STATUS AND FUTURE PLAN OF NSRL MICROWAVE POWER SYSTEM*

L. Shang, W. M. Li, Y. J. Pei, J. Hong, Y. M. Lu, Y. Zhang,
National Synchrotron Radiation Laboratory,
University of Science and Technology of China, Hefei, Anhui, 230029, P.R. China

Abstract

In this paper, the microwave power system for HLS (Hefei Light Source) Linac is introduced. The power system includes five s-band 20MW klystrons and their modulators. In 2002, the klystron modulators and the control system were upgraded. Constant-current, switching power supplies were employed to replace the old conventional LC resonant charging facilities. The new system has run for four years and played an important role in the operation of the 200MeV Linac. A new soft x-ray FEL project (HTF) is now proposed in NSRL, the energy of electron beam will be increase from 200MeV to 800MeV. Seven s-band 80 MW klystrons and modulators will be employed as the new microwave power sources. The low energy spread specification of the Linac sets a stringent requirement to the stability of the klystron modulators. The paper also presents the technical considerations and preliminary design of the new system.

INTRODUCTION

HLS is a second-generation, dedicated synchrotron radiation source. It consists of three major facilities which are the 200 MeV Linac, the transport line and the 800 MeV storage ring.

The Linac includes an 80keV gun, a pre-injector and four 6-meter long constant-impedance accelerating sections. The five RF modulators, each equipped with a 20MW klystron, are operated at either 50 Hz or 1Hz as shown in Fig1. The installation of the linac began in May 1987, and the commissioning took place in November later that year. After about one month commissioning, The Linac produced 220 MeV, 58 mA electron beam.

UPGRADE OF MODULATORS

Before 2002, the klystron modulators of the HLS 200 MeV Linac employed 50Hz high voltage power supplies and resonant charging scheme with De-Qing circuit[1,2]. The high voltage charging power consists of a 50kVA motorized 3-phase variable transformer, a high voltage step-up transformer, a rectifier assembly and a charging inductance as shown in Fig.2. After more than ten years' operation, some components were no longer in good condition and circuit failure occurred often. The stability of the output high voltage was not satisfactory, especially when the AC line voltage fluctuated. The control and monitor of the modulators was based on relay circuit and manual operation. There was no computerized controller in the modulators and therefore can not meet the requirement of the new EPICS control system of the HLS[3].

In order to increase the stability, operation reliability and follow the standard of the HLS EPICS system, an upgrading project was initiated in 2002. The project includes two major parts. One is the replacement of the old HV powers with five constant-current switching power supplies. The other is the addition of a PLC in each modulator as the local machine controller. The old control and monitor system were totally abandoned. Because HV power supply works at a frequency of 40 kHz and uses water cooling method, it is very compact in size. Much space in modulator cabinet is free out. The volume and weight of the new charging power reduces about 20 times compared with the old one. Fig. 3 shows the structure of the new modulator after modification.

