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Development of High Voltage Power Supply for PEFP Proton Accelerator RF system

Y.S. Cho, H.J. Kwon, B.H. Choi
Proton Engineering Frontier Project, Korea Atomic Energy Research Institute
P.O.B. 105, Yusong, Deajon, Korea 305-600

Abstract

The requirements of the high voltage power supply for PEFP Proton Accelerator RF systems are 100 kV, 20 A with the conditions that both the voltage ripple and regulation are less than 1 %, and energy deposition in the klystron at the tube arc is less than 20 J. The high voltage power supplies for the RFQ and the DTL are designed and fabricated. The high voltage power supply of RFQ consists of IVR, Transformer/Rectifier, and Iginitron Crowbar switch. For DTL, it consists of thyristor controller, Trasformer /Rectifier, and IGBT opening switch. The both systems are tested and the results satisfy the all requirements.

1. Introduction[1-5]

The PEFP 20MeV proton accelerator consists of 3MeV RFQ and 20MeV DTL. The operating frequency of the RFQ and the DTL is 350MHz, and the required RF power is 418kW, 895kW respectively. The structure power of the RFQ is the calculation result of the SUPERFISH code. The structure power of the DTL takes into account 20% margin of the SUPERFISH code result, which includes the power loss at the DTL tank wall (including end wall), drift

tubes, stems. The 20% margin may cover the additional loss originated from Q-degradation and other structure loss such as post couplers, slug tuners and so on. A 350MHz, 1MW klystron is used as a RF source for RFQ and DTL respectively.

2. Klystron power supply

The power supply requirements for the TH2089F klystron are summarized in Table 1. The high voltage power supply is the most important component for reliable operation of the klystron. Two types of klystron power supply were developed, those are IVR controlled type for RFQ klystron and thyristor controlled type for DTL klystron.

Table 1. Requirements of power supply for klystron

Parts	Specifications
Cathode P/S	-95 kVdc, 20 Adc, <20J Vripple < 1%
Mod. anode P/S	-85 kVdc, 20 mAdc
Heater P/S	25 V, 35 A Stabilization < 2%
Magnet P/S	300 Vdc, 12 Adc Vripple < 1%
Ion pump P/S	5±0.5 kVdc, 10 mAdc

3. Klystron power supply for RFQ

As shown in Table 1, the requirements of the high voltage power supply for

TH2089F klystron are 100kV, 20A with the conditions that the voltage ripple are less than 1%, and energy deposition in the klystron at the tube arc is less than 20J. The power supply that satisfies the above conditions has been developed and tested at PEFP. The schematic circuit diagram that includes high voltage power supply, modulating anode power supply and heater power supply is shown in Figure 1. The output voltage is adjusted by IVR (Induction Voltage Regulator). The 12 pulses after the rectifying diode are regulated through L-C filters. Ignitrons (NL-1489, National) are used as a crowbar switch which limits the arc deposition energy to the klystron. High voltage relays of NC (Normal Close) and NO (Normal Open) type which are operated by pneumatic were developed by PEFP and tested up to 130kV.

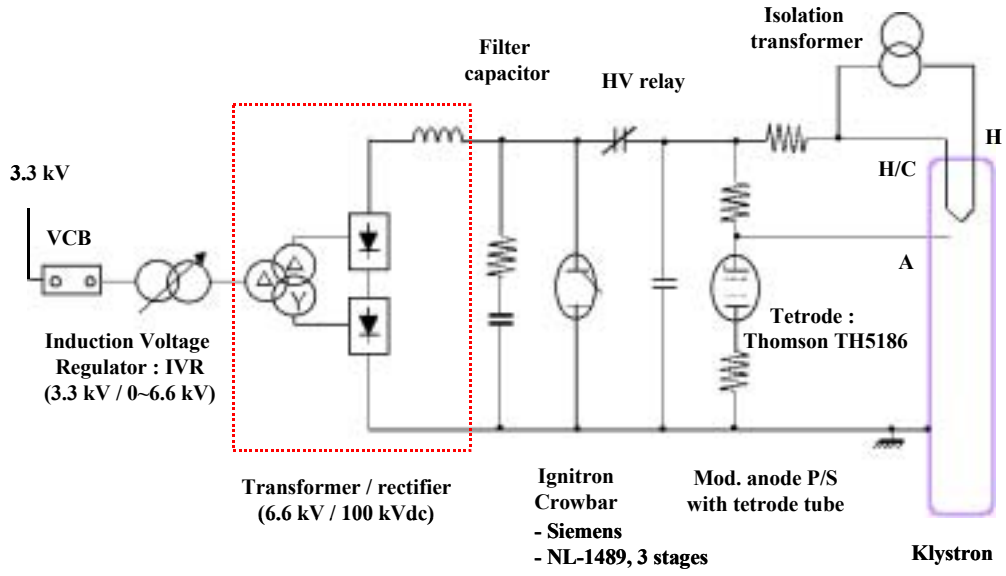

Figure 1. Circuit diagram of klystron power supply

The modulating anode power supply consists of voltage dividing resistors and tetrode. The modulating anode voltage can be controlled by adjusting the grid voltage of the tetrode. The heater power supply is simple AC heating using high voltage insulation transformer. The IVR, transformer/rectifier tank,

capacitor filter are shown in Figure 2 and the modulating anode, crowbar switch are shown in Figure 3. The high voltage power supply were tested. The high voltage test up to 95kV showed no problems.

