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THE HIGH VOLTAGE SYSTEM FOR THE HIGH INTENSITY CERN PROTON SOURCE

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Abstract

For the RFQ injector mounted on the CERN 50 MeV proton linac, the source needs to provide about 300 mA of 100 keV beam in pulses of 20 to 150 μs at 1 Hz. Although the high voltage supply is fairly conventional, a number of measures had to be taken to ensure not only the reliability of the source electronics, but also other equipments installed in the near vicinity. In view of the high current demanded from the source, a new and very simple form of beam load compensation was developed to stabilize the preinjector voltage to values acceptable to the RFQ.

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For the RFQ injector mounted on the CERN 50 MeV proton linac, the source needs to provide about 300 mA of 100 keV beam in pulses of 20 to 150 µs at 1 Hz. Although the high voltage supply is fairly conventional, a number of measures had to be taken to ensure not only the reliability of the source electronics, but also other equipments installed in the near vicinity. In view of the high current demanded from the source, a new and very simple form of beam load compensation was developed to stabilize the preinjector voltage to values acceptable to the RFQ.

1 BACKGROUND

The original 750 kV preinjector for the CERN Proton Linac (Linac2) used a Cockroft-Walton (C-W) high voltage supply with dynamic beam load voltage stabilization [1]. In 1993, this injector was replaced by a Radio Frequency Quadrupole (RFQ) system whose injection energy was 90 kV. This voltage was chosen to be close to that of standard commercial high voltage power supplies whilst still allowing a small margin for injector column conditioning.

The ion source is a standard CERN Duoplasmatron with the steel body adapted to the length of the injector column. This two-section column uses two porcelain rings 300 mm diameter by 60 mm thick which were recovered from parts of the original CERN Linac1 preinjector [2]. The porcelains are glued with Araldite to the end flanges and an intermediate disk, which is fitted internally with a stress relief electrode. Corona plates which also carry bleeder resistors complete the assembly.

Source supplies and controls were installed inside the Faraday cage in open racks supported on polyethelyene insulators. This assembly gave a very compact system at a location where space was at a premium, whilst also allowing easy access for maintenance. The minimum clearance between racks and the cage is about 330 mm.

Following problems with backstreaming oil vapours from turbopumps on the RFQ test stand, virtually oil-free magnetic bearing turbopump systems were adopted to pump the high hydrogen load.

2 HIGH VOLTAGE SYSTEM

For the operational injector a modified standard commercial high voltage supply was chosen. The supply was specified for 120 kV, 1.2 mA with a current limiting mode and modified for interlock and control purposes. High voltage was led into the Faraday cage via a length of RG218 cable.

Figure 1 shows the layout of the high voltage system which can probably be described as fairly conventional. During off-line tests of the RFQ, a 100 nF capacitor was used as an energy reservoir to maintain the voltage during the beam pulse. As this did not give rise to problems, it was adopted for its simplicity for the operational machine. A single point earth very similar to that used on the test stand was also installed. It soon became obvious that the selected earth point had been badly chosen as HT flashovers often resulted in trips of the vacuum pump electronics (and other power supplies).

A new star point was found which resulted in a complete elimination of the problems with the vacuum pump controllers although there are still occasional problems with power supplies latching up.

Flashovers are detected and cause the HT reference to be automatically reduced to a low value. A programmed ramping of the reference then takes place bringing the voltage back to normal after about one minute. During this time the source is inhibited until the HT has reached about 95% of the nominal. Depending on the weather the typical flashover rate varies from zero to about five per week. An additional interlock is provided to protect the system from the consequences of bursts of flashovers.

The control interface between ground and the source racks in this system has always been via fibre optic interfaces. Originally, it was based on a Camac serial loop. Now, in order to economize rack space, to reduce maintenance costs and to prepare for the obsolescence of certain Camac modules, an industrial based CAN bus controller interfaced to the ground level VME is in use [3]. Present experience has shown this to be rather resistant to the consequences of HT flashovers.

3 BEAM LOADING COMPENSATION

The original C-W set had stringent requirements for voltage stability. Fortunately, the RFQ is much more tolerant in its requirements for injection energy stability.