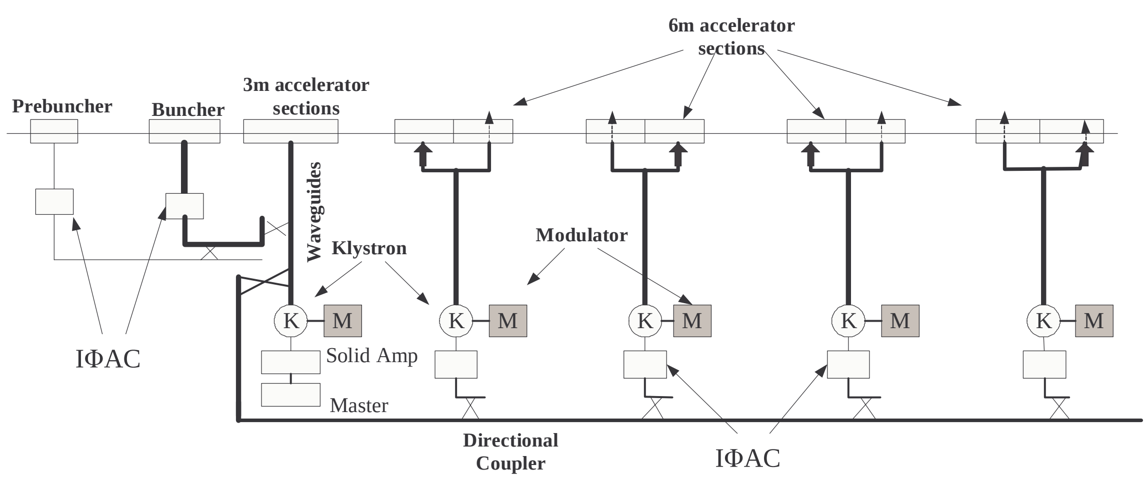

Figure 1: Existing 200 MeV Linac RF power system.

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#lshang@ustc.edu.cn

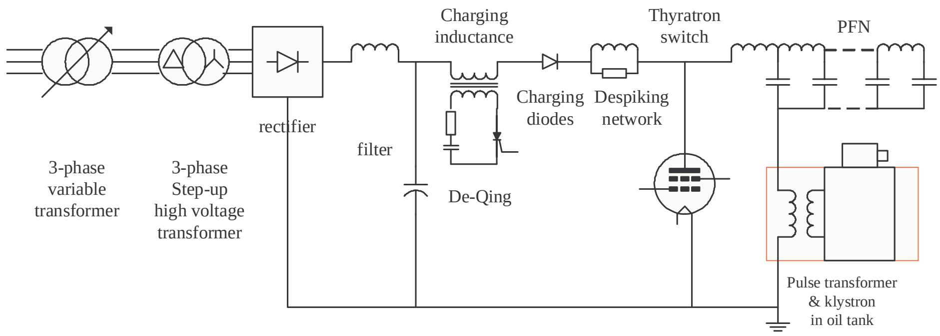

Figure 2: Simplified schematic of the old modulators.

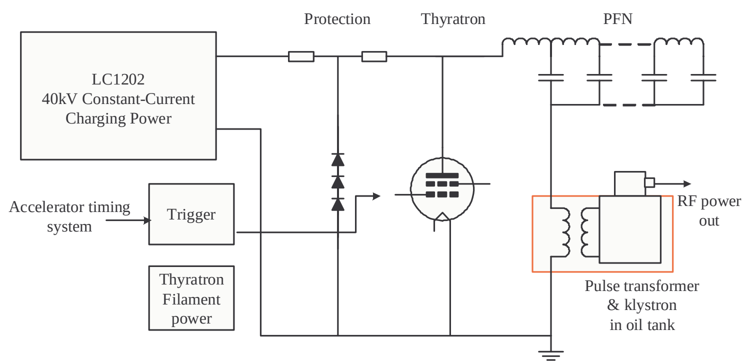

Figure 3: Simplified schematic of the new modulators.

PERFORMANCE AND EXPERINCE

The new system has run for four years and the performance is satisfactory. But we still encounter some problem during the commissioning. One phenomenon is the failure of HV connectors in the new power supply, which is caused by the continuous operation under humid environment just after the upgrade. We solved the problem by the improvement of the connectors and the application of insulation silicon grease. Working at 50Hz, the new HV power seems to protect more sensitively compared to old power. This requires more frequent adjustment of hydrogen gas pressure of the thyratron. Some time it is not easy to find the error source. This brings us some trouble. By experience, most protections happen due to the failure of thyratron discharging circuit not due to HV power supply. By statistic, the availability of the klystron modulator system is better than 0.992 for the past four years. The availability is defined as A = (the scheduled operation time- unscheduled downtime) / the scheduled operation time.

