A NEW LONG PULSE HIGH VOLTAGE EXTRACTION POWER SUPPLY FOR FETS

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Abstract

A new 25 kV 2 ms 50 Hz extraction voltage power supply has been developed for the high performance H-minus ion source for the Front End Test Stand at the Rutherford Appleton Laboratory. The power supply has been designed to fit in a single 19 inch rack and has a modular design for easy maintenance. This paper details the design and performance of the power supply.

INTRODUCTION

Ion source extraction systems are a challenging load for power supplies. Not only must the supply deliver regulated voltages for a wide range of currents it must also cope with breakdowns. Caesiated negative surface plasma Penning sources [1] pose a particular challenge because they have high extraction current densities, large co-extracted electron currents and caesium coated electrodes. All of which encourage breakdowns. The power supply must be able to keep working reliably with multiple breakdowns that inevitably occur during the electrode conditioning process.

TECHNOLOGY CHOICE

Digital control and solid state power electronics are not well suited for high voltage breakdowns, being likely to crash and burn respectively. These problems are caused by very fast current rise times and high peak currents respectively.

Analogue electronic control and feedback systems cannot crash like digital systems. Valve tube technology is particularly suitable to high current applications and because they are essentially just electrode systems in vacuum, they are very robust.

To ensure fast rise-times the capacitance of the circuit must be kept as low as possible. The anode-gate capacitance of a triode is too high. The additional screen electrode in a tetrode reduces this capacitance by several orders of magnitude, making the tetrode the obvious choice.

By choosing an overrated tetrode any tube related failures can be minimised.

The Amperex design 8960 tetrode (available from Richardson Electronics [2]) is manufactured in France by Covimag [3]. Its filament requires 7 V 36 A to heat it to operating conditions.

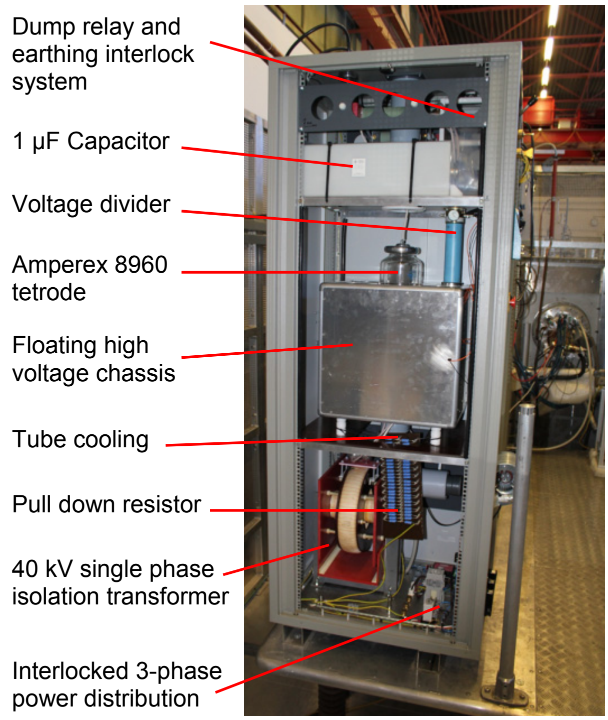

Figure 1: Inside the extraction voltage power supply.

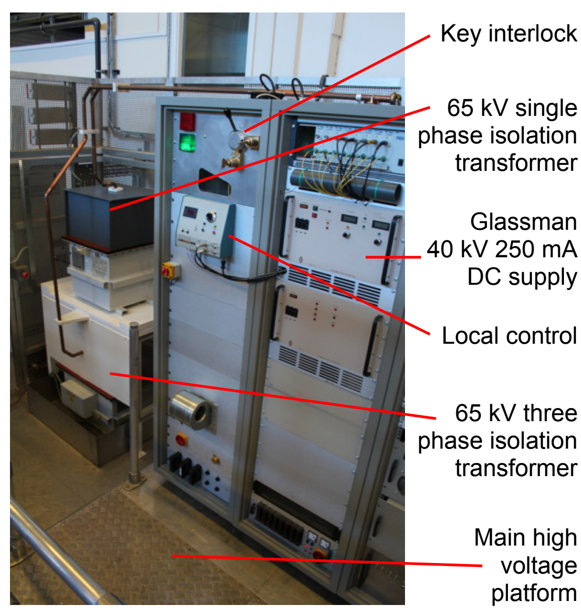

Figure 2: Power supply on the high voltage platform.

