BEPC INJECTOR UPGRADE

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Abstract

BEPC is a 2.2×2 GeV electron- positron collider with luminosity of $2\times10^{30}cm^{-2}s^{-1}$. Its injector is a 1.3GeV electron Linac. As a part of BEPC upgrades for higher luminosity, the Linac energy will be increased to 1.55 GeV of J/• physics energy region, and further to 1.75 GeV or higher. The main measures we took are: 1) to use 4 sets of high power RF sources, including newly designed 65MW klystrons and 150 MW modulators; 2) to rebuild local control system for more stable operation. After a few years effort with collaborating companies, main upgrades and relevant improvements (15 dB high power directional coupler, high power vacuum valve, RF pulse widening to increase the multiplication factor of SLED etc.) are completed. Now the machine can be operated stably at 1.55GeV.

Keywords: BEPC injector, high power RF source, Linac control system

1 INTRODUCTION

Full energy injection is necessary for any high luminosity storage rings, such as PEP-II• KEKB etc., because it can avoid beam loss during ramping or omit ramping process to shorten the injection time. For BES, the most important physics is J/• of 1.55GeV. So, to increase BEPC injector energy from 1.3GeV to 1.55GeV for J/• and further to 1.75GeV for other physics is significant.

BEPC injector [1], built in 1987, was a 1.3GeV• 200-meter electron Linac. HK-1 klystrons (35MW) were the RF power sources. The standard acceleration unit consists of four 3-meter constant gradient accelerator tubes, driven by one klystron with SLED. The energy gain can be expressed as $W\ (MeV) = 20\ M\sqrt{P}$, where M is the multiplication factor of SLED, and P the klystron output power. It is clear that higher energy can be obtained by both increasing the klystron output power and enhancing multiplication factor. There are 12 such acceleration units downstream of BEPC positron production system. If we replace three of them with 65MW klystrons (operating at 45MW at the first stage), we can hope to get 200MeV energy gain. For the rest RF power supplies, we are going to make some modifications. Widening the pulse width from 3.2•s to 3.7•s by adjusting the modulator PFN, we can increase the multiplication factor of SLED from 1.4 to 1.5. Using higher ratio of 1:14 pulse transformer, we can arise the pulse voltage a little bit from 260KV to 270KV, so that the average output power of the klystrons can be increased from 19MW to 22MW. By all measures mentioned above, it is hopeful to increase the positron energy to 1.75GeV as shown in Table 1.

Table 1: Energy Upgrade

	Before upgrade	After Upgrade
RF Power Source	11×19MW	8×22MW 3×45MW
RF pulse width	3.2μS	3.7μS
EMF of SLED	1.4	1.5
Injector Energy	1.3GeV	1.75GeV

Besides energy upgrade, another important upgrade is to rebuild the local control system. The old one was manually operated, complex and inconvenient, especially in our case, both electrons and positrons use the same beam line. When we made mode change, say from e^- to e^+, a lot parameters should be changed. Computer can do it very easily.

In what follows, the author will present the technique issues underneath the energy upgrade and the local control system rebuild.

2 TECHNIQUE UPGRADE

2.1 65MW klystron

Table 2: 65MW Specifications and Test Results

Parameters	Design	1st Tube	2nd Tube	3rd Tube
Frequency (MHz)	2856	2856	2856	2856
Cathode	Dispenser	Dispenser	Dispenser	Dispenser
Heater Volt.(V)	22	20.5	23	21.6
Heater Curr.(A)	36	38	41	38
Pulse Volt.(KV)	350	330±5	342	350
Pulse Curr. (A)	415	406	401	444.1
Microperv. (•P)	2.0±0.1	1.91~2.13	2.0	2.145
PPS	50	12.5	12.5	12.5
Pin •W•	600		~600	~800
Pout •MW•	65	50.4	58.5*,66**	63*,76**
RF Width (•s)	3.5	3.0	3.3~3.35	2.5~3.0
Efficiency (%)	45	37.6	42.6*,48**	
Gain (dB)	51		~50	
Lifetime (Hrs)	•15000	3500	8000	Alive

*Measured by thermocoupler
**Measured by peak power meter

The new high power klystron[2] was designed in 1992, the prototype was SLAC 5045 tube. After many trials, we got the first tube in 1995, manufactured by 4404 company in Wuhan. The output power on the test stand was about 50MW, not bad for the first tube. In succession, we totally got three 65MW klystrons from the company. Their test results and operation records at the gallery are listed in Table 2. From this table we can see, the output power is acceptable both on the test stand and at the gallery, but the lifetime is too short. Now we are trying to open the two failure tubes and analyse the problems with company people.

2.2 150MW modulator

Referring to high power modulator techniques of world class labs, such as SLAC, KEK, DESY, etc., and our own 80MW modulator experience, we designed the 150MW modulators [3] for 65MW klystrons. The specifications and pulse voltage output waveform are listed separately in Table 3 and Figure 1. We have made four 150MW modulators, two of them are now working at klystron gallery for a few years, very stable and low noise.

