Continuous Measurement of Output Fluctuation of Power Supplies for Lattice Magnets in the SPring-8 Synchrotron

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1. Introduction

The SPring-8 synchrotron accepts an electron beam with an energy of 1 GeV from the SPring-8 linac. The beam is accelerated up to 8 GeV and then ejected to stack into the SPring-8 storage ring [1]. The synchrotron consists of a FODO lattice of 40 cells and its circumference is 396.124 m. There are 64 bending, 80 quadrupole, 60 sextupole, and 80 correction magnets. Each kind of magnet was excited in series. The power supply for the bending magnets was named PS-BM. The power supplies for the focus- and defocus-quadrupole magnets were named PS-QF and PS-QD, respectively. The output current figures were controlled with similar trapezoids toward the beam energy [2].

A single-bunch beam is formed in the synchrotron and injected in one or some rf buckets in the storage ring (single-bunch or several-bunch operation) for pulsed-light users. Using an rf knockout system (RF-KO), the single-bunch beam is formed during a flat-bottom period [3]. To remove the electrons in the other bunches, they were excited by RF-KO with a synchronized frequency toward the vertical tune (υ_y = 8.7871). At present, the impurity of the single-bunch beam defined as a ratio of another-bunch-beam-current to main-bunch-beam-current is less than 7×10^{-8} [4]. To keep this impurity, it is necessary that fluctuation of the vertical tune is maintained at less than 0.015.

For PS-BM, PS-QF and PS-QD, external DC-CTs were installed to observe a long-term output-current stability of these power supplies.

Table 1. Technical specificaitons of external DC-CT

Related voltage	10V/1500A$^{a)}$, 535A$^{b)}$
Maximum load current	5 mA
Output impedance	10 mΩ
Output slew rate	1.5 V/μs
Rms value of output noise $^{c)}$	< 0.1 ppm (at 10 Hz)
	< 0.3 ppm (at 100 Hz)
	< 1.5 ppm (at 10 kHz)
DC accuracy v.s. temperature $^{c)}$	< 0.25 ppm/K
DC accuracy v.s. time $^{c)}$	< 5 ppm/year
Linearity error $^{d)}$	< 2.5 ppm

a) for PS-BM.
b) for PS-QF and PS-QD.
c) related to rated output voltage.
d) related to actual output voltage.

2. Installation and Measurement

Three external DC-CTs for PS-BM, PS-QF and PS QD [Hitec Co., Ltd. TOPACC2000] were installed on the roof of each cubicle. The technical specifications of the DC-CT are shown in Table 1. The top view and side views of the DC-CT for PS-QF are shown in Fig. 1 and 2, respectively.

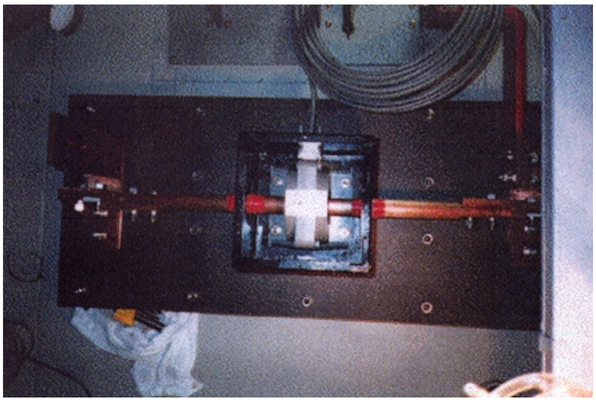

Fig. 1. Top view of the DC-CT for PS-QF is shown. Gray-plate indicates the roof of the PS-QF cubicle. An external DC-CT was installed in an iron box to avoid an external magnetic field. A bus-bar for the output was isolated from the roof by isolation material (blown-plate).