Figure 2. IVR, transformer/rectifier tank, filter

Figure 3. Mod. anode P/S, crowbar switch

The modulating anode power supply was also tested. The modulating anode voltage can be adjusted from -95kV to -20kV according to the grid voltage of the tetrode from -500V to -100V. The result showed that the electron beam current of the klystron can be adjusted by tetrode in a very stable manner. A ignitron crowbar test was carried out. At first, the performance test of the switch was done. Figure 4 shows typical discharge waveform. The test results were reproducible at high voltage above 30kV. To confirm whether the energy deposition in the klystron at the tube arc is within the limit, wire test was carried out. A test using 0.3mm diameter and 200mm long copper wire

showed that the dissipation energy at the wire was less than 20J.

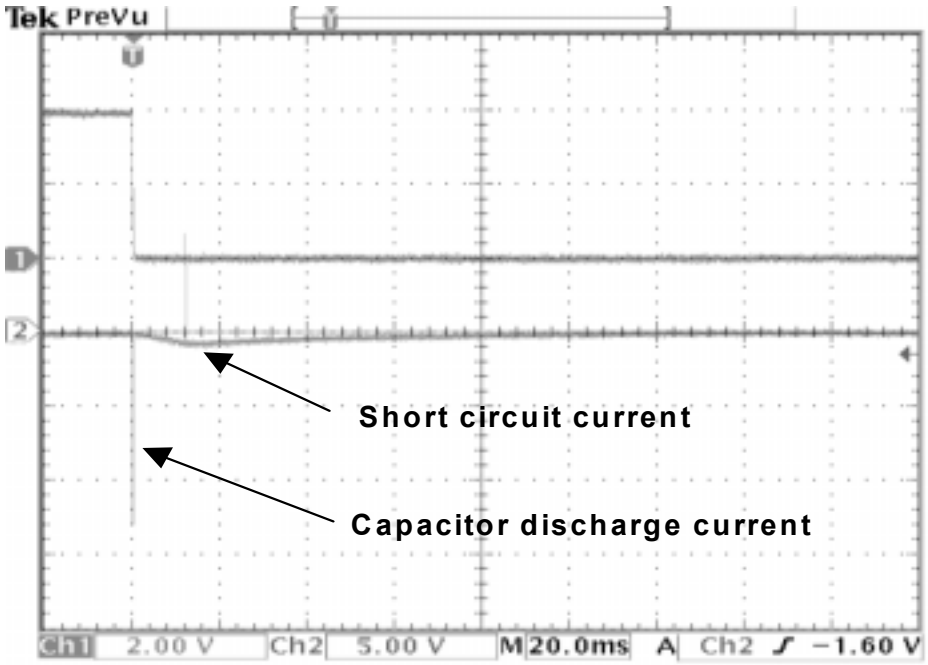

Figure 4. Typical discharge waveform of the crowbar switch.

4. Klystron power supply for DTL

A high voltage DC power supply which was developed by SIEMENS and has been used as a part of the plasma heating system for fusion device is modified for klystron power supply for DTL. The circuit diagram of the power supply is shown in Figure 5. As shown in the figure, the power supply is three phase AC voltage controller type using thyristor. The thyristor controller at the low voltage side adjust the output voltage by controlling the conduction angle of the 12 pulse AC voltage. The device which limits the load arc energy is the opening switch type using IGBT instead of crowbar and developed by PEFP.

