# Development of control system for magnetic field of the BigRIPS separator with a feedback algorithm

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We have designed and constructed a new control system for magnetic field of the BigRIPS separator[1)] at RIKEN. The absolute $B\rho$ value was derived from the magnetic field of a dipole magnet measured with an NMR probe and the central trajectory radius of the dipole magnet determined from the magnetic-field map.[2)] A new control system has been designed to satisfy zero deviation between the preset and measured $B\rho$ values. Furthermore, the control system is required to show not only high stability but also high reproducibility within a reasonably short time, since the settings of the BigRIPS separator are frequently changed during an experiment.

In order to enhance the reproducibility of the $B\rho$ value of the dipole magnet, a new control system was designed with a proportional-integral-derivative (PID) algorithm.[3)] The output current $I_n$ of the power supply after the $n$th sampling is given by

$$\begin{aligned} I_n &= I_{n-1} + \Delta I_n, \\ \Delta I_n &= -K_P(B_n - B_{n-1}) + K_I \Delta T_n (S_n - B_n) \\ &\quad - \frac{K_D}{\Delta T_n}(B_n - 2B_{n-1} + B_{n-2}), \end{aligned}$$

where $\Delta T_i$ is the sampling time, $S_i$ is the preset $B\rho$ value, and $B_i$ is the measured $B\rho$ value in the $i$th sampling. $K_P$, $K_I$, and $K_D$, all non-negative, denote the parameters of the PID feedback algorithm corresponding to the proportional, integral, and derivative components, respectively. Note that the integral action only responds to changes in the preset $B\rho$ value because the proportional and derivative actions produce a large unwanted spike when the preset $B\rho$ value is changed.[3)]

The magnetic field is required to be changed and stabilized so that the position of the central particle in the focal plane is set within 0.0±0.5 mm in 3 min. The 0.5 mm at the 5th focal plane of the BigRIPS separator corresponds to $6 \times 10^{-4}$ Tm at 4 Tm. Therefore the values of the parameters $K_P$, $K_I$, and $K_D$ were optimized such that the magnetic field is changed and stabilized within $\pm 5 \times 10^{-4}$ Tm in 3 min.

Figure 1 shows typical magnetic-field responses of the 2nd dipole magnet of the BigRIPS separator as functions of time. The red and blue solid lines show the results changed from 6.93 Tm and 7.07 Tm to 7.00 Tm. Some overshoots remained because an NMR probe could not work owing to a rapid change of magnetic field in the beginning when the preset $B\rho$ value

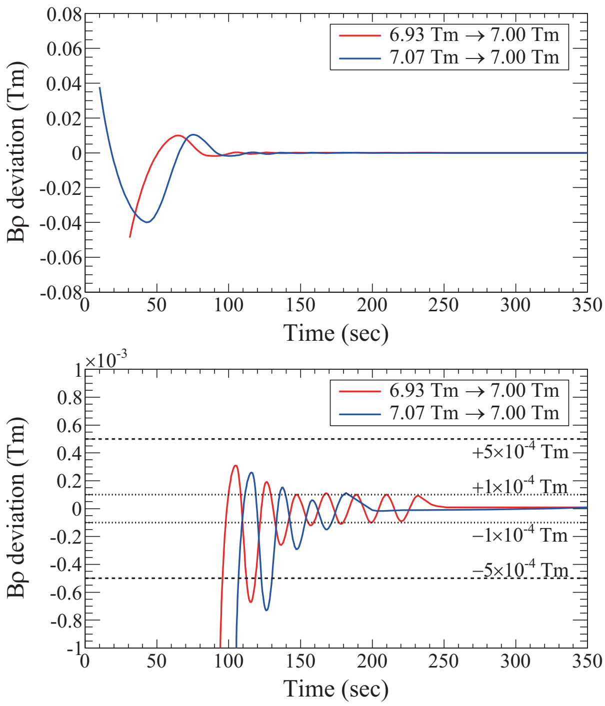


Fig. 1. Typical magnetic-field responses of the 2nd dipole magnet of the BigRIPS separator as functions of time. The bottom panel shows the plots enlarged around $\pm 1 \times 10^{-3}$ Tm.

was changed. However, they were negligibly small in the BigRIPS tuning. The bottom panel of Fig. 1 shows the plots enlarged around $\pm 1 \times 10^{-3}$ Tm. Dashed and dotted lines show the values of $\pm 5 \times 10^{-4}$ Tm and $\pm 1 \times 10^{-4}$ Tm, respectively. The PID feedback system successfully functions, and the magnetic field is stabilized in 2.5 min within $\pm 5 \times 10^{-4}$ Tm. The fluctuations of the magnetic fields are limited within $\pm 1 \times 10^{-4}$ Tm after 4 min.

A new control system for the magnetic field of the BigRIPS separator with a PID feedback algorithm is currently operational well.

References

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