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MODULATORS FOR SPring-8 LINAC

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Abstract

Pulse modulators for 80MW klystrons (TOSHIBA E3712) had been designed. The modulator is a line-type pulser, consists of rectifier section (a rectifier circuit, IVR and step-up transformer), charging section (de'Qing circuit) and discharging section (PFN) . In the charging section, re-chargeable de'Qing circuit are used, and the discharging section is composed of four parallel coupling type PFN (Pulse-Forming-Network). A first modulator was already constructed and tested in June 1995. The test data were good enough compared with design parameters. In this paper, modulator design are mentioned, and performance test are reported.

1.Introduction

As the SPring-8 is a commercial operating machine, it is to be desired that shutdown or maintenance time is shorter as possible. So even if one or two klystrons failed, beams of which energy is more than 1GeV has to be provided, to the Synchrotron. For this reason, we selected TOSHIBA E3712's, of which peak output power are 80MW, for main klystrons. The number of E3712's are 13, and each klystron feeds rf power to two accelerator structure except of first klystron for just after bunching section. Usual operating power from E3712 klystron will be about 52MW compared with design parameter of 80MW.[1)]

So in this system, 13 sets of 190MW Modulators for E3712 are required. Design of the modulator had been accomplished and now, 7 units of modulators are delivered to the SPring-8 site, another 6 modulators are now under construction by TOSHIBA Corporation. All modulators will be delivered to SPring-8 site until this November.

2.Design of Modulator

The modulator is separated into two units, control unit and high voltage circuit unit. Size of the high voltage circuit unit is 3900W×1900D×2300H. The control unit are mounted in two 19 inch racks. The parameter of the modulator is shown in Table.1. Outline of circuit is also shown in Fig.1.

2.1 Rectifier Section

The rectifier section consists of IVR, step-up transformer, and rectifier circuit. Input voltage of the IVR is 3ϕ420V, and output voltage is 580V maximum. We selected the IVR that minimum output voltage is 260V, not 0V, so that it is smaller compared with the same class IVR. Output voltage of the step-up transformer is 25kV maximum. In order to keep phase balance, halves of the 13 modulators are delta-star connection, and others are delta-delta connection. Input power of the modulator is 95kVA.

2.2 Charging Section

For regulating charging voltage, we adopted a de'Qing circuit in a usual way. A de'Qing circuit is a re-chargeable type circuit[2)], and has a range of 7% regulation. Almost all energy stored in charging choke are fed back to the rectifier circuit. So This section can be made compact.

2.3 Thyratron

Originally, thyratron F-157 (ITT) is adopted as switch tube.[3)] Its maximum anode voltage and current are 75kV and 15,000A respectively. These tubes are mounted in several modulator and tested for two months. But pre-fire trouble were appeared. The number of pre-fires are different in each tube case, they were averagely occurred twice or three times during 8 hours operation. So we decided to replace thyratrons. New thyratron is F-351 (ITT). It is remodeller of F-241, which has been used at SLAC for many years and had few pre-fire trouble. But F-351 is a new tube and does not have operation data. Maximum anode voltage is 55kV and current is 10,000A. Major difference between F-351 and F-157 is the number of gaps. F-157 is three gap type but F-351 has two gaps.

Table.1 Modulator parameters

Input Power	95KVA
Output Voltage	391kV
Output Current	474A
Pulse Width (FWHM)	5μ sec
Pulse Width (flat top)	≥2μ sec
Voltage Regulation at flat top	≤±0.5%
Regulation Value of de'Q	≥7%
Repetition Rate	60pps
Pulse Trans. Turn Ratio	1:16