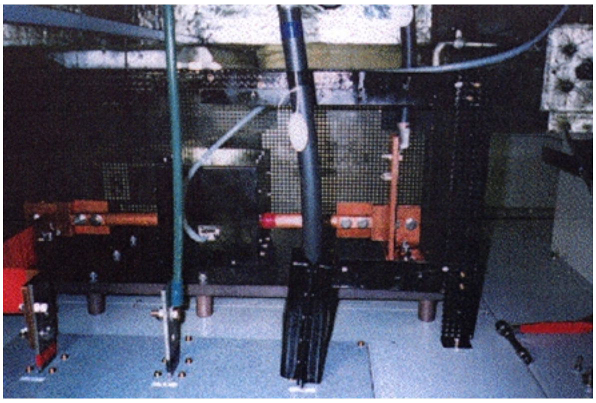

Fig. 2. Side view of the DC-CT for PS-QF is shown. Gray plate at the bottom of the figure indicates the roof of the PS-QF cubicle. Whole DC-CT system was covered by a punched iron box to prevent electrification. Three square-bars at bottom of the figure indicate the output terminals.

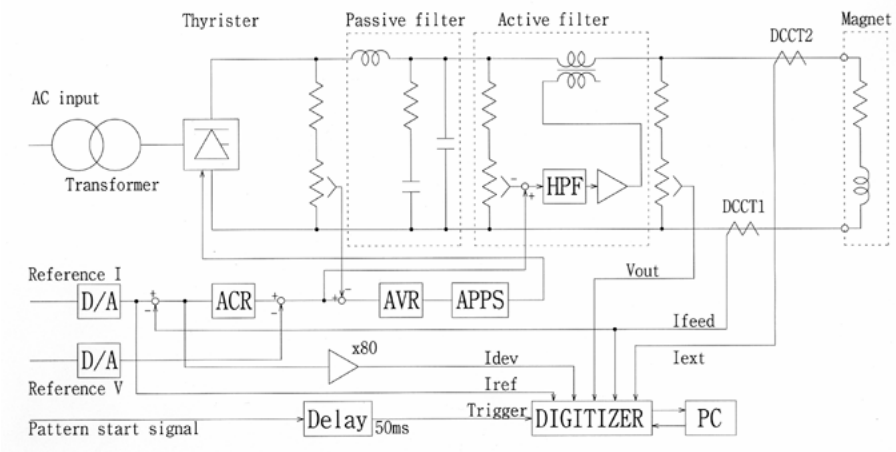

Fig. 3. Block diagram of the power supply is shown. ACR and AVR indicate an automatic current and a voltage regulator. APPS indicates an automatic pulse phase shifter. DCCT1 indicates a DC-CT for feedback control. DCCT2 indicates the external DC-CT. Iext and Ifeed indicate output current by external DC-CT and one by feedback DC-CT, respectively. Iref, Idev and Vout indicate reference current, current deviation and output voltage, respectively.

To observe output-current fluctuation at flat-bottom, output voltage of the external DC-CT was digitized by a digitizer [YOKOGAWA Co., Ltd. WE7271, isolated 4ch, 100 kS/s, 16 bit] at the time of 50 ms from the pattern start. A block diagram for the measurement is shown in Fig. 3. Several data can be observed simultaneously, the output current by the feedback DC-CT, the reference current, the current deviation which refers to the amount of subtract reference current from output current by feedback DC-CT and the output voltage. These measurements were carried out every 1 s. The digitizer was controlled by a PC.

3. Result and Discussion

Fluctuation of output current of PS-BM, PS-QF and PS-QD are shown in Fig.4. In the synchrotron, the power supplies were operated with the trapezoidal figures (pattern-operation) about one hour before the time of injection to the storage ring, and then the power supplies were operated with 1-GeV-DC (DC-operation) after the end of the injection. The measured value at the DC-operation in November 1999 was selected as a reference for the measurement. The output currents changed gradually during a period of 30 minutes after the power supplies were turned on. Then, the output current vibrated in a cycle of about 10 minutes. The fluctuation correlated with the temperature of the magnets.

The horizontal and vertical tune fluctuations were estimated based on the data on the fluctuations of the external DC-CTs (Fig. 4). In the pattern-operation, both fluctuations were less than 0.003. The value was less than 1/5 times of the fluctuation due to a ripple in the power supplies.

