Power supply backup system for injection and extraction magnets of cyclotrons

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A large number of electromagnets are used to accelerate ion beams in the RIBF[1]. For example, in the case of the uranium-beam machine time, there are 500 electromagnets from RILAC2 to the end of SRC through RRC, fRC, and IRC, each of which is excited by a DC power supply with high current stability. As a high-quality beam cannot be emitted unless all power supplies are available, it is important to perform the regular maintenance of power supplies and to consider how to handle them if a failure occurs. In particular, in the case of a failure during the machine time, it is necessary to restore the power supply as quickly as possible to minimize downtime.

If any power supply fails, we attempt to repair it first. However, if the defective part cannot be identified immediately, the part is estimated to take time to repair, or a replacement is not at hand, it is necessary to consider whether another power supply can be used. As power supplies with relatively low output current, such as those for quadrupole magnets and steering magnets, have relatively small chassis and are easy to handle, it is easy to replace them with the same type of power supply used for other beam courses. Since the output current of the power supply for the trim coil and the dipole is not very large, about 500 A at maximum, it is possible to substitute a power supply for other courses. On the other hand, the main coil power supply for the four cyclotrons (RRC, fRC, IRC, and SRC) typically has an output of several hundred to several thousand amperes and several hundred volts, and no power supply can be replaced. Therefore, in the event of a failure, it is necessary to repair this power supply; therefore, we prepare as many spare parts as possible.

Each cyclotron has 4 to 5 injection magnets and 3 to 5 extraction magnets. These magnets require extremely high current of approximately 1000 A to 3500 A and various voltages ranging from 20 V to 120 V. Despite the large number of power supplies, the power supply chassis are large and need many thick output-current cables; therefore, it is difficult to relocate the power supply after a failure occurs. Therefore, a plan has been considered in which a power supply that can be replaced in the event of a failure is arranged at an appropriate place and used as a replacement for as many injection/extraction power supplies as possible by adding partial temporary wiring.

The fRC-EBM power supply, a power supply for the fRC Extraction Bending Magnet manufactured in 2012, was designed to be operated in the dual pattern of large current-low voltage (2800 A–65 V) and medium current-medium voltage (1500 A–100 V) in anticipation of use as an alternative power supply. The thyristor rectification part of the power supply is equipped with two units, which can be connected in parallel or series, and the voltage-current ratio can be changed. In addition, the transistor driver is prepared in two patterns having different control constants. In 2014, we reassigned the power supply as that for the DAKR magnet on the IRC-E5 beam line, which is operated several times a year, and wired it so that it could be used as an alternative power supply for injection and extraction magnets of the RRC cyclotron (hereafter referred to as "backup power supply"). In 2019, the wiring was extended so that it could be used as a substitute for the power supply for injection and extraction magnets of the IRC cyclotron if a failure occurs. Figure 1 shows the current wiring layout of the backup power supply.

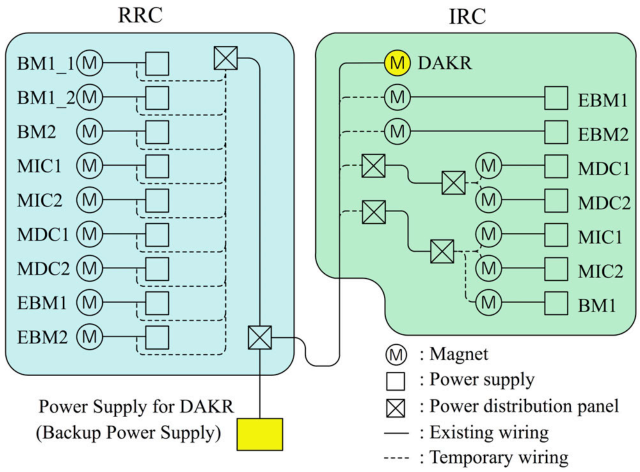

Fig. 1. Wiring layout of the backup power supply for the injection/extraction magnets of RRC and IRC.

A malfunction of the RRC-EBM1 power supply occurred on November 13, 2019 during a preparation period for uranium machine time. It was caused by the failure of a shunt made of zeranin, a low-resistance alloy for high-precision current detection, immersed in cooling water and had been used since the power supply was manufactured in 1985. It was expected that it would take about a week to remove the failed shunt, install the DCCT, replace the accompanying control boards, and make overall adjustments. Therefore, we immediately decided against repairing, switched the RRC-EBM1 magnet to the backup power supply, and resumed operation on the same day.

In addition, to enable the immediate use of the alternative power supply in case of trouble, we installed AC 400 V power receiving equipment, cooling water piping for the alternative power supply, and wiring for the DC current output in various places. In this manner we are preparing to maintain the machine time.

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Reference

1) Y. Yano, Proc. PAC07, TUYKI02, **700** (2007).