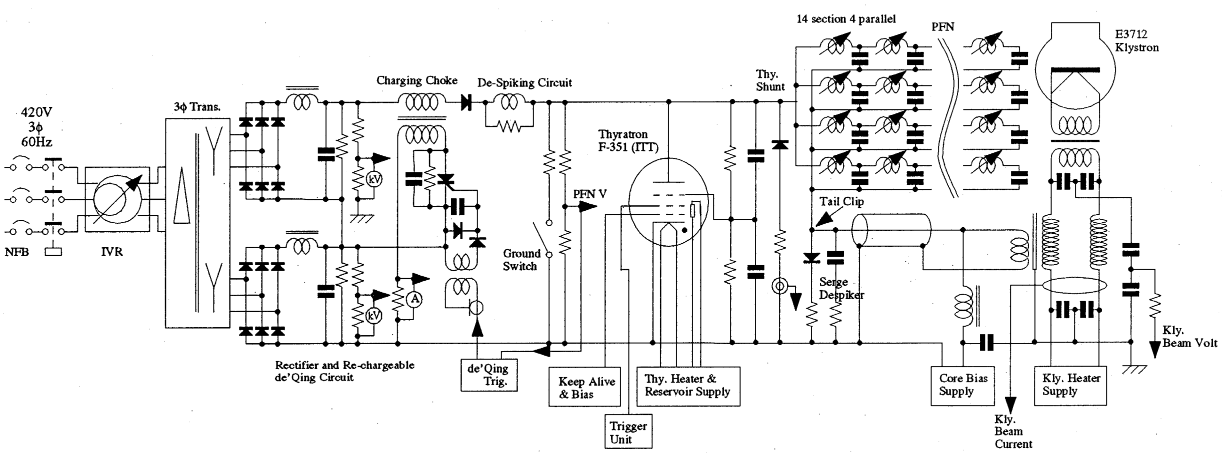


Fig.1 Outline of the modulator circuit

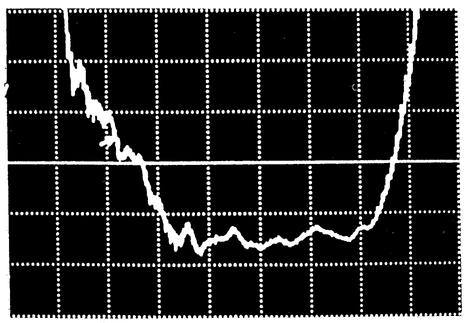
So F-351 is more compact and volume of inner gas are smaller compared with F-157. Two F-351's are tested in two different modulators individually. There were no knock out during 8 hours operation.

2.4 Discharging Circuit

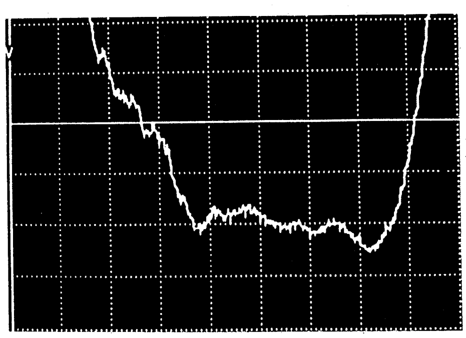
Design value of pulse width of flat top is more than 2μsec with fluctuation of less than ±0.5%. In order to obtain this design, pill-box type oil condensers, of which leakage inductance are less than 250nH (This includes value of circuit between the condenser and an analyzer) are selected for pulse-forming-network (PFN) condensers. And moreover, pares of adjoining coils in the PFN have mutual inductances which decrease leakage inductance of the condenser equivalently. In this case, value of mutual inductance is arranged equal to the leakage inductance. But It is difficult to form large mutual inductances. So, in order to obtain small leakage inductance of the condensers, we selected small capacitor. Therefor, the PFN forms 4 parallel networks. Each network has 14 sections. Capacitance is 0.015μF, and maximum voltage is 50kV. Simulation data of this coupling type PFN cleared the fluctuation level.

Impedance of the PFN is about 3.3Ω. The PFN is designed not to be negative mismatch, but slightly positive mismatch during discharge. But if positive mismatch keeps after discharge, stored energy in primary side of pulse-transformer backs to the PFN and the condensers become to have initial storage charge. In order to avoid this, the PFN designed to be slightly negative mismatch after discharge and the storage charge of condensers are discharged by shunt circuit.

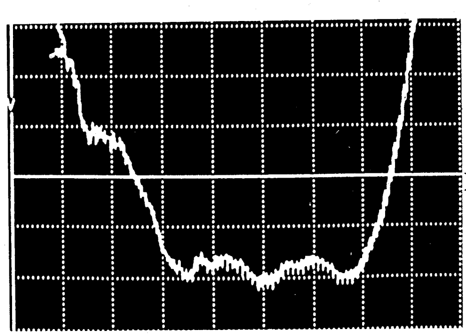
Assemblies of modulator output cable are triaxial, made by STANGENES, where two cables are connected parallel to a pulse-transformer tank. A pulse transformer and the tank are also made by STANGENES.



No.2 modulator



No.3 modulator



No.4 modulator

Fig.2 Magnifications of klystron beam voltage after 8 hours operation with keeping full power. (ordinate : 500ns/DIV, abscissa : 1.0%/DIV)

2.5 Control

The modulator itself is controlled by a sequencer unit, and communicates to the upper control system through VME boards, which are mounted near the modulator body. And analog signal between the sequencer and the modulator are range of less than 10V. So it is very important to reduce noise level of the modulator. Three kinds of filters, isolators, passive filters or bypass condensers, are inserted in cable lines.

3. Test Results

Now 7 modulators had finished performance test and all of them achieved output power level (see Table.1) which are needed to drive klystrons.

Fig. 2 shows the fluctuation of klystron beam voltage with connection to a dummy klystron. These waveforms are after 8 hours operation with keeping full power. Length of pulse top with fluctuation of less than $\pm 0.5\%$ are about 2.1μsec in each case.

Noise level of the analog signal connected between the sequencer and the VME board are observed. Magnitude of signal is 10V maximum but there was spike noise of about 20V at the point of thyratron trigger. Earth level fluctuations or noise at another timing were not occurred. Something like LC filters for reducing the spike noise are needed.

Control test from the VME had been also done. We could confirm expected communications.

4. Conclusion

Halves of the modulators have been constructed and they were cleared the design value. Noise level were relatively smaller than predicted level.

All modulators are accomplished by this November and operation start will be next year April.

5. References

[1] S. Suzuki et al. ;"RF System of SPring-8 Linac", Proc. of this symposium

[2] Akemoto et al. ;"Pulse Modulator for 85MW Klystron in ATF Linac", Proc. of 17th Intentional Linac Conference, 1994, Vol. 1, p.414-417

[3] T. Hori et al. ;"Pulse Modulator for 80MW Klystron in SPring-8", Proc. of 20th Linear Accelerator Meeting in Japan, Osaka, 1995.