

UPGRADE OF THE PF 2.5-GeV LINAC KLYSTRON MODULATOR FOR THE KEKB

Hiroyuki Honma , Tetsuo Shidara , Shozo Anami , and Isamu Sato
KEK, National Laboratory for High Energy Physics
1-1 Oho, Tsukuba-shi, Ibaraki-ken, 305, Japan

Abstract

An upgrade of the rf source is now progressing at the PF 2.5-GeV linac in order to increase the acceleration energy from the present 2.5 GeV up to the 8 GeV required for the KEKB. It was decided that all of the existing klystron modulators should be reinforced so as to be capable of producing pulses with a 110 MW peak power and a 5.4 μ s pulse duration. An additional 12 new modulators are necessary for 8-GeV operation. Up to March, 1994, the 10 existing modulators have been upgraded and 2 new ones have been fabricated. This paper describes the details concerning the modulator upgrade and the results of output tests performed with the new klystrons.

Introduction

The construction of the KEKB positron-electron collider rings is being undertaken at KEK. 8-GeV electrons and 3.5-GeV positrons will be used at the collider. An upgrade of the PF linac in order to increase the acceleration energy from the present 2.5 GeV to the 8 GeV for the collider is now in progress [1]. In the rf source, the rf power and pulse width from the klystrons will be increased from 27 MW (max. 33 MW) and 2 μ s to 41 MW (max. 46 MW) and 4 μ s, respectively. In addition to these, the peak power of the rf pulse will be increased using SLAC-type rf compressors (SLED). The multiplication factor of the energy gain, evaluated using the characteristics of our 2-m-long structures, is about 2. With these upgrades, an energy gain of 160 MeV per one acceleration unit, comprising one klystron and 4 structures, is obtained [2]. Therefore, 60 units (including spare units for practical operation) are required in order to reach an acceleration energy of 8 GeV. In the PF 2.5-GeV linac there are currently 48 units, including 2 injector units for electron and positron beams. All of these units must be upgraded, and an additional 12 units must be fabricated.

Upgrade of the Klystron Modulators

There are two limitations concerning our modulator upgrade: the maximum available space at the klystron gallery and the budget for the modulator modification. The charging voltage of the pulse-forming network (PFN) can't be increased by the PFN capacitor rating and the allowable anode voltage of the thyratrons. It was thus decided that the total capacitance of the PFN would be increased [3]. If we use the maximum available space effectively it will be possible to extend the PFN cabinet by 80 cm in height, just enough to double the capacitance. Figure 1 shows the PFN enclosing

cabinet along with the new klystron and SLED. The two-times increase in the PFN capacitance with the same charging voltage requires new transformers (an IVR, a rectifier transformer, a filter choke and a charging choke). There are two oil tanks; one is for a rectifier transformer, rectifier diodes and a filter choke; the other is for a charging choke and hold-off diodes. The number of these tanks can be reused by adopting water cooling.

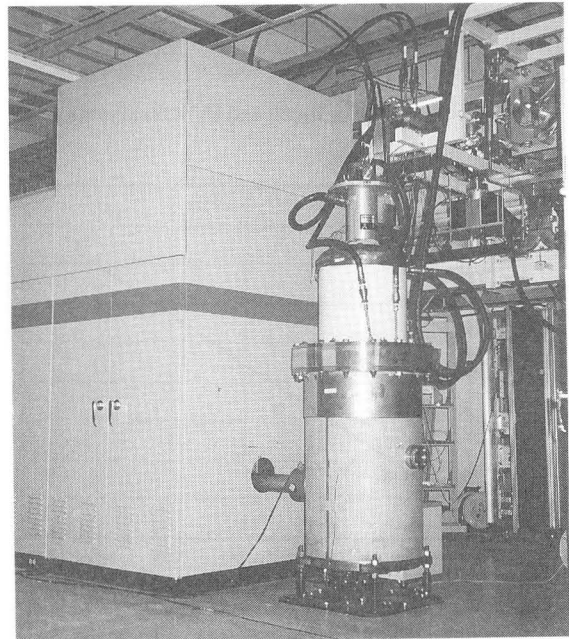


Fig.1 Extended PFN enclosing cabinet along with the new klystron and SLED.

In order to keep the same charging time (10 ms) as that of the existing modulators, the inductance of the charging transformer was reduced to half that of the existing one in accordance with a doubling of the PFN capacitance. The rectifier, hold-off and shunt diodes originally have sufficient margins for current. Even if the average current is increased in accordance with the increase of the PFN capacitance, they will still have more than two-times the margins for the average current. They can thus be reused. A circuit diagram of the upgraded modulator is shown in Fig.2.