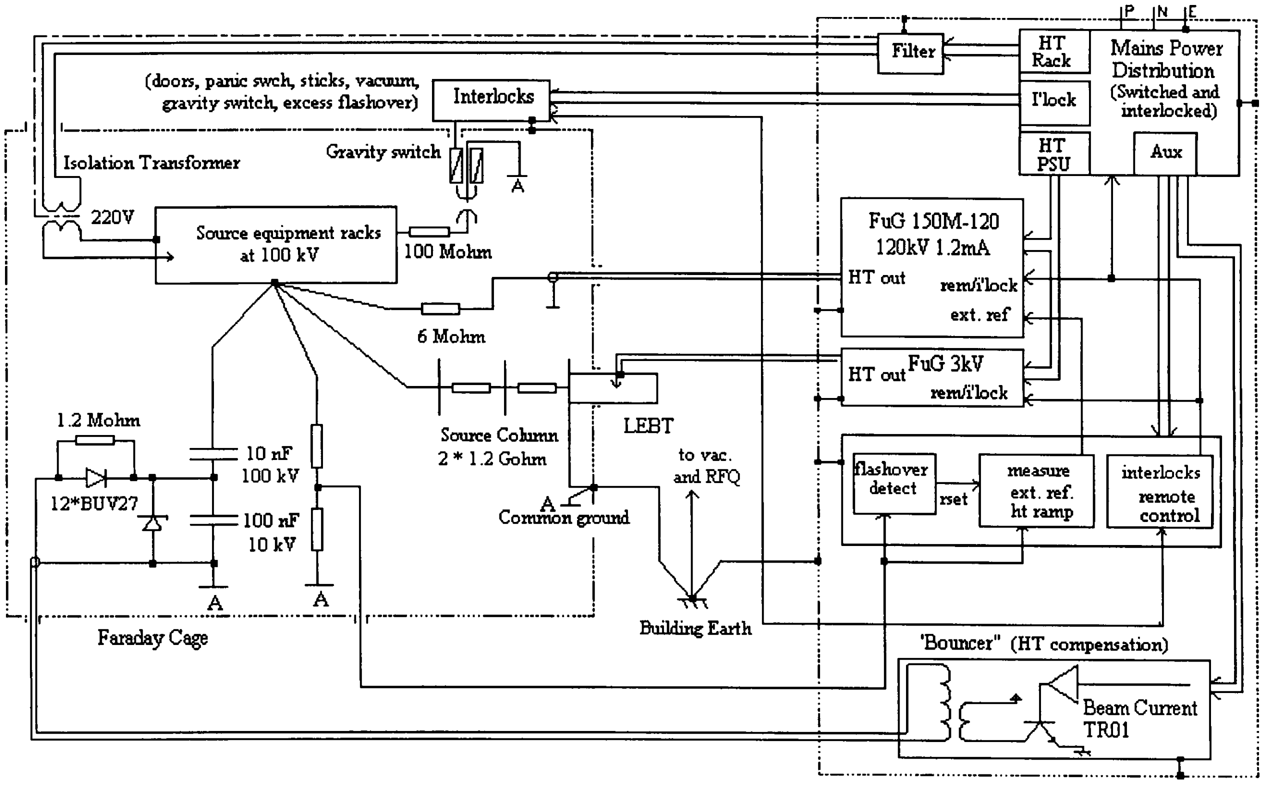

Figure 1: Schematic layout of the High Voltage system

With the chosen power supply, passive energy storage with a 100nF capacitor could maintain the voltage for the 120 µs beam to within 0.5%. However, with the desire to reduce the stored energy of the system, a simple active compensation scheme was developed.

If capacitor (C2) in Fig.2 is charged at constant current, the voltage at its high terminal increases linearly. It is then only necessary to arrange that the increase in voltage compensates the fall due to beam loading on the system capacitance. For a beam of constant intensity and length, a square pulse synchronous with the beam would be suitable to charge the capacitor.

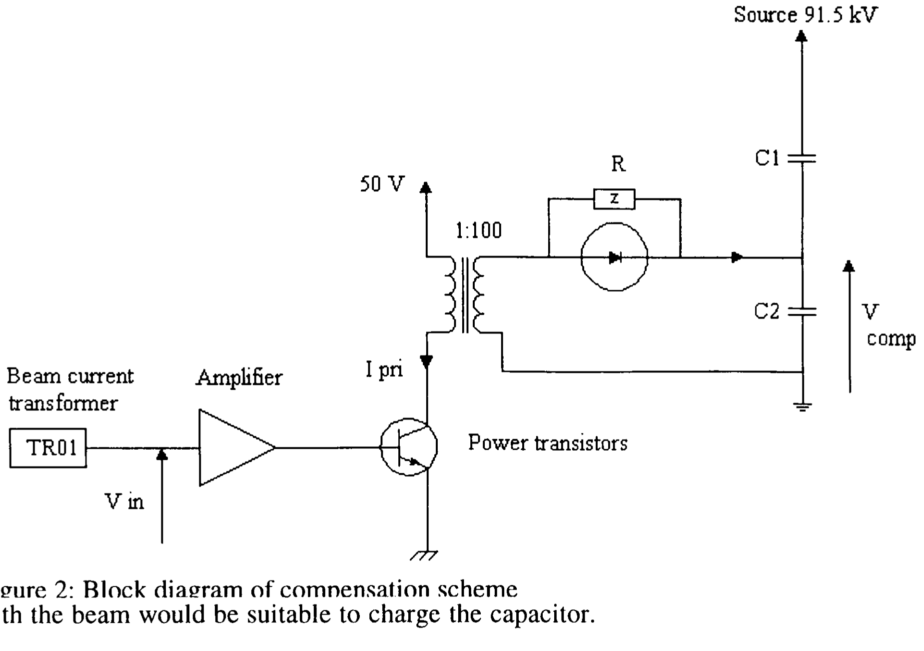

Figure 2: Block diagram of compensation scheme

Unfortunately, at CERN pulse to pulse modulation of the beam length is used to provide only the number of protons that are actually demanded by the user. This results in the proton pulse length varying from 20 to 150 µs.

