103 B2-1 Hall probe was used to measure the main magnetic field on the magnet axis. The residual magnetic field was measured with the AD22151YR Hall probe. These probes provide necessary measurement accuracy. Simultaneously, the magnet current was measured with a current shunt. Signals were read on the Tektronix TDS2012 oscilloscope. The relative instability of the magnetic field amplitude and non-uniformity of the sinusoid pulse top were measured ±100 µs from the pulse top center.

At a pulse repetition rate of 50 Hz, the long-term, 4-hour, instability was less than 0.05%. Pulse-to-pulse instability was also less than 0.05%, which completely meets the performance specifications. The short-term, several-second, falls of the magnetic field amplitude outside the allowable limits were observed. However, the proton beam was switched off for these time moments, and this should not influence the accelerator operation.

The residual magnetic field after the main pulse caused an anxiety. The measurements performed demonstrated that it was lower than $5 \cdot 10^{-4}$ T, which completely meets the performance specification.

CONCLUSIONS

The kicker magnet with the pulse modulator designed and manufactured in the D.V. Efremov Institute for the linear accelerator operated in the INR RAS (the Moscow Meson Factory) meets the main technical requirements. Active losses in the pulse magnet and pulse modulator appeared to be close to design values. The used technique of the magnet yoke assembly allowed high eddy current loss to be avoided. The residual magnetic field after the main pulse was lower than we expected.

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