RENEWAL OF KLYSTRON POWER SUPPLY FOR THE PHOTON FACTORY STORAGE RING AT KEK

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Abstract

Four klystron power supplies have been used at the Photon Factory storage ring for more than 20 years. We are on the way to replace these old power supplies to up-to-date ones in stages. To protect the klystrons against internal discharges, we adopted a high-speed solid-state switch for the new power supplies. Following the first replacement in 2003, we carried out the second replacement in 2008. We report the design and the performance tests of the new klystron power supply.

INTRODUCTION

In the 2.5-GeV Photon Factory storage ring at KEK, four 500-MHz accelerating cavities are driven by four 200-kW klystrons (Toshiba, E3774) [1]. Each klystron is driven by a high-voltage (HV) power supply which can provide a voltage of 45 kV with the maximum current of 9 A. We have used old klystron power supplies which were fabricated in 1979-1987. In order to operate the PF storage ring stably in future, we planned to replace old power supplies in several stages. Following the first replacement [2] in 2003, we replaced the second power supply in the summer of 2008. The new power supply took over the old one at the rf station No. 2.

DESIGN OF THE POWER SUPPLY

The specifications of the new power supply are shown in Table 1. Figure 1 shows a block diagram of the new klystron power supply. It comprises an AC 6.6 kV receiving terminal, a step-down transformer, a thyristor voltage regulator, a step-up transformer with a rectifier, a high-speed high-voltage switch for klystron protection, and a high-voltage terminal for providing heater and anode powers. Input voltage of AC 6.6 kV is transformed to 440 V by a step-down transformer, and is regulated using thyristors. The voltage is then stepped up with a transformer, and rectified to DC high voltage. The DC voltage is provided to the klystron through a high-speed solid-state switch. This switch is composed of a series of 80 Insulated Gate Bipolar Transistors (IGBT). When an over current due to klystron troubles is detected with a current transformer (CT), the high-voltage switch turns the output voltage off within ten microseconds.

Figure 2 shows a picture of the new power supply which was installed in the Photon Factory. Figure 3 shows a picture of the high-voltage panel including the high-speed HV switch and a heater/anode power supply.

The klystron power supply was designed and fabricated in Nichicon Corp. All components were assembled in the works, and final adjustments were carried out in the Photon Factory.

Table 1: Specifications of the Klystron Power Supply

Output voltage	10 - 45 kV
Polarity	minus
Output current	Max. 9 A
Output voltage ripple	Less than ±0.5 %
Output voltage variation	Less than ±1 %

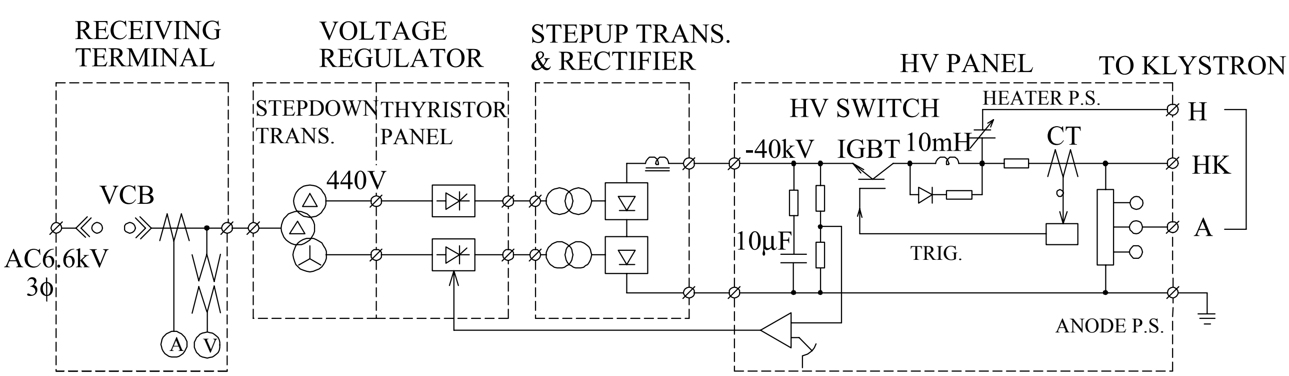

Figure 1: Block diagram of the new klystron power supply for the PF storage ring.