A beam transformer downstream of the source provides a quasi square wave signal which reflects both the intensity and length of the beam pulse. This signal is amplified in a transistorized power amplifier which drives a 100:1 pulse transformer. The output pulse of the transformer charges capacitor C2. Typically, the primary current is of the order of 300 A. Figure 3 shows the HT with and without beam load compensation for a source current pulse of 300 mA (trace 2), with a useable length of 92 µs.

Figure 4 shows laboratory measurements on the system for a simulated beam of 300 mA and the linear rise of the voltage at C2 can be clearly seen for a constant charging current (traces 3 and 2).

The transistorized power amplifier consists of 240 BUV27 transistors in parallel made up into eight removable modules and is placed between the pulse transformer and ground, the high side of the transformer being connected to the supply rail. A RG213 cable 6 m long connects the secondary to the capacitive divider. After the passage of the beam, C2 is discharged through the resistor R in preparation for the next cycle. In the laboratory the compensation has run at up to 5 Hz but could probably run at a higher frequency.

Fine tuning of the compensation is achieved by trimming the gain of the preamplifier and the high voltage can be maintained to better than 0.1% during the passage of the beam (trace 1 Fig 3). Apart from amplification of the beam current signal no other treatment of this signal has proved necessary.

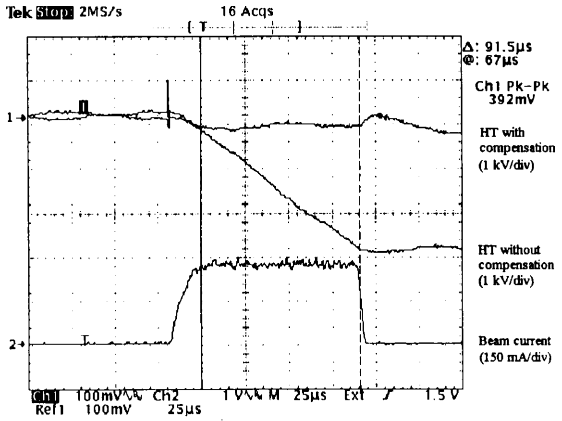

Figure 3: Comparison of high voltage stability with and without beam loading compensation.

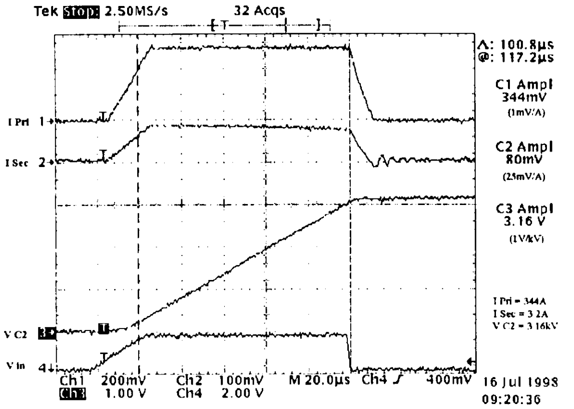

Figure 4: Voltage and current waveforms at key points in Fig.2 under simulated operation at 1 Hz.

4 RELIABILITY

Reliability of the injector is of prime importance, especially with the increasingly longer operational periods now becoming common at CERN. In 1998, the longest continuous period will be of 29 weeks. For the systems described here, the commercial power supplies have shown themselves to be particularly reliable and it has proved to be of great advantage to use a current limiting HT power supply. After a particularly severe flashover which caused some damage to the accelerating electrodes in the HT column, current limiting enabled the problem to be diagnosed quickly without repeated tripping of the high voltage.

Surprisingly, the transistorized drive amplifier for the beam loading compensation has not suffered any failure in its six years of operation. However, the main problems experienced to date concern the pulse transformers. Although specified for the required service in consultation with, and manufactured by, industry, they have suffered internal insulation failures. Investigations showed that the insulation was inadequate and badly designed. To overcome this problem, the transformers are being rewound “in house”.

The high voltage system and the beam loading compensation now meet the requirements of simplicity and reliability. In the near future, as new modules pass flashover immunity tests, it is intended to replace the residual Camac and NIM based cards to Eurochassis standards thus eliminating obsolete, ageing and expensive equipment.

5 REFERENCES

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