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THE POWER SUPPLY SYSTEM FOR 10 MeV & 20 kW INDUSTRY IRRADIATION FACILITY*

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Abstract

10 MeV & 20kW industry irradiation facility (IIF) has been designed by National Synchrotron Radiation Laboratory (NSRL) for years. Modular design power supplies are employed for the latest version, depend on the performance of these power supplies with high precision and high stability, the operating reliability of the IIF has been greatly improved.

INTRODUCTION

In recent years, the high energy electron beam as a very powerful tool for sterilization has been promotion and application rapidly [1]. Especially, the COVID-19 was spreads widely in the world, the need of the disposable medical supplies, such as disposable gloves, protective suit, has been increased rapidly, [2] compared with the radiation sterilization, the high energy electron beam can greatly shorten the production cycle and increase output [3].

As we know, energy of the electron beam determines its depth of penetration into the product, a "medium energy" (1 to 5 MeV) or a "high energy" (5 to 10 MeV) beam would be required [4]. Considering this factor, a 10 MeV & 20 kW industry irradiation facility (IIF) has been designed by NSRL and operated for several years.

The power supplies MTBF performance requirements are much more stringent than what can be achieved with off-the-shelf commercial power supplies. In order to improve MTBF, the power supply system is upgraded with the modular design and use the commercial products as it's part. This paper reports on the parameter and principle of the power supply system.

THE POWER SUPPLY SYSTEM

The IFF needs variety power supplies (PS) for different units, some of them can be achieved with off-the-shelf commercial power supplies, such as unipolar PS, high voltage PS and modulator, the other must be customized, such as bipolar PS, pulse PS. But all of them requires high long-term stability, fast and reliable inter-lock, and quick maintenance. The PS system is shown as Fig. 1 and the details are shown as the Table 1.

Table 1: Power Supply System

Type	PS Function	Description
Unipolar DC PS	Focus solenoid for accelerating tube	30 A / 60 V
	Corrector magnet	10 A / 10 V
	e-gun Filament-heater	2.5 A / 6.3 V
	Thyratron filament-heater	100 A / 15 V
	Thyratron hydrogen	20 A / 15 V
	Focus solenoid for klystron	40 A / 120 V
Bipolar PS	Scan magnet	±10 A / 37 Hz
Pulse PS	Grid-controlled pulse	+300 V / pulse; -100 V /DC bias
Modulator	For klystron	130 kV / 500 Hz /16 μs
DC-AC Inverter PS	Klystron filament-heater	AC 3 A / 220 V
High Voltage PS	e-gun HV	DC 45 kV / 200 W
	Ion HV	DC 7 kV / 400 W

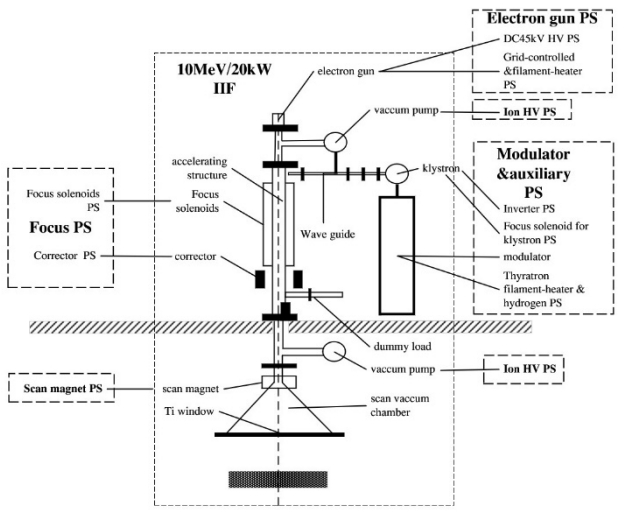

Figure 1: Power supply system of the IIF.

Unipolar DC Power Supply

The IFF needs 14 sets unipolar DC power supplies for focus solenoid, e-gun filament and thyratron with the stability better than 200 parts per million (ppm) and the MTBF⩾50000 hours. Two loop hybrid design has been developed for this unipolar DC power supply, the analog

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closed-loop achieved by a customized AC-DC power module with voltage-stabilized, and the digital loop achieved by a microcontroller unit (MCU). The conceptual design shown as the Fig. 2.

