DC POWER SUPPLIES FOR 1 MW KLYSTRON IN THE TRISTAN MAIN RING

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Abstract

In the present operation of the TRISTAN Main Ring which is working at 25 GeV for electron and positron, 16 high power klystrons are driving 64 accelerating cavities. Each klystron continuously delivers an rf power of 1 MW at 508.58 MHz. As a power supply for the cathode, two types are manufactured. The maximum current at - 90 kV is 40 A and 20 A for type A and B, respectively. The DC voltage is obtained by twelve-phase rectifying scheme. The phase of the half number of the cathode power supplies is shifted by 15 degrees from the phase of the other half. The high voltage supply of the modulation anode is a Cockcroft Walton generator and feeds 10 mA at 80 kV maximum available power.

Introduction

In the TRISTAN main ring, a considerable efforts were required for the development of accelerating cavities and re-power sources. In order to feed four 9-cell cavities (1), a 1 MW cw klystrons is indispensable. Naturally the dc power supply system for the klystron becomes one of the main equipments in the rf design. For the convenience of operation, we have made two kinds of power supply A and B, each of which is able to drive two and one klystron, respectively. Type B consists of power supplies for cathode, heater, modulation anode and focusing coil. The power supplies are doubled for type A (Fig. 2). The equipments are now distributed around the accelerator housing of the TRISTAN main ring as shown in Fig. 1 and Table 1. The sixteen sets of klystron assemblies are installed in four structures of D1, D2, D7 and D8. Table 2 shows the design parameters of dc power supplies for a 1 MW cw klystron. The 840 W heater power supply and 800 W modulation-anode high-voltage supply are connected to - 90 kV cathode voltage line, where the output voltage and current of the modulation-anode power supply is 80 kV and 10 mA at maximum, respectively. The other power supplies are connected to the earthed line. In order to protect the klystron when the load is short-circuited, a crowbar switch works to release the charged energy within 6 μs. Therefore, impulsive components are superimposed on the power supply of the klystron. In other words, compared to a conventional high voltage power supply, the present system is operated in a rather noisy environment. When the same power supplies are operated in parallel, the switching of the crowbar circuit would lead the false firing of other power supplies. We had to pay much attention to avoid this malfunction.

Table 1 Installation of rf power supplies around the accelerator

HOUSING / TYPE	D1*	D2*	D4	D5	D7*	D8*	D10	D11
A	2	2	2	2	1	1	1	1
B	1	1	1	1	1	1 (1)	0	0

(1) : Test and conditioning stand
* : Running equipment at present

DC high voltage rectifier for the cathode

The simplified diagram of the whole circuits is shown in Fig. 2. The voltage rectifier consists of a receiving terminal board, an inductive voltage regulator (IVR) and a rectifier transformer. The voltage can be adjusted in a range of ± 10 % at dc-90 kV by the IVR with an accuracy of ± 1 %. The stepped-up alternating current is rectified to direct current in 12-phase full wave scheme.

The phase of the half number of cathode power supplies is shifted by 15 degrees from that of the other half. In other words, one half of the three-phase rectifying transformer has delta vs. delta and star connections, and the other half has delta vs. zigzag connections of opposite directions. Thus the ripple components contained in the cathode dc voltage are re-

