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A NEW POWER SUPPLY FOR THE PULSED BENDING MAGNET IN J-PARC 3-50BT

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Abstract

J-PARC has three accelerators, 400 MeV linear accelerator (LINAC), 3 GeV rapid cycling synchrotron (RCS), and 50 GeV (currently 30 GeV) main ring (MR), which are connected by beam transport lines. The proton beam is delivered from the RCS to muon and neutron targets in the materials and life science experimental facility (MLF) via a beam transport line called 3NBT. A pulsed bending magnet in the 3NBT which is also the first magnet of another beam transport line called 3-50BT, provides 8 bunches of proton beams to the MR. In this proceeding, the specifications of the new power supply, and the measured result of operating tests using dummy loads and the pulsed bending magnet will be described.

PULSED BENDING MAGNET

A power supply excites the pulsed bending magnet according to the cycle of MR to deliver the proton beam at the injection timing of MR. In near future the repetition rate of MR will be higher to increase the output beam power [1]. However, the current power supply of the pulsed bending magnet does not support higher repetitive operation, so we planned to manufacture a new power supply that supports 1 Hz operation.

In the J-PARC 3-50BT, bunches at K1, K2, K3, and K4 timing are delivered to the MR by exciting the pulsed bending magnet as shown in Figure 1. The rising and fall time of the current pattern should be shorter than 39.5ms since the repetition of RCS is 25Hz. However, rising time of the magnetic field is slower than 39.5ms since the eddy effect of the pulsed bending magnet. To overcome the problem, a device which can add overshoot current pattern was built in the currently used power supply [2].

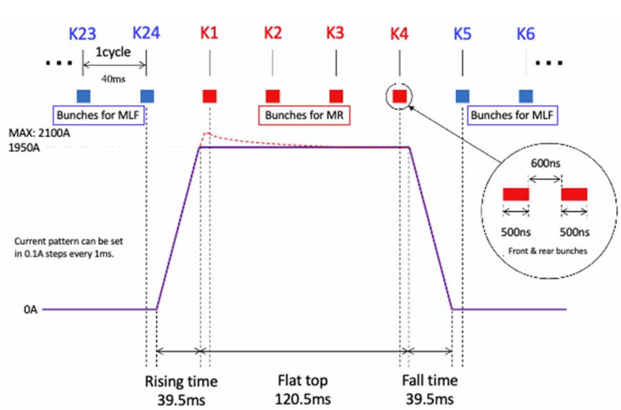

Figure 1: Current pattern of the pulsed bending magnet.

At the timing of K5, K6, and K7, the residual magnetic field the pulsed bending magnet is observed. To correct the residual magnetic field, trim coils were wound to the poles of the magnet [3]. A picture of the pulsed bending magnet is shown in Figure 2.

Figure 2: Pulsed bending magnet in the 3-50BT.

SUPECIFICATIONS

The additional overshoot system was required since the setting point of currently used power supply is only one parameter. To avoid this problem, the new power supply has 256 setting points in each 1 msec. Therefore, the additional overshoot current pattern system is not necessary with the new power supply.

Table 1: Specifications of the Power Supplies

Specifications	New P.S.	Currently used P.S.
Setting points	256 each 1 msec	1
Current step	0.1 A	0.1 A
Max current	2100 A	2180 A
Stability	0.8e-4	1.0e-4
Repetition	1 sec	2 sec

The new power supply is controlled remotely by using PLCs and EPICS [4]. The PLCs of new power supply has two sets of waveform memories to switch current patterns. Since the pulsed bending magnet is one of the key components to inject proton beams to the MR, the power supply should be under personal protection system. Therefore, if the MR is not ready to receive the beam, triggers to excite the pulsed bending magnet will not be sent to the power supply.

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INSTALLATION

The new power supply was shipped and installed to the J-PARC site in January 2023. Dummy loads were also installed to have operation test of the power supply. In February, two sets of cable connections were prepared to connect the power supply to the dummy loads and the pulsed bending magnet. While the MR is in beam operation, the tests are performed with the dummy loads, otherwise the new power supply connects to the pulsed bending magnet. Figure 3 shows the new power supply of the pulsed bending magnet.

Figure 3: Installed new power supply.

