HIGH VOLTAGE TERMINAL IN COSY ELECTRON COOLER

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Abstract

In Budker INP SBRAS was developed electron cooler with energy up to 2MeV for COSY accelerator (Germany). Due to restricted footprint, cooler's collector and gun parts were combined in a single acceleration system – high voltage terminal. All power and control electronics were placed in a single isolated volume, filled with SF6 gas under 4-6 atm. pressure. Electronics is controlled via wireless CAN, and powered by multistage transformer, capable of 15 kW power at 26 kHz. Wireless control is passed through dedicated optically transparent window, also served for modulated laser beam, used in electron beam diagnostic. By construction, electronics is divided on two standalone units: collector power supply and gun-filter system (SGF). SGF is built on 19" EuroPak chassis, where were placed all power modules, needed for collector and gun pipe electrodes. All power outputs were protected against overvoltage and sparks, available while cooler exploitation. In SGF there were controlled up to 40 parameters altogether. SGF inner power supply provides stable operation in wide range of input voltage, up to +/- 50% from nominal. Also included in SGF are 2 auxiliary systems, used for beam guiding and beam diagnostics.

INTRODUCTION

High Voltage Terminal (HVT) in electron cooler is intended for generating of electron cooling beam and collecting the beam back, producing thus continuous up to 3A electron current. Due to this task, it consists of:

- Gun of electron beam, including cathode, anode and 4 control grid electrodes.
- Collector of electron beam, including collector, suppressor and 2 Wien filter electrodes.

Both grid and collector bodies are encircled with a number of magnetic solenoids intended for shaping a proper magnetic field profile inside. Also measurement of the collector current and the so-called leakage current should be provided. HVT has an outer metal shielding cap with smooth rounded shape, intended for uniform voltage distribution under high voltage circumstances. Powering of HVT electronics is provided by cascade transformer, that is a part of accelerator column, with output voltage varying in wide range of 400 – 800VAC at 26 kHz frequency [2]. Accelerator column itself provides up to 2MV negative acceleration voltage, so HVT chassis ground is under this voltage too.

The electronics needed for providing power supply (P.S.) for HVT electrodes and solenoids is divided on 3 separate units. The most power consuming is collector power supply, with up to 15KW output power, therefore it was designed as standalone unit equipped with an oil force-cooling system. Another unit, housing magnetic solenoids power supplies, is situated at opposed to collector power supply side on HVT chassis. The remaining electrodes power supplies are united in the third unit, named Gun-Filter System (SGF), it is mounted on top of the second unit. Each unit was developed by the different developer; we will focus from now on mainly on SGF unit.

SGF UNIT DEVELOPMENT

SGF power supplies detailed specifications are summarized in Table 1. Besides power supplying, the following additional requirements are imposed for SGF functioning:

- Each of 4 grid electrodes can be modulated individually with 3MHz sinusoidal wave at regulated amplitude from 0 to 8Vrms.
- Computer control of the whole cooler system is based on CAN protocol.
- Collector power supply unit control requires CAN control with optic fibre transport.
- Collector and leakage current should be measured by means of voltage drop on the corresponding resistors given.
- The collector to cathode return current is passed via HVT chassis.

Table 1: SGF Power Supplies Specifications

Name	Uout, Iout	Tolerance
Anode	0…+10kV, 1,5mA	0,1%
Suppressor	-3…+5kV, 3mA	0,1%
Control grid	-3…+5kV, 3mA	0,1%
Filament	+7…+25V, 5A	1,0%
Wien filter x2	0…+30kV, 1mA	0,1%

Connections requirements

The layout of collector and gun on the HVT chassis is illustrated in Fig. 1. Note how the electron return current (shown in red colour) flows on the chassis. Taking into account that the material of chassis is stainless steel, and the current value is up to 3A, care must be taken to eliminate unexpected voltage drops in control paths, because both gun and collector electrodes (shown in blue colour) are powered from a single unit (SGF), which is electrically and mechanically connected to the same chassis. Due to high risk of damage because of high voltage breakdowns and uncontrollable discharges, all electrodes power supply's return paths must be of low impedance, that is achieved by 10kV rated coaxial cable used for all electrodes except Wien filter electrodes. Those are to power with a voltage up to +30kV, so an appropriate shielded cable could not be used. Instead, a

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high resistance (1kOhm/m) unshielded cable was used, with an external flexible shield manually enveloped.