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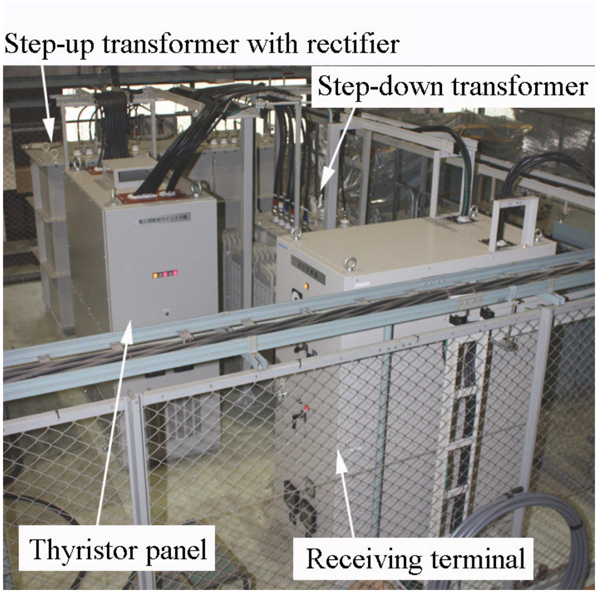

Figure 2: The main body of the new klystron power supply. A receiving terminal, a step-down transformer, a thyristor panel, and a step-up transformer with rectifier are shown.

Figure 3: A high-speed HV switch and a HV terminal (left side) and the klystron (right side).

PERFORMANCE TESTS

Short Circuit Test

We carried out a short circuit test under high voltages to confirm the performance of the high-speed solid-state switch. The output line (*HK*) was connected to a short-circuit tester without connecting any loads. After we raised the output voltage to a high voltage of 45 kV, we shorted the output line to the ground using the short-circuit tester. During this test, we measured the change in the short-circuit current using a current transformer. Figure 4 shows a result of the test. After the short, the short-circuit current increased gradually. After approximately 15 microseconds, the high-speed switch turned the output voltage off. The maximum short-circuit current was approximately 35 A. It should be noted that the oscillation in the signal, shown in Fig. 4, should be due to a noise which was accompanied by the spark in the tester. Through this test, we confirmed that the high-speed HV switch worked well.

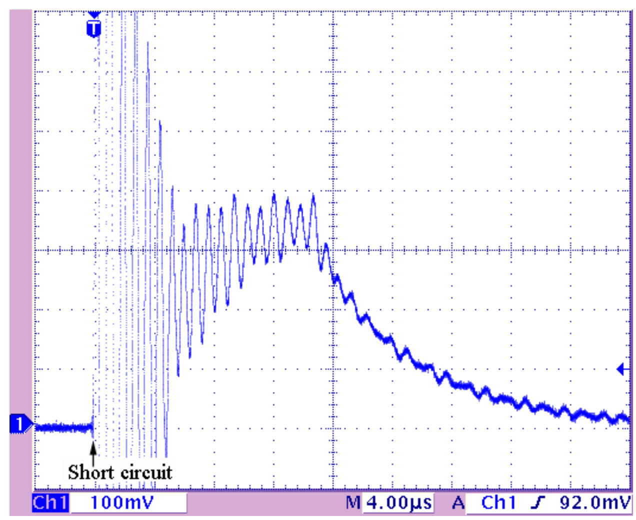

Figure 4: Result of the short circuit test. Ordinate: short-circuit current (10 A/div.), abscissa: time (4 µs/div.).

Ripples in the Output High-voltage

After connecting the HV output line (*HK*) to the klystron, we measured ripples in the output voltage. Figure 5 shows the ripple at a typical operating voltage of 40 kV. The output voltage fluctuated by ±200 V peak-peak which corresponded to ±0.5 %. The lowest frequency of the ripple was 50 Hz; this frequency corresponded to the fundamental frequency of the electricity. By adjusting the phase angles for the thyristors further, we can reduce the ripple in 50 Hz. Although these ripples of the output voltage can cause some fluctuations in the output rf from the klystron, we can stabilize them using rf feedback loops.