1 Hz MODE OPERATION

Originally the Linac was designed not only as the injector of the storage ring but also a machine that can be used to do nuclear experiments. The repetition rate was chosen to be 50 Hz whereas the injection cycle of the storage ring is only 0.5 Hz. Most of the beam goes into the dump. So it is not an optimised design. In order to reduce the MTTF, improve the lifetime of expensive components and lower the radiation dose, we decide to change the repetition rate of the Linac to 1 Hz. This is achieved by modified the timing system, thyratron triggers and HV power delay circuits. From Mar, 2006, the Linac run at 1 Hz. And the no single failure happens up to now. And it can be switched back to 50 Hz conveniently when necessary

FUTURE PLAN

A soft x-ray, cascaded HGHG FEL project (HTF) is now proposed in NSRL[4] The goal of the project is to generate 8.8nm soft x-ray radiation in the range of 100MW peak energy and in the mean time achieve full energy injection of the storage ring. The electron beam has the following specification: 800 MeV, 1 nC, 1.6 ps, an emittance of 2.1 mm·mrad and .an energy spread of 0.1%. The Linac will be reconstructed but the existing tunnel can be utilized. The new designed 6-meter accelerating section adopts constant-gradient structure, symmetrical coupler and coaxial load. When the input power is 31.5MW to each 3-meter section, the energy gain is 61 MeV with a maximum gradient of 21 MV/m.

Together seven s-band 80 MW klystrons and modulators are needed as the new microwave power sources as shown in Fig. 4.

Although the solid state induction modulators appeared and are used in some labs, in the case of HTF with low frequency of 10 Hz, the average power consumption is not large and the efficiency is not the most import concern, a line type modulator with PFN/Thyratron design is still to be the best choice. The repeatability of the high voltage pulse is required to be better than ±0.1%. The pulse should have 1.2μs flattop with ripple less than ±0.15%. The PFN has 20 cells with 0.033μF capacitor in each cell. Table 1 list the parameters of the new and the old modulators.

Table 1: comparison of the old and the new klystron modulator

Klystron	KMF1017A	ToshibaE3712
Peak RF power	20MW	80 MW
Beam voltage	250kV	400 kV
Beam current	200A	480 A
Perveance	1.6 μp	1.9 μp
Modulator peak power	50MW	200 MW
Modulator average power	9kW	8 kW
Thyratron anode voltage	40kV	47 kV
Thyratron current	2.5kA	8 kA
PFN impedance	8.7 Ohm	3.0 Ohm
Transformer turns ratio	1:12.5	1:17
Rise time	1.0μs	1.0μs
Fall time	1.4μs	1.8μs
Flattop width	2μs	1.2μs
Jitter	±5ns	±5ns
Repetition rate	50 Hz	10 Hz
Repeatability	± 0.15%	± 0.1%
Total PFN capacitance	0.22μF	0.66μF

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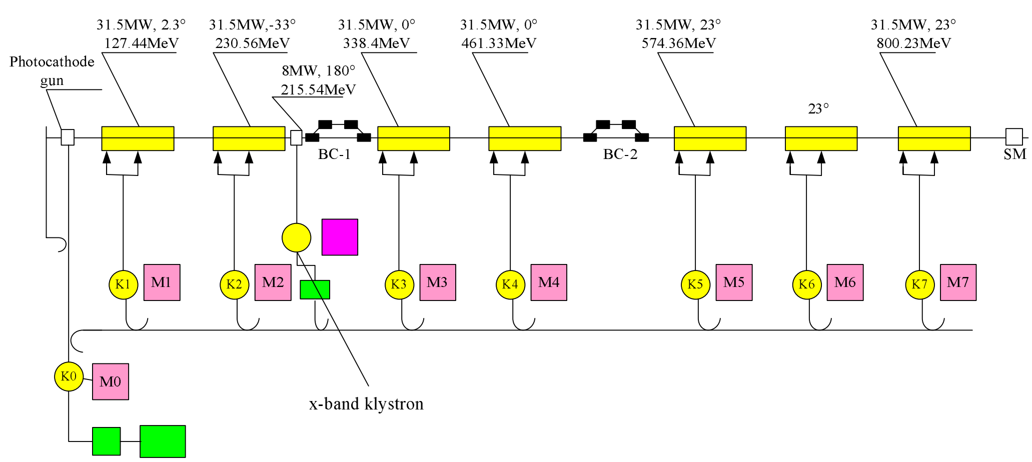

Figure 4: Proposed HTF project.