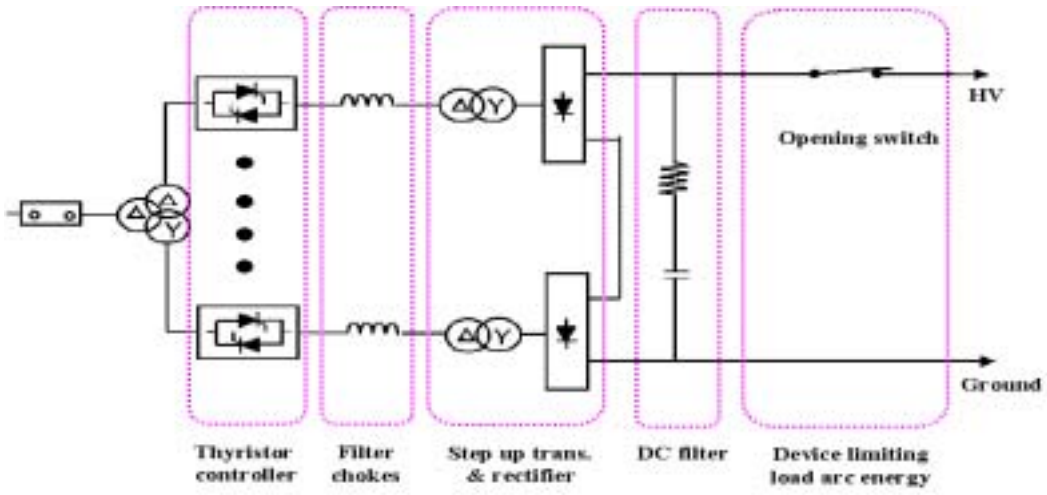

Figure 5. Circuit diagram of the klystron power supply for DTL.

The components developed for RFQ klystron power supply were also used for DTL such as HV relay, modulating anode power supply, heater power supply and so on. The transformer/rectifier tank and filter capacitor are shown in Figure 6, the opening switch and its circuit diagram are shown in Figure 7, Figure 8, respectively.

Figure 6. Transformer/rectifier tank, capacitor filter

Figure 7. IGBT opening switch

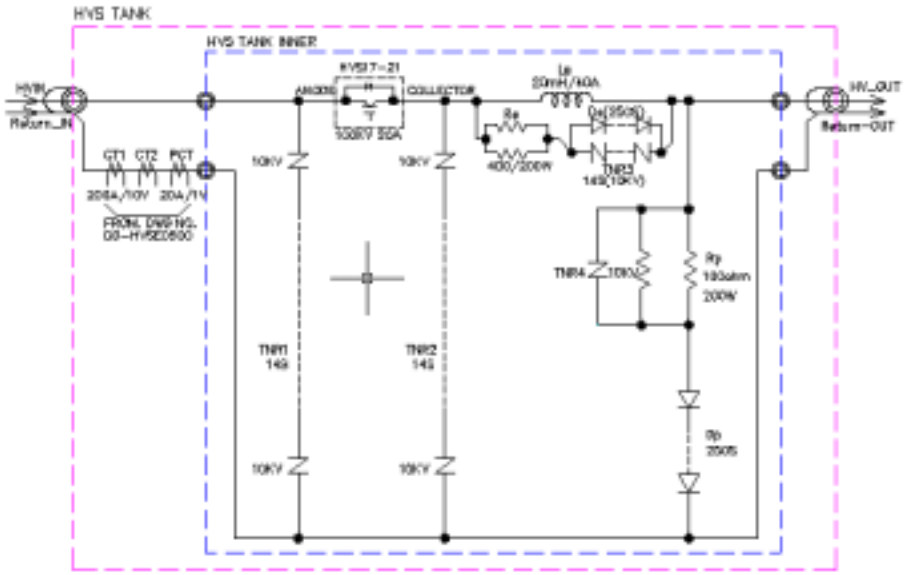

Figure 8. Circuit diagram of the opening switch.

Each component was tested up to 120kV and the overall system tested up to 95kV which is the overvoltage limit of the interlock system. The IGBT opening switch was tested as shown in Figure 9. The typical waveform is shown in Figure 10, which shows good performance as a opening switch. The wire test shows that the load arc energy is below 6J at 95kV.

Figure 9. Test setup for opening switch

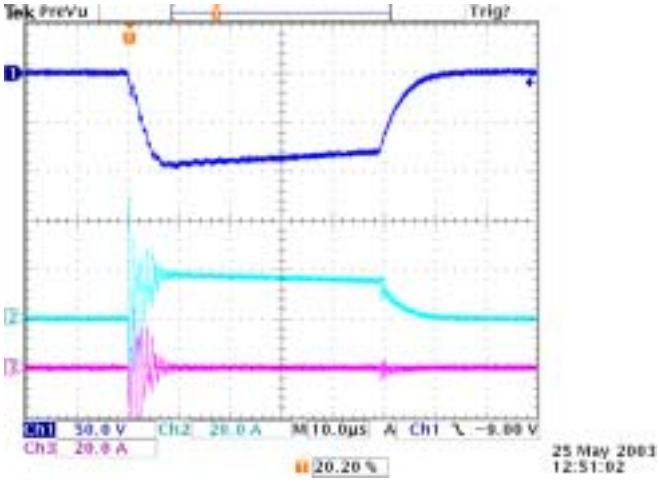

Figure 10. Typical waveform of the opening switch

5. Conclusion

Two high voltage power systems for 20MeV PEFP proton accelerator had been developed. The requirements of the power system are 100kV, 20A, 20J. The high voltage power supply are tested and the all requirements are satisfied.

Acknowledgement

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