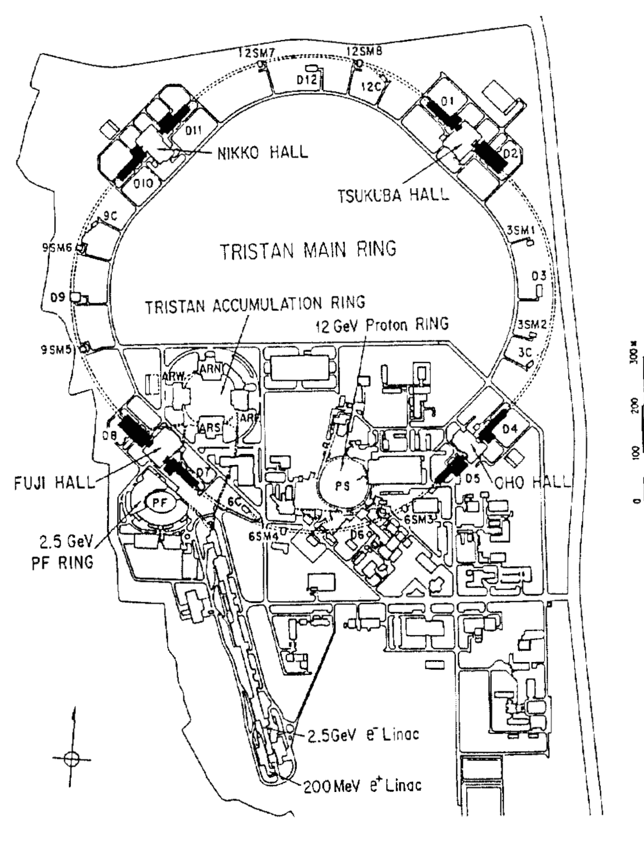

Fig. 1 RF sections of the TRISTAN main ring.

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duced to less than ± 0.3 %.

Crowbar circuit

The crowbar circuit is composed of a capacitor and a crowbar switch. The capacitor is used to reduce the contained ripple components in the high voltage supply for the cathode. In order to reduce the rush current in charging, a limiter is prepared, which is by-passed after suitable charging time. The crowbar switch, which is five serially-connected ignitron tubes, starts to work within 6 μs (Fig. 3) and discharges the capacitor and drops the cathode voltage. An insulated pulse transformer, which triggers the five serial ignitrons, is specially developed by Nichicon Capacitor Ltd. It consists of five transformer units with loose coupling among each other and helps to ensure simultaneous ignition of all ignitrons.

Heater and modulation anode high voltage supplies

The electric power requisite for the heater and modulation anode high voltage supplies are fed through an insulated transformer at dc - 90 kV. The dc current of the heater power supply is regulated by controlling the phase of a TRIAC on the primary side of a voltage-step-down rectifying transformer. The measured stability is within ± 0.4 %. Fig. 4 shows the simplified circuit of the heater power supply.

Table 2-A

Design parameters of dc power supplies
for 1 MW klystron

Cathode dc high voltage supply	
Rectification method	12 phase full-wave rectifier
Difference of phase angle between the half of main transformers and other	15 degrees
Regulating range of IVR	± 10 %
Maximum output voltage	-90 kV dc
Choice of rated output voltage	-50, -65, -80, -90 kV dc
Maximum output current	40 A(type A), 20 A(type B)
Crowbar circuit	
Maximum output voltage	-90 kV dc
Maximum output current	40 A(type A), 20 A(type B)
Working time for the shortage at the output terminal	≦ 6 μsec
Working rate	< 0.3 times/min < 100 times/year < 1000 times/total
Working method	Five stage ignitrons in cascade
Temperature	0 - 40°

Table 2-B

Heater and modulation anode high voltage supplies	
Heater power supply	
Maximum output voltage	30 V dc
Rated output current	18 - 28 A
Regulation	Constant current scheme
Ripple (peak to peak)	< 0.5 %
Stability (for an ac line voltage change of ±5% and load change ±10%)	< ±0.5 %
Modulation anode high voltage supply	
Output voltage	0 - + 80 kV dc
Output current	0 - 10 mA
Ripple (peak to peak)	< 0.5 %
Stability (for an ac line voltage change of ±5% and load change ±100%)	< ±0.5 %
Response time (at the voltage of 0-95%)	< 0.3 sec
Temperature	0 - 40°

Table 2-C

Focusing coil dc power supplies	
Main focusing coil dc power supply	
Maximum output voltage	+900 V dc
Rated output current	5 - 12 A
Regulation	Constant current scheme
Ripple (peak to peak)	0.5 %
Stability	±0.5 %
Temperature	0 - 40°
Auxiliary focusing coil dc power supply	
Maximum output voltage	55 V dc
Rated output current	10 A
Regulation	COnstant current scheme
Ripple (peak to peak)	0.2 %
Stability	±0.2 %
Temperature	0 - 40°