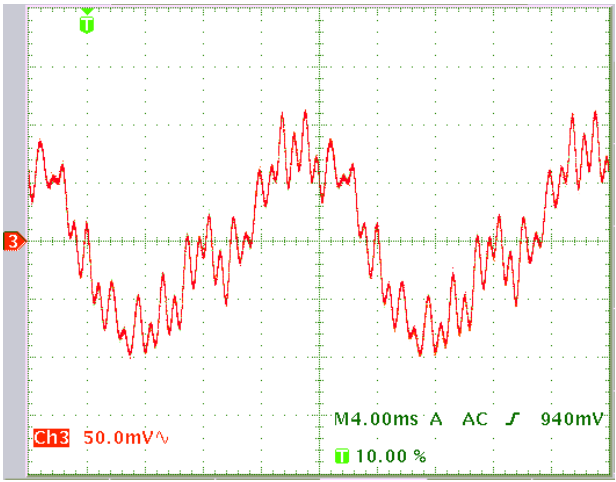

Figure 5: Measured ripple in the output voltage from the klystron power supply. Operating voltage: 40 kV, current: 6.4 A. Ordinate: output voltage (100 V/div; AC coupling), abscissa: time (4 ms/div.).

Stability

The new power supply was brought into operation in September, 2008. During long-term operations, we measured the stability in the output voltage. Figure 6 shows the measured fluctuation during 24 hours where the data were taken every ten seconds. In the figure, the changes in the input AC voltage and in the beam current of the klystron are also shown. The statistics in the fluctuations, which were calculated from the data in Fig. 6, are shown in Table 2. Corresponding to the change in the input voltage by 3.9% (peak-peak), the output voltage fluctuated by 0.5% (peak-peak).

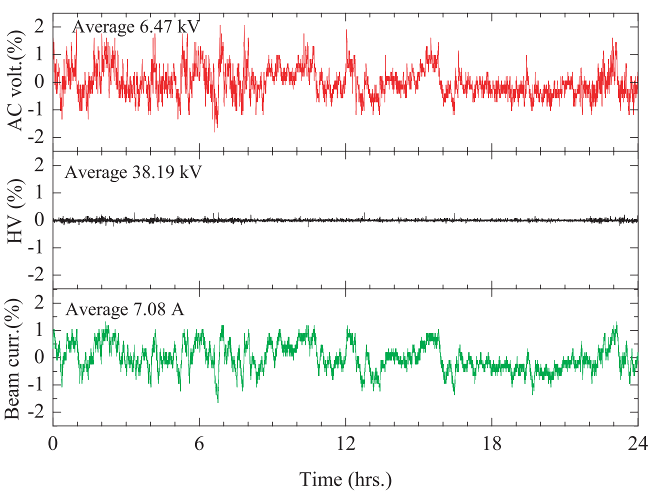

Figure 6: Stability in the high voltage of the new power supply during one day. Relative variations in the input AC voltage, in the DC high voltage, and in the klystron beam current are shown.

The new power supply has been working well for about six months.

Table 2: Summary of the Stability in the High Voltage

	Mean	Variation (peak-peak)
Input AC voltage	6.47 kV	3.9 %
DC high voltage	38.19 kV	0.5 %
Beam current	7.08 A	3.0 %

CONCLUSIONS

One of the klystron power supplies for the rf system was upgraded in the PF storage ring. We adopted a solid-state (IGBT) switch for klystron protection, and it worked well. The new power supply has been working since September, 2008, without any troubles.

REFERENCES

[1] M. Izawa, S. Sakanaka, T. Takahashi, and K. Umemori, "Present Status of the Photon Factory RF System", APAC'04, Gyeongju, Korea, 2004, p. 389.

[2] S. Sakanaka, M. Izawa, T. Takahashi, and K. Umemori, "Installation and Operation of New Klystron Power Supply with Fast Solid-State Switch for Klystron Protection at the Photon Factory Storage Ring", EPAC'2004, Lucerne, Switzerland, 2004, p. 1699.