Table 3: Parameters of New and Old Modulators

	Old	New
Output Power	80MW	150MV
Output High Voltage	260KV	350KV
Repetition Rate	12.5Hz	25Hz
Anode Voltage of Thyratron	42KV	44KV
Anode Current of Thyratron	3240A	6500A
Pulse Transformer	1:12	1:15
Pulse Width	3.0•s	3.5•s
Rise Time	0.7•s	0.9•s
PFN Impedance	6.2•	3.3•
PFN Total Capacitance	0.34•f	0.9•f
Charging Current	3.7A	2.53A
Charging Time	5.5ms	2.6ms
Charging Inductance	10H	30H

2.3 Local control system

Linac control system[4] reconstruction includes following parts as illustrated in Fig.2.

a. *RF power source*

A new local control system based on the PLC was installed and the communication between the control room and modulators was accomplished. PLC was used to replace the original relay control logic circuits of the modulators. The control PC inspects the PLCs through the RS-232 port. The DC voltage, charging current, external failure signal and filament current are sent to the control room. DC voltage can be remotely controlled.

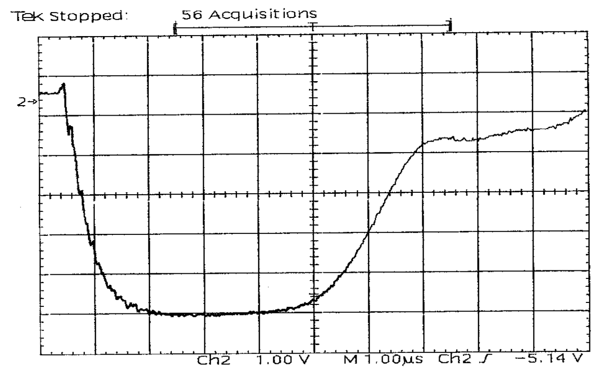

Figure 1: 150MW Modulator Output Waveforme

b. *Magnet power supplies*

There are 88 sets of DC power supplies used for quadrupoles, steering coils and focusing solenoids. Now the adjustment can simply be done by the PCs. Good data are saved on the hard disk for further analysis and reference.

c. *Vacuum*

A PC is used for inspecting the status of the Linac vacuum. All parameters can be shown on the screen with proper colours. When there is any trouble, a sound and red colour warning will appear.

d. Mode change and RF phase

As mentioned above, in our Linac e^- and e^+ beams use the same beam line. When changing modes, we need switch the stepping motor to arise or put down the target, and adjust the capture section RF phase and all the optical parameters downstream. In order to get the highest energy, the RF phases of the klystrons are controlled. All these are now accomplished by a PC.

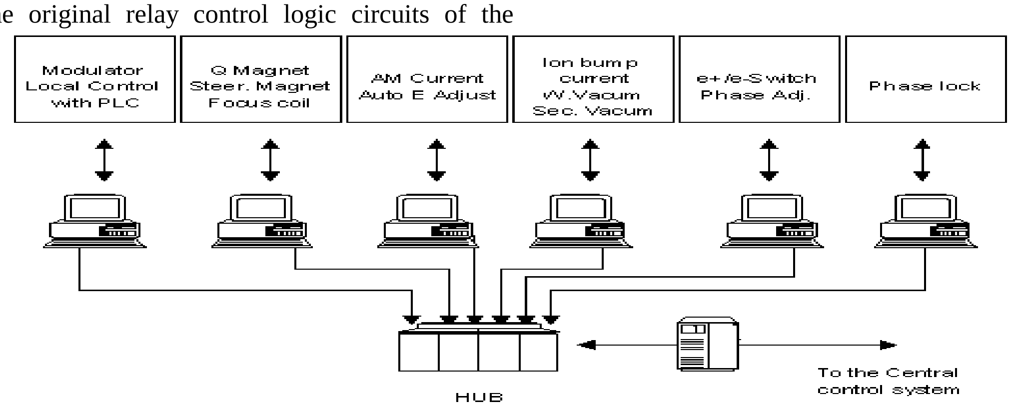

Figure 2: Linac Control System

2.4 High power vacuum valve[5]

Between klystron window and the downstream RF structure, there is an valve for vacuum separation. The one used for HK-1 klystron is SLAC old design, which is Indium sealed and only can bear 35MW power. For 65MW klystron, we must use new one. The new design is a two part U type waveguide. These two parts can be set apart a little bit to let seal plate with fluorine O ring insert into the gap to separate vacuum.

2.5 15dB high power coupler

In our system, the first klystron is driven by an RF amplifier. The following tubes are driven with part of the power from No.1 tube by directional coupler. In order to ensure enough driving power for 65MW klystrons, 15dB directional coupler was designed and used to replace the original 20dB one.

3 CONCLUSION

Except the lifetime of 65MW klystron need to be further studied, all other upgrades have reached the design targets. They are working smoothly on the machine, especially the modulators and local control system. Because only two 65MW klystrons were installed (including one SLAC 5045 tube) at the gallery, not four as planned ,the linac can only work at 1.55GeV.

4 REFERENCES

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