Figure 3 shows the structure of the new PFN. The same twenty capacitors as those in the existing PFN (twenty sections) are being added there in order to double the capacitance; therefore, the size of the insulating plate for mounting the capacitors needed to be changed from 87 cm wide and 114 cm high to 89 cm wide and 210 cm high.

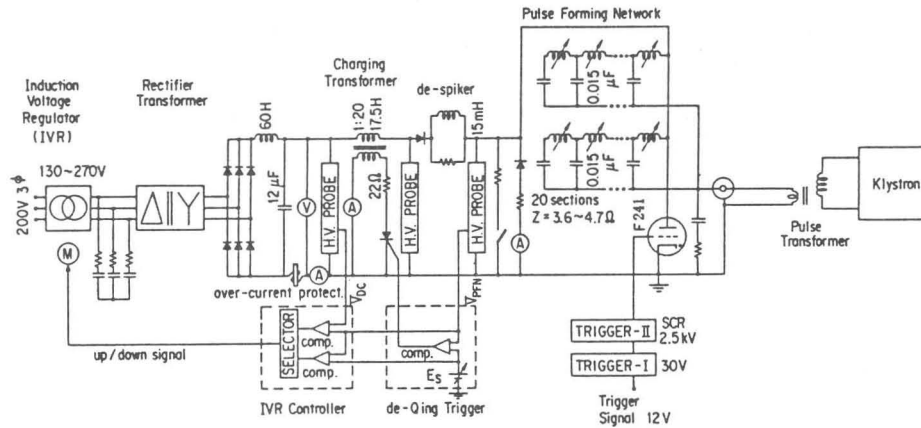


Fig.2 Circuit diagram of the upgraded modulator.

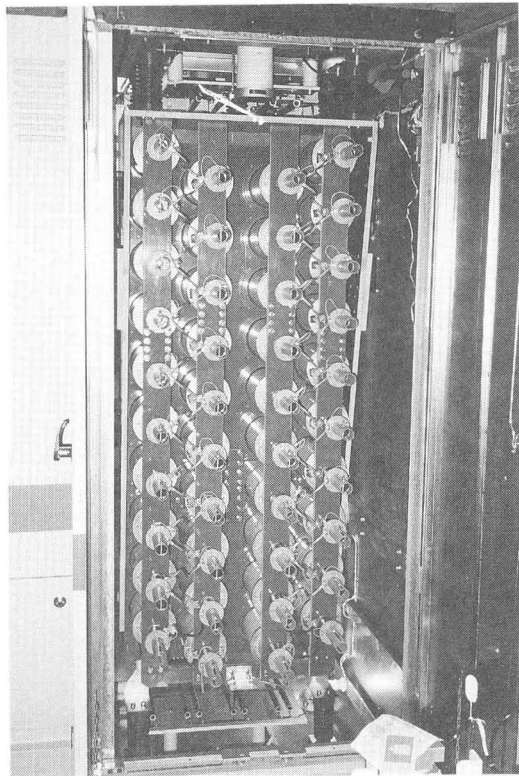


Fig.3 Structure of the new PFN.

Forty capacitors are placed in four vertical lines on the plate, and the two lines of 20 capacitors are connected in a zigzag fashion by 20 inductors. This is one PFN. The other two lines (another PFN) have identical arrangements with it and the two PFN's are connected with each other at the thyatron end. There are thus two identical PFN's in parallel. In this arrangement we can obtain smooth flat-top pulses without any ripples caused by the PFN structure. In addition to this, since the impedance of each PFN is twice that of the total PFN, the inductance of each section can be enlarged, which results in a reduction in the influence by the other inductances of the capacitor and the wiring.

The specifications of the upgraded and the existing modulators are shown in Table 1. A pulse duration of 5.4 μ s is expected when the new klystron becomes operational at a 304 kV applied voltage and a 46 MW peak power.

TABLE 1
Comparison of the Existing and the Upgraded Modulator Specifications

	Existing	Upgrade
Maximum peak power (MW)	84	110
Maximum average power (kW)	14.7	30
Pulse transformer step-up ratio	1:12	1:13.5
Output pulse voltage (kV)	22.5	22.5
Output pulse current (A)	3600	4800
PFN impedance (Ω)	6	4.7
PFN total capacitance (μ F)	0.3	0.6
Pulse duration (μ s)	3.5	5.4
Rise time (μ s)	0.7	0.8
Fall time (μ s)	1.2	1.3
Pulse repetition rate (pps)	50	50
Maximum pulse height deviation from flatness (%)	0.3	0.3
Maximum pulse amplitude drift (%/hour)	0.3	0.3
Thyratron anode voltage (kV)	45	45