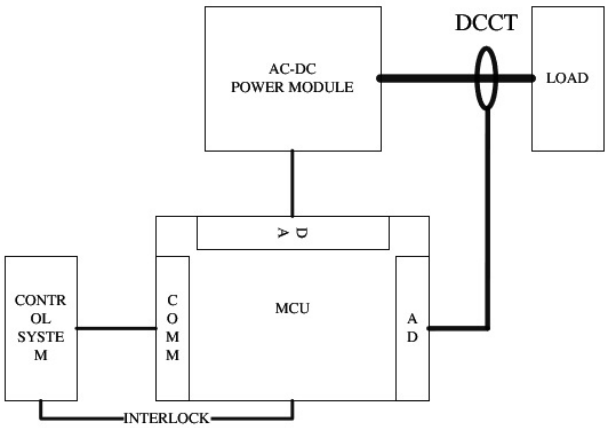

Figure 2: Unipolar DC power supply.

Bipolar Power Supply for Scanning Magnet

The bipolar power supply is driven by a H-bridge converter consisting of four MOSFETs as shown in Fig. 3. The output current is 37 Hz triangular waveform with the amplitude ±10 A, the four MOSFETs divided into two parts, Q1 and Q4, Q3 and Q2, they are driven by two sets PWM separately with dead-time about 4us. The output current waveform shown as Fig. 4.

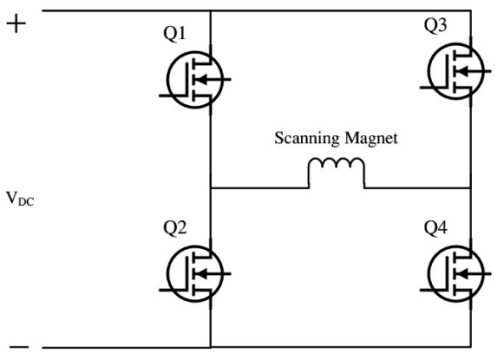

Figure 3: H-bridge converter for scanning magnet.

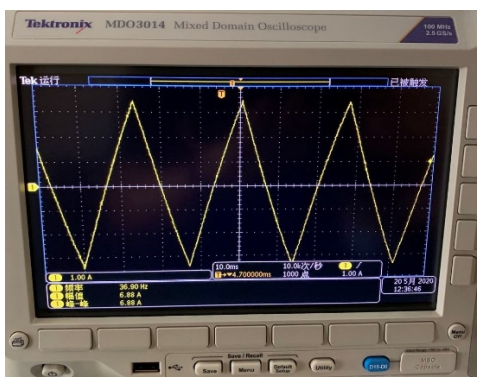

Figure 4: The output current waveform.

In the IIF, once the scanning magnet power supply stop output, the beam will be bombardment straight in the center of the Ti window, which will be cause the window breakdown in few seconds. By test of artificial disconnection, this time to respond to failure may short than 200 ms, and the result is shown as Fig. 5.

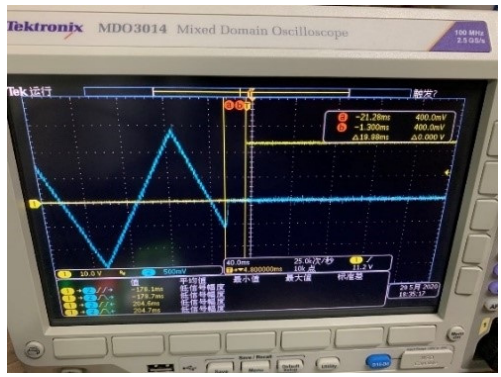

Figure 5: The time to respond to failure.

Power Supply for Electron Gun

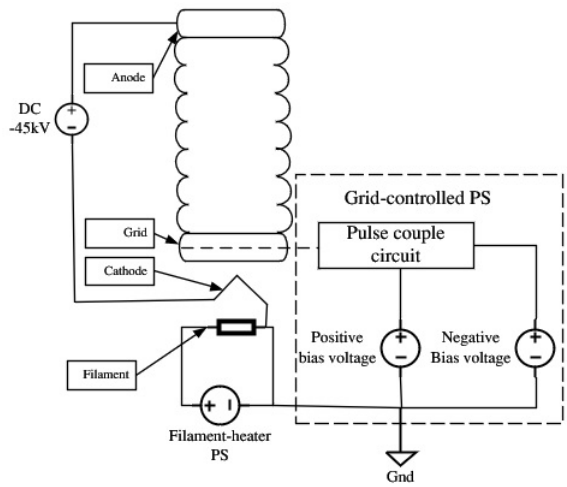

Figure 6: DC electron gun PS.

As shown in Fig. 6, the DC electron gun PS includes: DC-45 kV high voltage PS, filament-heater PS and grid-controlled PS. The grid-controlled PS was employed two MOSFET, that one for start the pules and the other one cut off, the circuit is shown in Fig. 7. The parameter of the pulse-forming circuit was measured, the rising edge <10 ns and the falling edge <42 ns, the result is shown as the Fig. 8.