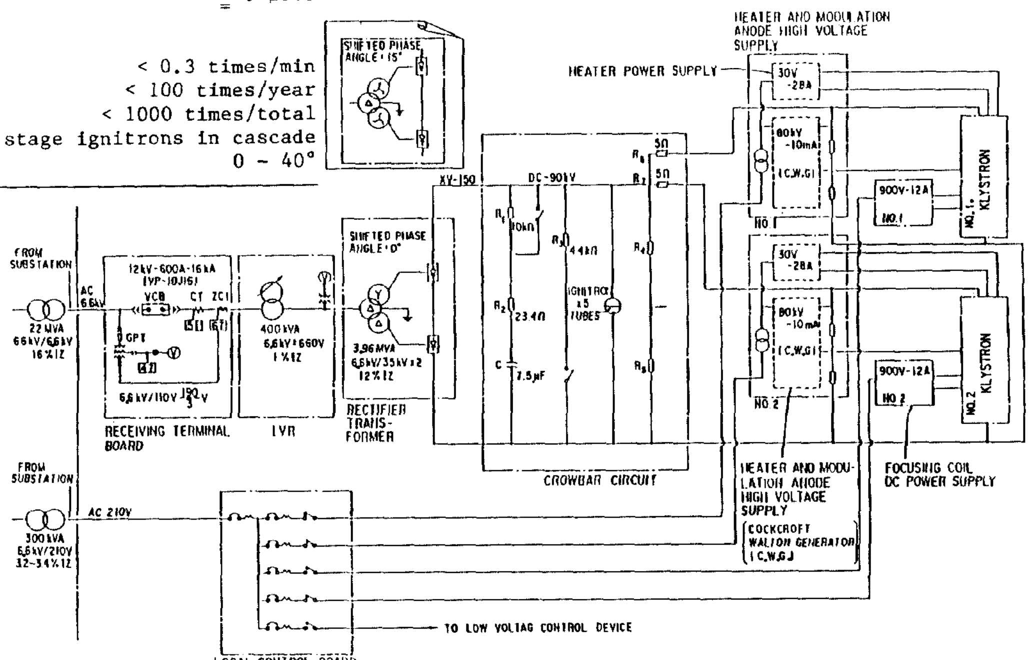

Fig. 2 Simplified diagram of the power supply system (type A).

The high voltage of the modulation anode is generated by a 10-step Cockcroft-Walton scheme. In the same way as the heater power supply, a converter circuit produces a sequence of 20 kHz pulses with a constant amplitude. The inverter compares the output voltage with a reference signal fed through an optical fiber cable, modulates the pulse width and controls the phase of the TRIAC, so that the output voltage of the Cockcroft-Walton generator is stabilized. The measured high voltage is stable within ± 0.1 %. It is shown in Fig. 5 that the response time from the setting of output voltage is less than 0.3 sec. The maximum output voltage of the modulation anode is 80 kV.

Focusing-coil dc power supply

Two kinds of constant current sources are prepared as the power supply of the focusing coil. One excites the main focusing-coil and the other an auxiliary focusing-coil. The former is used for every klystron, meanwhile the latter is used only for the klystrons of Valvo. The phase control method is used for the main focusing-coil exciter. The measured current stability is ± 0.1 %. The auxiliary supply is a commercially available constant current dc power supply.

Operation of rf system

Since the middle of October 1986, six type-A and four type-B power supplies have been feeding 16 klystrons, each of which is coupled to four APS 9-cell cavities. The rf power at the cavities reached 80 % of the designed maximum wall loss. After sufficient conditioning of the rf system including the power supplies, the energy of the accelerated e^+e^- beam reached the design level of 25 GeV. At the same time, the first e^+e^- colliding event was observed in the VENUS detector. Fig. 6 shows the situation for the actual acceleration. The top of the figure is the beam current, the middle the output power of klystron and the bottom the feed back control signal. At present, the accelerator is operated in a four-week running cycle, and the number of interruptions due to the initial default is greatly decreased.