The long-term stability of PS-BM, PS-QF and PS-QD is shown in Fig. 5. The error bars show the fluctuations during a time of the the injection. In this measurement, long-term fluctuation was less than the fluctuation during the time of the injection.

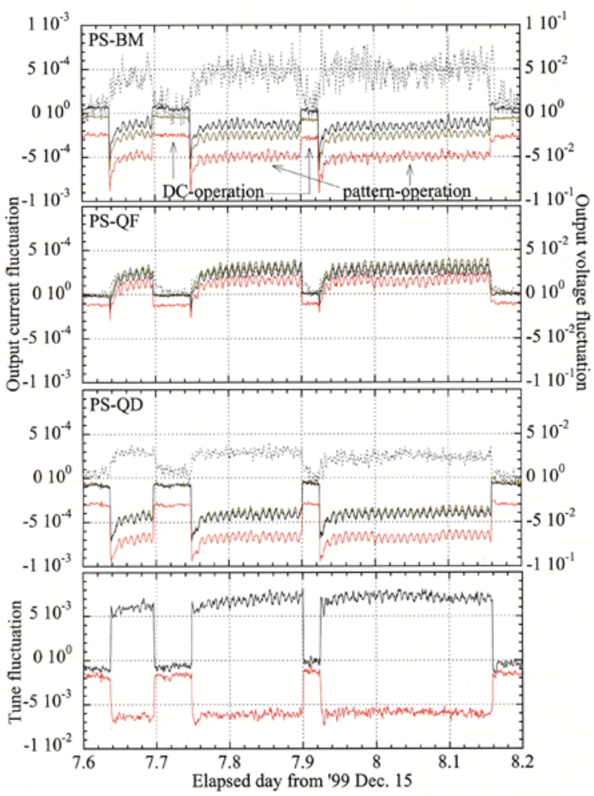

Fig. 4. Upper three figures show an example of output current and voltage fluctuation of PS-BM, PS-QF, PS-QD. Black- and green-solid lines indicate measured output current by the external DC-CT and by the feedback DC-CT, respectively. Red-solid line indicates the current deviation. Black-dotted line indicates the output voltage. Lower figure shows the estimated tune fluctuation based on the measured output current. Black- and red-solid lines indicate the horizontal and vertical tunes, respectively.

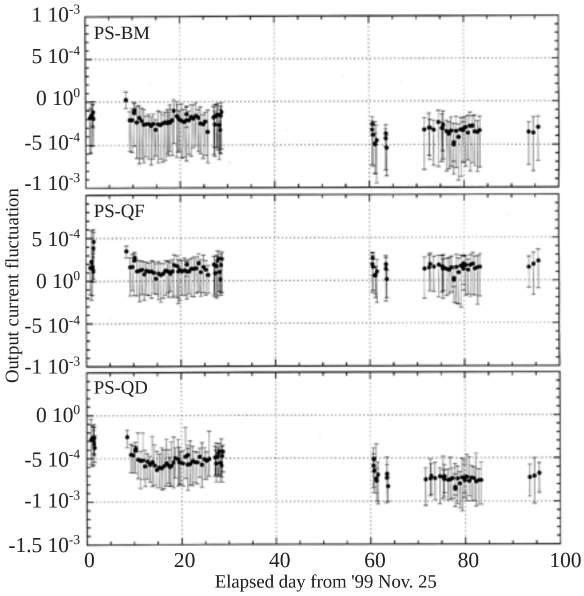

Fig. 5. Output current fluctuations by the external DC-CT at the pattern-operation are shown. Closed circles indicate the average value during a time of injection. Error bars indicate the maximum and minimum values during a time of injection.

4. Conclusion

The output-current of the power supplies for the lattice magnets was satisfied with the necessary stability to form a single-bunch beam during about 100 days. We are planning to continually measure the horizontal and vertical tunes using a real-time-spectrum-analyzer.

Acknowledgement

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References

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