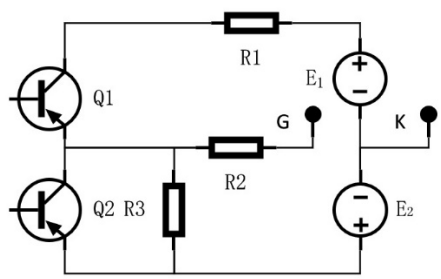

Figure 7: MOSFET coupling circuit.

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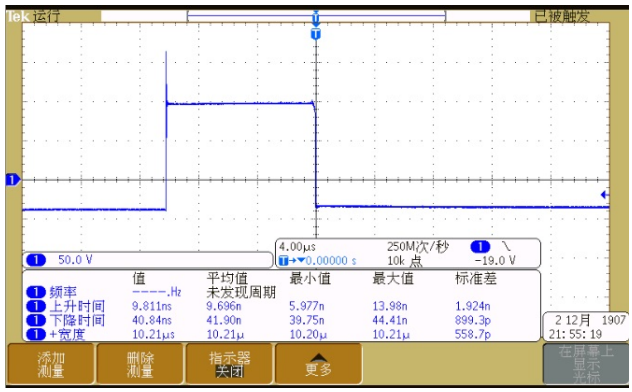

Figure 8: Parament of the pulse-forming circuit.

Modulator and DC-AC Inverter Power Supply

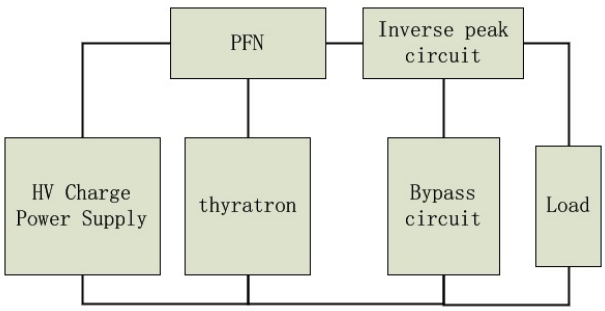

Figure 9: Linear modulator.

As the Fig. 9 shown, the linear modulator is commercial products, that work stable and reliable. However, the commercial modulator usually use the transformer which is reliable but not precision and accurate regulation as the klystron AC filament-heater power supply. The DC-AC inverter is developed for the IIF, the conceptual of the DC-AC inverter is shown as the Fig. 10.

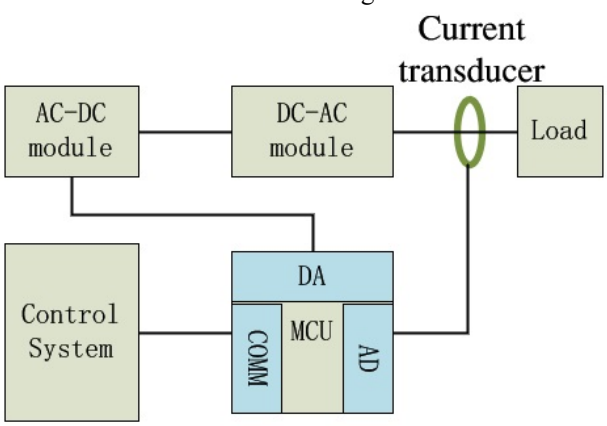

Figure 10: Conceptual of the DC-AC inverter.

High Voltage Power Supply

The IIF PS system contains two sets of the high volt-age power supply: one for the e-gun and the other for the ion pump, they are designed by same method, that the front converter use LLC circuit and the voltage doubling circuit for output. The conceptual is shown as the Fig. 11.

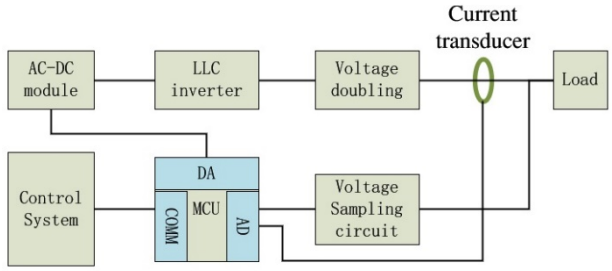

Figure 11: Conceptual of high voltage PS.

CONCLUSION

The power supply system is used in IIF already, by use the modular design and the commercial products, MTBF is significantly improved and the debugging period is reduced.

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