After the units were secured, electrical wiring between each unit, and insulation resistance measurements were taken and all passed the criteria. The cooling water piping was also connected to the power supply, and a high-pressure test of the cooling water was conducted at 1 MPa for 10 minutes to confirm that there were no problems such as water leakage in the power supply. After the high-water pressure test, the flow rate of cooling water is set above the specified interlock value of 36 L/min. In addition to the above, we also confirmed that the interlocks functioned properly for overcurrent, overvoltage, overheat, fan stop, DCCT failure, setting pattern data mismatch, data communication error, door open, emergency stop, etc.

MEASUREMENT RESULTS

Before turning on the new power supply, the resistance and inductance were measured when connected to dummy loads and when connected to the pulsed bending magnet. Tables 2 and 3 are the measured results.

Table 2: Measured Resistance

Frequency	Dummy loads	Pulsed bending magnet
DC	0.046 ohm	0.044 ohm
100 Hz	0.348 ohm	0.721 ohm
1 kHz	4.760 ohm	10.60 ohm

Table 3: Measured Inductance

Frequency	Dummy loads	Pulsed bending magnet
100 Hz	32.4 mH	29.1 mH
1 kHz	31.9 mH	37.5 mH

There are three differences between dummy loads and pulsed bending magnet. The first is the number of coils turns. The second is the length of the cable from the power supply. The third is that pulsed bending magnet has an iron core made of laminated steel, while dummy loads have no core.

As a first measurement, dummy loads were used to check the reproducibility of the factory tests. Figure 4 shows the result of rise and fall time measurement. Green is output current, yellow is set value, and magenta is current deviation during start trigger and the end of flat top.

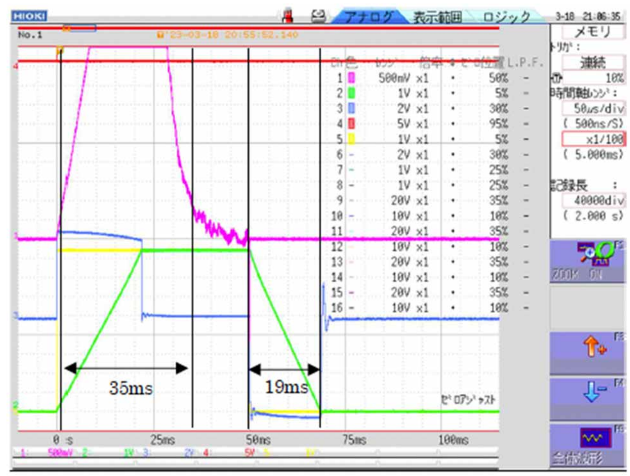

Figure 4: Rise time measurement with dummy loads.

As a result, the output current reached the set current at 22 msec after the start trigger, and the current deviation was within the specified 1.0e-4 at 35 msec from the start trriger. This result was comparable to the factory test and satisfies required rise time of 39.5 msec. The same measurement in case of the pulsed bending magnet is shown in Figure 5.

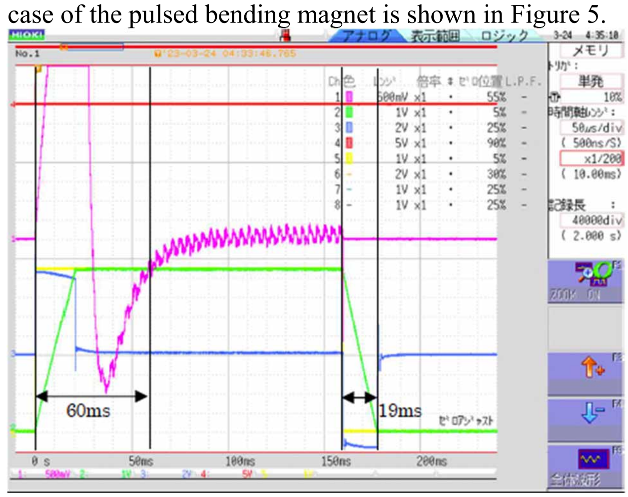

Figure 5: Rise time measurement with pulsed bending magnet.

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In this case, it was 60 msec for the current deviation to fall within a predetermined range. This may be caused by the eddy effect due to the lamination steel of the pulsed bending magnet and differences in L and R with dummy loads. Based on these results, the parameters of the new power supply should be adjusted in the near future.

One of the features of this power supply is fast repetition. The measured plots of 1 Hz operation is shown in Figure 6.