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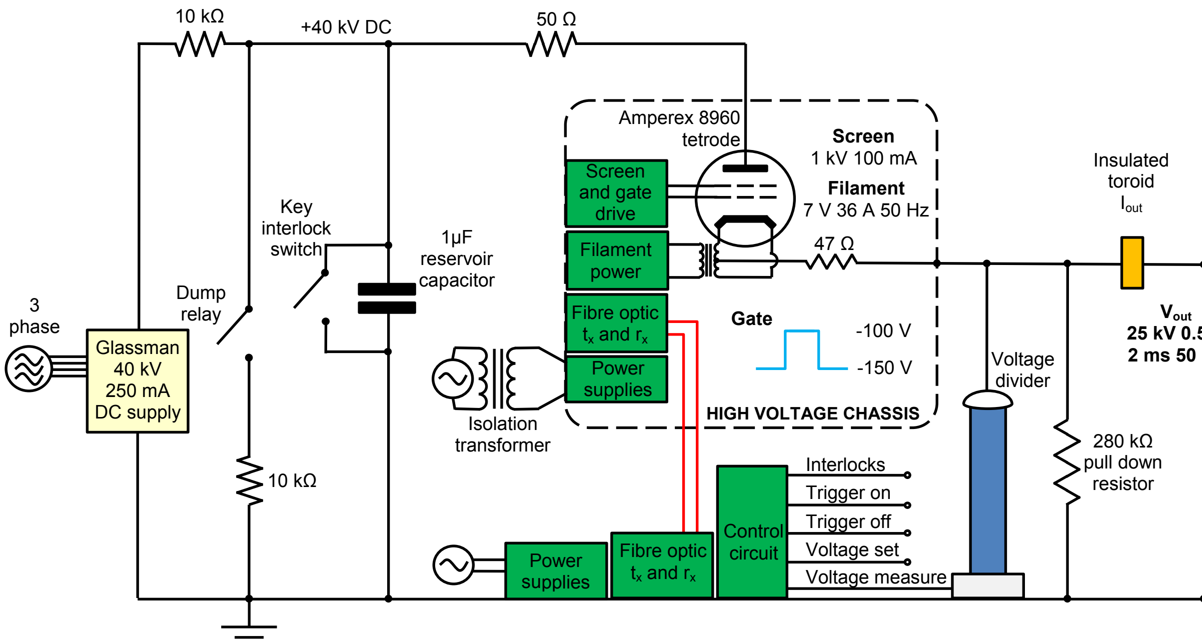

Figure 3: Schemtic showing the operation of the pulsed extraction power supply.

CIRCUIT DESIGN

The basic circuit schematic is shown in Figure 3. A 1 µF reservoir capacitor is charged by a 40 kV DC 250 mA Glassman series LH power supply. The charging current is limited by a 10 kΩ resistor.

The tetrode then acts like a switch, connecting the reservoir capacitor to the output. The anode of the tetrode is connected to the reservoir capacitor via a low value (50 Ω) current limiting resistor. When the tetrode is made to conduct its cathode is pulled up to the anode volts. The cathode is connected to the output.

The tetrode screen and gate drive circuits are referenced to cathode potential, as is the cathode filament heater. Thus it is necessary to float all the drive circuitry in a high voltage chassis connected to the cathode. The common point of the high voltage chassis becomes the output. The power is delivered to the tetrode drive circuits by an internal isolation transformer shown in Figure 1. The gate drive pulse is sent to the high voltage chassis via a fibre optic link. To prevent damage to the valve a fibre optic interlock signal is sent back from the high voltage chassis confirming that the heater and drive circuits are functioning correctly.

The tetrode screen is held at 1 kV above cathode potential. The gate drive pulse is set to 150 V below cathode potential when the tetrode is off and around 100 V below cathode potential when the tetrode is on. When the gate is biased to 150 V the tetrode still conducts about 1 mA of quiescent current. The gate is biased to 150 V to achieve the fastest possible rise time.

The high voltage chassis is measured with a voltage divider. This signal is fed into the analogue control circuit to regulate the output voltage. This along with the desired set voltage and timing signals is used to generate the gate drive signal sent over the fibre optic link.

A 300 W, 280 kΩ pull-down resistor is connected across the output. When the tetrode gate drive signal is removed the pull down resistor rapidly drops the output voltage in about 200 µs.

For safety, an automatic dump relay is used to discharge the reservoir capacitor if an interlock is triggered. Interlocks also control the Glassman charging supply. None of the systems can be energised until the manual key interlock switch is opened.

IMPLEMENTATION

For this application the power supply is mounted on a 65 kV high voltage platform as shown in Figures 1 and 2. This allows the beam to be extracted to 25 keV then further post accelerated by 40 keV to 65 keV. The Glassman power supply requires a three phase supply and the rest of the equipment a single phase supply. To achieve this two separate oil-filled 65 kV isolation transformers are required, these are shown in Figure 2.

In the event of a post acceleration gap breakdown the extraction power supply becomes shorted across the 65 kV DC platform power supply. To prevent damage to the extraction power supply, a protection electrode sits just in front of the ground plane electrode of the post acceleration gap [1]. In the event of a post acceleration gap breakdown the current between the two power supplies is limited by a 750 kΩ resistor.

The downside of the 1 mA quiescent current in the tetrode is that significant levels of x-rays are produced in the tetrode via bremsstrahlung. Lead sheet is used to shield the inside of the 19 inch rack around the tetrode to bring the externally measured radiation down to background levels.

