Replacement of the RIKEN ring cyclotron (RRC) power supplies

K. Kumagai,[*1] M. Nagase,[*1] and N. Fukunishi[*1]

The RIKEN ring cyclotron (RRC) has been in operation since 1986. The magnet power supplies that have been operating for 28 years were generally aging. For example, their capacitors have exceeded their service life and cooling water has been leaking from pinholes that open on the blocks for thyristor cooling.

This year, we decided to replace the main coil power supply and several trim coil power supplies. The specifications of these power supplies are shown in Table 1.

The replaced six power supplies for the trim coil are being used for the coils 4E, 4S, 5E, 5S, 26E, and 27E. The maximum current of the power supplies has been increased from 500 to 600 A in order to obtain a margin of adjustment for cyclotron's magnetic field. The 4th trim coils were used at the same polarity for various beam operations, the polarity switching systems were not equipped.

The main coil of each sector magnet was composed of two coils. One coil was connected to power supply M1, and the other was connected to power supply M2. M2 also had four bypass circuits (100A-34V), which compensated for the variation in the magnetization of four sector magnets. The new main-coil power supply is connected to two coils that are rewired in series as shown in Fig. 1.

Table 1. Specifications of the new main coil power supply and trim coil power supplies.

	Main coil power supply	Bypass power supplies	Trim coil power supplies
Number	1	4	6
Current (DC) [A]	1080	30	600
Voltage [V]	500	130	20
Output current range [%]	30 - 100	0 - 100	0.8 - 100
Stability, Ripples [*2]	$\pm 3\times10^{-6}$	$\pm 1\times10^{-5}$	$\pm 5\times10^{-6}$
Setting resolution [bits]	20	16	16

*2 The ratio of the maximum current.

It is necessary to slightly adjust the current of the main coil power supply in order to cancel the variation of the magnetic field due to temperature rise of the yoke. The power supply of M1 and M2 had a resolution of 16 bits. However, the change in the current per bit corresponds to 11.1 ppm for M1 and 4.2 ppm for M2, which is insufficient for the fine adjustment of the current. As the new main coil power supply has a digital-to-analog convertor (DAC) with a resolution of 20 bits, the change in the current per bit is 0.95 ppm, which is equivalent to 0.001A/bit. As the NIO-S board used for the remote control of the power supply is capable of setting a current of 16 bits, we used two NIO-S boards for controlling 20 bits. One board is used for coarse current adjustment, and the other is used for fine adjustment of ±33.75A of the preset value.

The main coil power supply is exposed to radiation under the beam operation because it is placed in the same room as the RRC magnets. As a result, there is a risk of malfunction due to the radiation for the precision electronic devices installed in the power supply, such as the programmable logic controller (PLC), NIO-S boards, and the field-programmable gate array (FPGA). These devices are stored in a small chassis and are connected to the main power supply unit by optical cables and serial cables. They can be placed at a maximum distance of 15 m to avoid exposure to radiation.

The current stability over 8 hours was less than ±1 ppm excluding the initial drifts when the environmental temperature change was less than 3 °C, as shown in Fig. 2.

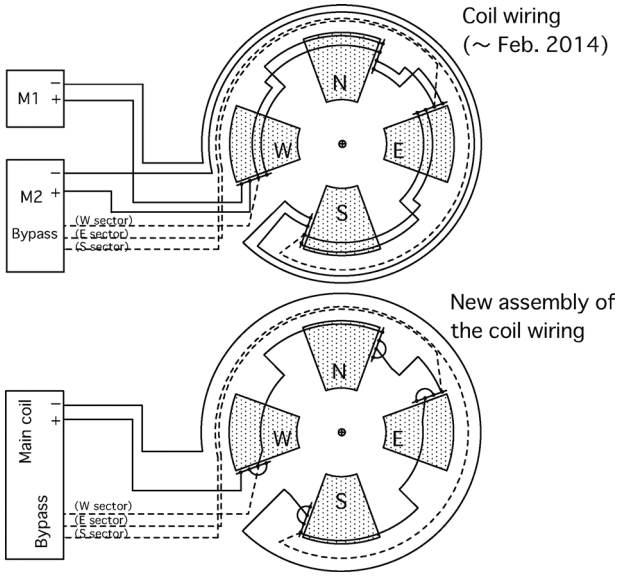

Fig. 1. Wiring of the RRC main coil.

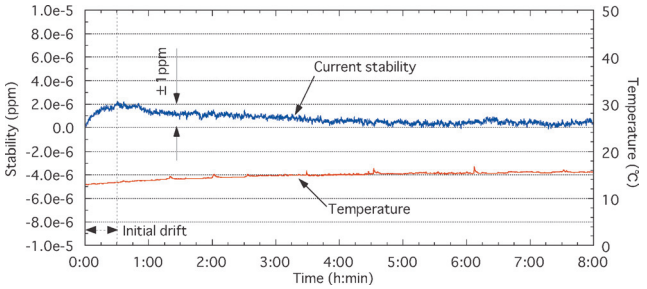

Fig. 2. Current stability of the main coil power supply over 8 hours.

The trim coil power supplies were installed in January 2014 and they began to operate smoothly at the beam service time by the end of January. The installation of the main coil power supply was completed in February 2014. Its usage began in the middle of March.

*1 RIKEN Nishina Center