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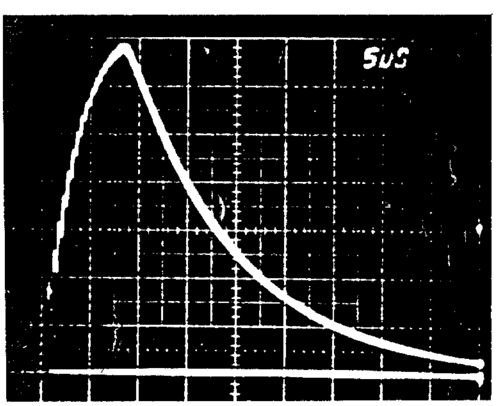
Reference

(1) K. Akai et al., KEK Preprint 86-54 (1986).



625 A/DIV

5 μSEC/DIV

Fig. 3 Current of the ignitron when the load is short-circuited.

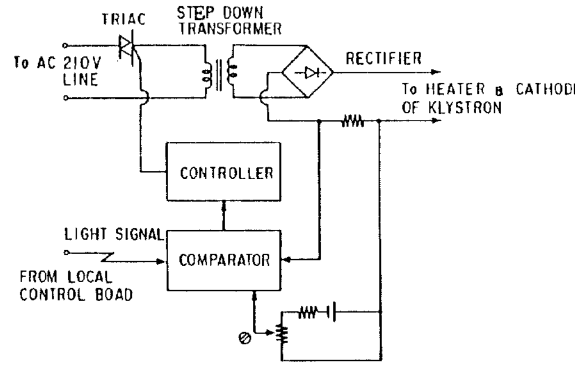
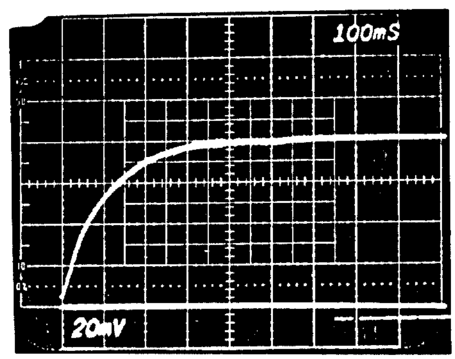


Fig. 4 Simplified diagram of the heater power supply.



20kV/div

100mS/div

Fig. 5 Response time of the modulation-anode voltage.

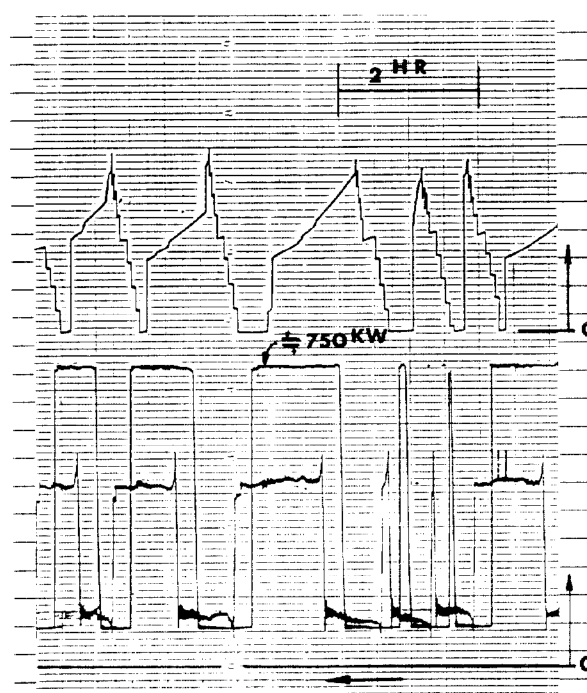


Fig. 6 RF output at the acceleration.