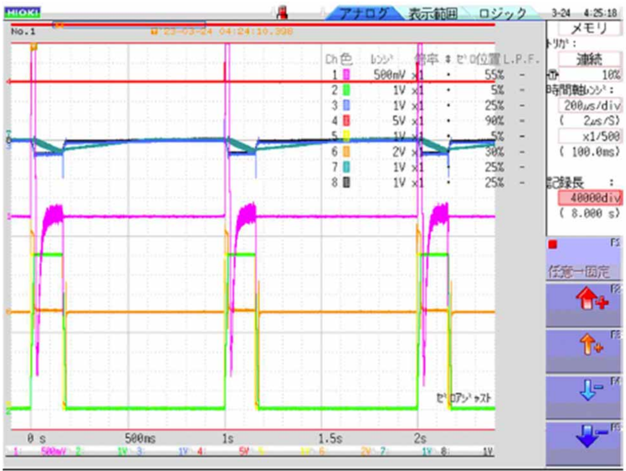

Figure 6: 1 Hz operation.

Since it was confirmed that 1 Hz operation could be performed without any problem in a short period of time, the next step was to test a longer time of 8 hours as shown in Figure 7.

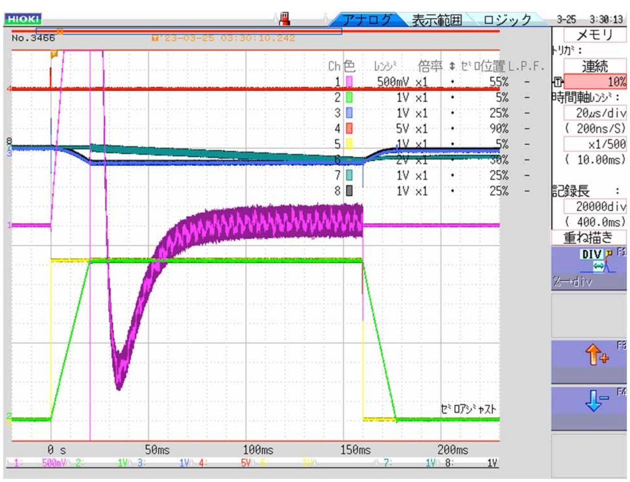

Figure 7: 1 Hz 8 hours continuous operation.

This overlapped plot shows that there is no significant shot-by-shot variation in output current and current deviation even after long hours of operation. It means that the output of the new power supply is stable from shot to shot and can be applied to beam operation.

Finally, the additional overshoot pattern was performed as shown in Figure 8.

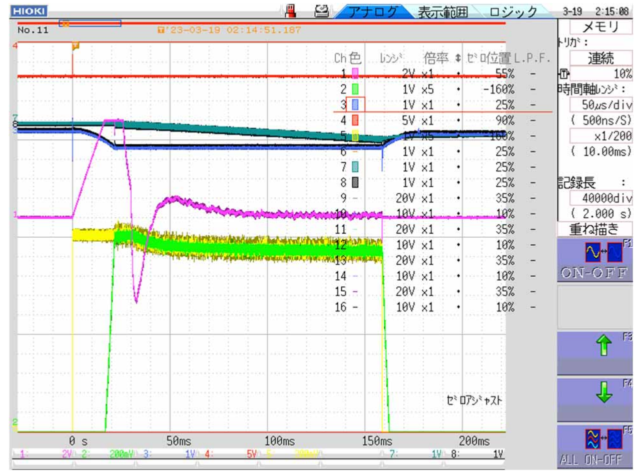

Figure 8: Additional overshoot pattern.

This result shows that the characteristic design of the new power supply, which changes the current value in 0.1 A steps every 1 msec, is operatable. The bunches at K1, K2, K3 and K4 will be kicked as it should.

CONCLUSION

A power supply for excitation of pulsed bending magnet at high repetition rate was manufactured, and installed in the power supply building at the J-PARC site. Operation tests of the power supply were completed for several cases. As a result, it was confirmed that the power supply is capable of high-repetition operation and operation with a correction pattern, which are the features of this power supply. In the future, we will proceed with long-term heat runs to confirm that there are no problems, for example, with the stability of the output current day by day.

The power supply currently in use should not be discarded but preserved as a slower cycle backup machine. If the new power supply has trouble, beam operation can be resumed by changing the cable connections.

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