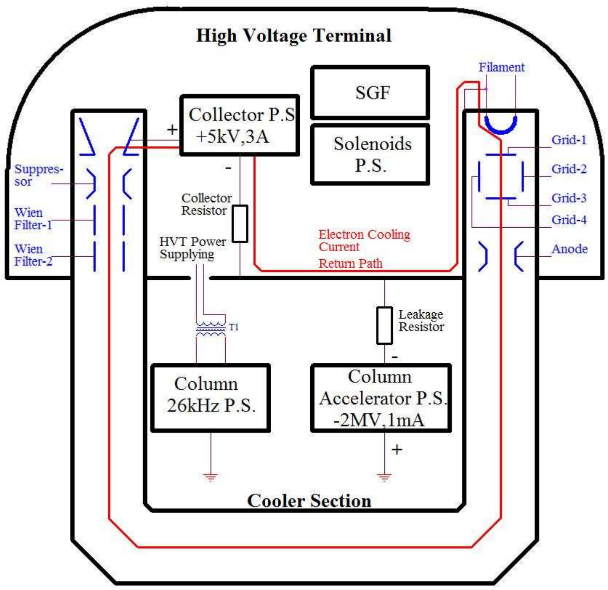

Figure 1: Position of High Voltage Terminal in COSY electron cooler.

A special attention was paid to cathode ground connection. The cathode implemented in gun is of filamentary type, with MHV-type sockets used as input pins, both isolated from ground. Since both collector return current and filament current (which are of the same order of magnitude) flow across a single pin, a special decoupling scheme was applied, using BNC T-connector and a zero resistance BNC terminator on one side of it. Furthermore, to eliminate chassis voltage drop, a phantom filament powering was implemented, withstanding up to +/-10V voltage output shift.

All high voltage electrode (except Wien filter electrodes) cables are connected to SGF face panel by means of LEMO high voltage sockets, and Wien filter cables are permanently fixed to SGF face panel. This provides more safety and reliability when routing high voltage cables in HVT.

Structural Considerations

Block diagram of SGF inner structure is shown in Fig.2. Input power AC voltage is down transformed to the value, which after rectifying is related to input voltage as follows: 400V set on control program's panel is corresponded to 40V DC of inner voltage, when no load is applied. The inner voltage is used by a number of DC/DC converters to produce all specified output voltages, along with +5V power supply for control modules. The DC/DC converters used have extra wide input voltage range of +18…+72V, it suited well to input voltage significant instability when all the system is under a load. But there can be situations, when input voltage exceeds the rated voltage. At this case, the overvoltage protection module shuts off the supplying DC/DC converters line at the level of +75V; in case of further increase to +150V level, the supplying line is forcedly shorted to ground, causing the fuse break.

Another protection channel monitors the leakage current. If this current exceeds 0,9mA, that indicates that the electron beam surely leaks to ground, anode voltage is forced to zero, and grid voltage is forced to -3kV to stop the electron current. This state is latched, and reset afterwards manually.

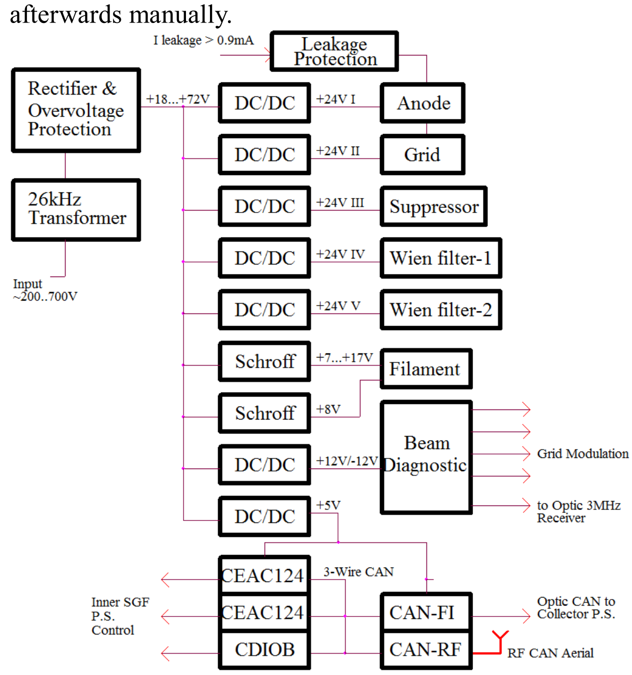

Figure 2: Block diagram of SGF.

All SGF output power supplies should have an output current control. In case of Wien filter power supplies, the MATSUSADA +30kV/1mA DC/DC converter fully satisfies this demand. At all other cases, a special schematic was used, illustrated in Fig.3.

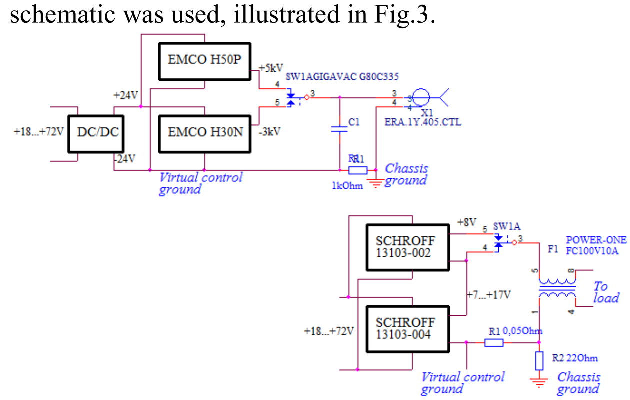

Figure 3: Output stages with current sense resistor.