Results of Output Tests

Two existing modulators were upgraded in 1992. After that, these modulators have been operated in order to confirm their long-term stability. Up to now, there have been no particular problems concerning their performance. They have also been used for high power tests of new klystrons and the SLED. In this section, the output characteristics of the modulator are described. The pulse flat top of the output pulse voltage from the modulator was about 0.5 μ s shorter compared with the design value (4 μ s). As a result of a beam-acceleration test using an upgraded modulator, an energy gain of 179 MeV per one acceleration unit was obtained, since the efficiency of a new klystron was larger than that of the

existing one [4] [5]. Though the energy gain required for the KEKB is 160 MeV (averaged for the total number of klystrons), it is desirable to increase the pulse flat top as much as possible for SLED operation. Thus, the capacitance of the PFN capacitors to be used for the next upgraded and newly fabricated modulators was increased from 0.0146 μF to 0.0155 μF , which is the maximum obtainable capacitance without changing the outer size while maintaining the same working voltage. With this change, we could increase the flat top by 0.2 μs . In 1993, 8 existing modulators were upgraded and 2 new ones were fabricated. Figure 4 shows the pulse shape of the output pulse voltage (282 kV) measured at a klystron cathode. The durations of the pulse and the flat top are 6.2 μs and 3.7 μs , respectively. A beam-acceleration test using this modulator is now being prepared in order to confirm the effect of this flat-top increase on the energy gain. Figure 5 shows an expanded trace of the pulse flat top of the output voltage. The pulse top is flat within 0.3% after adjusting the PFN inductances, though the flat-top width appears to be shorter than that of figure 4 because of a long recovery time of the oscilloscope.

Since a few unstable behaviors occurred in the existing thyratrons (ITT F-175's) during the tests, we decided to replace them with ITT F-241's, which are designed to permit operation at long pulse widths.

We are preparing to upgrade another 12 existing modulators and to fabricate 7 new ones during FY 1994.

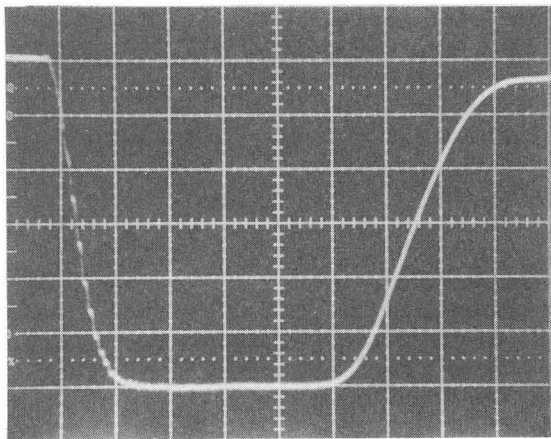


Fig.4 Pulse shape of the output pulse voltage measured at the klystron cathode (horizontal scale: 1 $\mu\text{s}/\text{div}$, peak voltage: 282 kV).

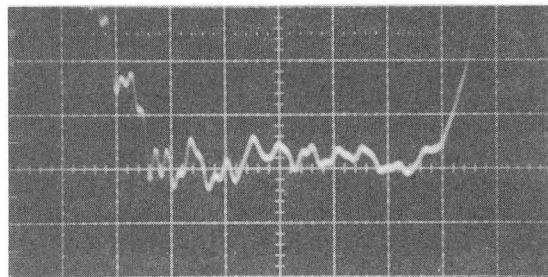


Fig.5 Expanded pulse top trace of the output pulse voltage (peak voltage: 282 kV, vert.: 0.3%/div., hor.: 0.5 $\mu\text{s}/\text{div}$).

References

- [1] A.Enomoto et al., "Linac Upgrade Plan for the KEK B-Factor", Proc. 1993 Particle Accelerator Conf., Washigton, D.C., USA, May 1993.
- [2] S.Anami et al., "Upgrading of the PF Linac Rf Source for the KEK B-factory", Proc. 17 th Linear Accelerator Meeting in Japan, Sendai, Japan, September 1992, p.177 (in Japanese).
- [3] T.Shidara et al., "Modulator Upgrade of the KEK 2.5 GeV Linac", Proc. 1993 Particle Accelerator Conf., Washigton, D.C., USA, May 1993.
- [4] H.Hanaki et al., "Use of SLEDS for High-Gradient Acceleration", these Proceedings.
- [5] S.Fukuda et al., "Development of The B-Factory Linac 50-MW Pulse Klystron", these Proceedings.