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RESULTS

The extraction power supply has been succesfuly tested with a running ion source. Figure 4 shows a 23 kV, 2 ms, 50 Hz extraction voltage pulse extracting beam from a 50 A 2.2 ms, 50 Hz ion source discharge. During the conditioning process there were mutiple breakdowns between the ion source aperture plate and the extraction electrode. The breakdowns did not cause any problems for the extraction power supply which continued to operate normally.

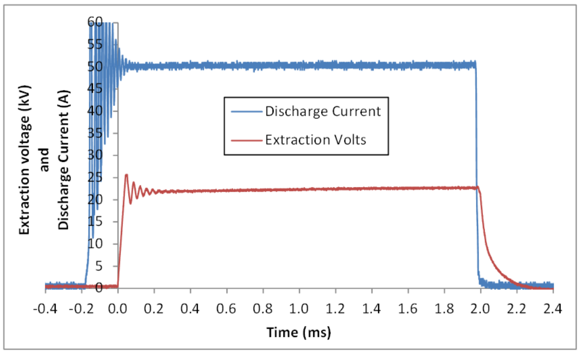

Figure 4: A 23 kV, 2 ms 50 Hz extraction from a 50 A, 2.2 ms, 50 Hz ion source discharge.

Figure 5 shows extraction voltage pulse regulation for a range of different voltages. The component values in the analogue control circuit have not been optimised; this results in the slight rise in voltage during the pulse. The component values also limit the maximum voltage obtained to 23.8 kV. Figure 6 shows the corresponding extraction currents when extracting from a a 50 A 2.2 ms, 50 Hz ion source discharge.

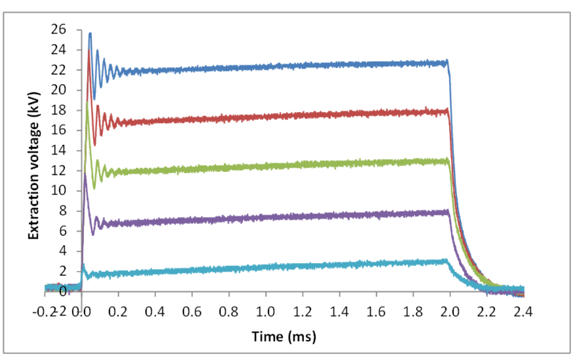

Figure 5: 2 ms 50 Hz extraction voltage pulses of various amplitudes.

The peak reservoir capacitor charging current shown in Figure 7 never went above 50 mA. This shows there is plenty of spare capability in the charging power supply.

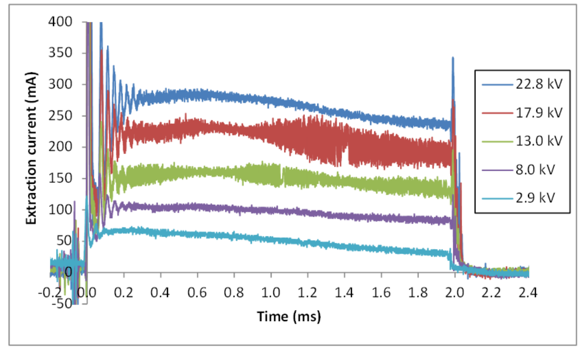

Figure 6: Extraction currents for different extraction voltages at 2 ms 50 Hz extraction from a running ion source.

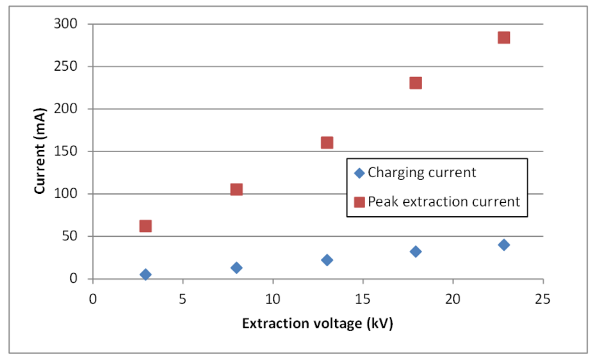

Figure 7: Peak pulsed extraction currents and reservoir capacitor DC charging currents for different extraction voltages at 2 ms 50 Hz.

SUMMARY AND OUTLOOK

The extraction power supply has demonstrated that it is capable of meeting the 2 ms, 50 Hz duty cycle requirements. The analogue control system and tetrode tube technology is very robust and can withstand breakdowns on every pulse. The supply is able to condition the ion source extraction electrodes without any problems.

Minor component value modifications to the voltage regulation circuit will allow completely flat extraction voltage profiles without the slight rise shown in Figure 5. The same component modifications will also allow the full 25 kV specification to be met. When these modifications are complete it to should be possible to achieve 30 kV extraction voltages.

REFERENCES

[1] D.C. Faircloth et al., "The front end test stand high performance H− ion source at Rutherford Appleton Laboratory", Review of Scientific Instruments, Volume 81, Issue 2, (2010).
[2] http://www.rell.com
[3] http://www.covimag.fr/

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