On the top, the grid and suppressor output stage is shown, where two EMCO type DC/DC converters get isolated from ground +24V power supply. Positive or negative output is selected with a high voltage GIGAVAC type relay, after RC-filtering it connects to high voltage LEMO type output socket. Socket's case is mounted on grounded SGF face panel. The load current returns back across 1kOhm resistor, producing the voltage drop to measure. The similar is output stage of filament power supply, there output voltage is selected from either a

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single regulated SCHROFF type DC/DC converter, or a sum of two converters; this approach gives a full +7…+25V output voltage range. High current (10A) output T-filter of POWER-ONE type effectively protects the output stage. To prevent the collector current leak into this circuit, as it was mentioned above, all output stage was isolated from ground, thus resembling phantom power supply, only single 22Ohm resistor ties negative output to ground to give the control function properly. Chassis current flow can run across this resistor, resulting in voltage shift that can be allowed up to +/-10V.

Beam Diagnostic and Control

To couple the high voltage grid power supply output and beam diagnostic outputs with four grid electrodes, a summing schematic, shown in Fig.4 is used, where 50Ohm low impedance modulator signals are decoupled with high voltage capacitors.

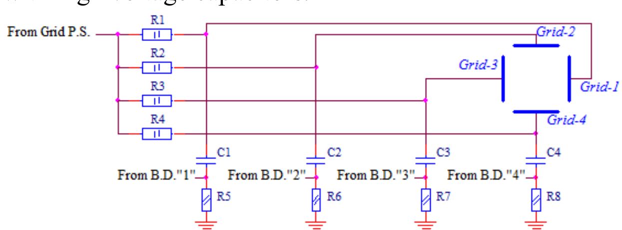

Figure 4: Feeding four grid electrodes.

Taking into account the low output impedance of grid power supply output at 3MHz frequency, channel-to-channel grid separation is better then 1%. Synchronising 3MHz signal the beam diagnostic module gets by a remote optical receiver, attached near inner shield cap window. The laser diode transmitter is situated on the matched outer shield cap window.

All the SGF control is concentrated in 3 modules: two widely used in BIMP DAC/ADC converter modules of CEAC124 type, and one CDIOB input/output register with extended functionality. These are CAN-controlled modules, so along with collector CAN-controlling it was a task to deliver CAN to HVT high voltage potential. The solution was made to use one wireless CAN module in SGF, while another wireless CAN module is fixed near the outer shield cap window. Both modules are of Agilion manufacturer. The distance of 50cm between them provides good reliability in communication. To provide the collector power supply with optic CAN, CAN-FI wired-to-optic CAN translator was used. The advanced control, provided by CEAC124 modules, gives wide opportunities to monitor all parameters of SGF modules.

Fig.5 illustrates a screenshot of the control program, where available are for every power supply: programming the output voltage, monitoring the output voltage by high voltage divider and from dedicated high voltage DC/DC converter output, monitoring the output current. Collector and leakage current values are shown in "Collector" tab. The beam diagnostic control is shown in corresponding tab too. Additionally, all inner voltage lines and temperature level inside SGF unit are monitored under "AUX PS" tab.

Figure 5: A screenshot of SGF control program.

SGF Design

For placing all the modules used in SGF, the SCHROFF EuroPak was chosen; it is the metal case with a standard 19inches wide, 6U height and 160cm depth dimensions. All the heat producing DC/DC converters were placed on the back panel, serving as heat radiator; heat dissipation of the modules is equalized by the natural convection of gas inside HVT volume. The SGF unit with all modules installed is shown in Fig.6.

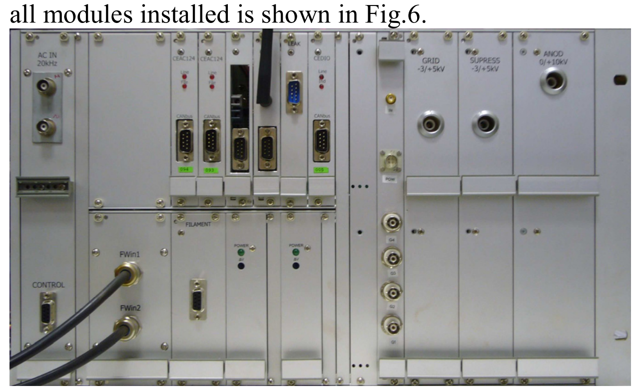

Figure 6: The SGF unit front panel.

All cables except Wien filter cables are detachable. Both leakage and collector current signals are handled in a dedicated module, where low-pass filtering and clamping is applied.

RESULTS

Thorough testing of all cooler electronic systems in BINP showed that SGF unit can successfully withstand high voltage breakdowns up to 1,6MV while staying in good condition. Temperature level inside SGF unit is not exceeds 60° C at 5 days continuous cooler test under unconditioned room environment. Input voltage working span of +200V…+600V was confirmed.

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