THE COMPENSATION FOR BEAM LOADING ON THE PREINJECTOR OF THE NEW CERN 50 MeV LINAC

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Summary

The original two-tube bouncer built by Haefely has been replaced by a single tube bouncer featuring a simpler and cheaper design, without compromising on the precision of the HV regulation. This paper describes the basic design and construction of the new system, putting special emphasis on reliability and ease of maintenance.

Introduction

The problem of HV beam loading compensation for pulsed beams is well known, but technical problems and solutions can be quite different. The first approach at CERN was a programmed compensation using a triggered spark gap. In 1970, a compensation with feedback and regulation with a series tube had been installed.[1] For the preinjector of the new linac, the HV compensation was built by Haefely. It had to cope with currents of up to 400 mA, a pulse length of up to 200 μs (the maximum charge being limited to 50μC), and a repetition frequency of up to 2 Hz. The Haefely bouncer used a two-tube configuration and a 1 MHz carrier frequency to drive the grids. Its performance was within the specification (5×10^{-4}) but its reliability caused problems. Especially, the 1 MHz rectifying diodes caused several breakdowns and were difficult to replace. The main parts of this bouncer, i.e., the 100 kV supply, the two tubes, their filament transformers, the 1 MHz transformer and the rectifying diodes, were housed in a big oil-filled steel tank. Just to undo the bolts and lift the top cover with a crane took a very long time.

The new bouncer construction

It was decided to completely rebuild the bouncer, simplifying it and paying special attention to ease repairs. It was clear that only an open construction could satisfy the last condition, because only then would it be possible to have immediate access to a faulty component. It was also clear that two tubes (one only for reducing the 5 kHz ripple from the Cockroft-Walton generator) are not at all necessary, as we (like other people too) were already accepting an initial transient of some 10 μs. The value of the HV between beam pulses is completely unimportant; what matters is just the value during the beam time. This means that one single tube to "bounce up" the HV is completely sufficient. All one has to do after the beam has started, is just to wait until the HV drops down to a level, which is equal to or smaller than the minimum reached, due to the presence of the ripple before the beam pulse. Only then the compensation should start and keep the HV constant.

As can be seen from Figs. 1 and 2, the large high-voltage, high-μ triode(ML 7668) sits in an air-cooled, oil-filled copper and glass reservoir. The design of the reservoir radiator is closely based on that of the earlier device used for many years on the old linac,[2] and which has the useful fail-safe characteristic of maintaining the oil temperature below the critical value in the event of a ventilator failure. For the new device, a 12 mm-thick lead glass (∿30% PbO content) cylinder serves as the insulation between the anode and cathode sides of the reservoir. This helps to reduce the X-radiation emitted by the triode, which can be a hazard for personnel working close to the device during testing and setting up. It was not possible to find a supplier of such a cylinder with a higher PbO content. Since the triode is mounted with the anode down, forced circulation of the oil is not necessary to remove the 365 Watts generated in the tube filament. The power dissipated during the beam pulse is, of course, negligible with a duty cycle of 10^{-4}. For the electrical connections on the tube, standard rf type finger contacts are used, inserted in special housings, to avoid any undue mechanical stresses on the glass envelope.

The whole assembly of triode, reservoir and electronics, plus anti-corona housing or dome, is mounted on three standard HV insulator legs of the kind used on some electricity transmission lines. These have proven reliability, great strength and low cost. The large alloy disc which serves as the anode connection to the triode and support, is screened from the cathode side of the reservoir by means of the large impregnated glass fiber insulation disc. The main storage capacitor of 80 nF, is of a dual dielectric plastic film double-paper type, capable of repeatedly accepting short-circuit conditions at the full voltage of 100 kV, without damage.

The 100 kV HV source being used is a home-built Cockroft-Walton generator also of open air construction for easy accessibility. The rectifier assemblies are made from 15 controlled avalanche-type diodes in series with alternate limiting resistors, each set being cast in araldite. The voltage rating of each set is >10 kV and they screw together easily to form assemblies of higher voltage ratings. These diode assemblies have proved very reliable in the past on other HV equipment.

All the HV resistors used, such as the 5 MΩ on the bouncer output, are constructed from chains of low inductance carbon resistors, selected for their reliability and stability. The soldered chains are enclosed in standard PVC tubing and wound on plexiglass support tubes. Although plexiglass is not the best material under high voltage arcing conditions, no problems have been found yet and are not expected, due to the "over dimensioning" of these components. The individual resistors in each chain are operating well below their rated voltage and current/power values.

The 5 MΩ resistor assembly, in parallel with the output of the bouncer serves as the high voltage side of a resistor-divider network for measuring the output voltage and I_K, the cut-off current of the triode.

After some months of operation, it has been noted that the ML 7668 shows an increase in leakage current, but according to the manufacturer, this is probably normal and should not exceed 1 mA eventually.[3]

Also across the output is a diode chain, identical to those used on the 100 kV generator, and a spark-gap. The spark gap and diode chain protect the triode, etc., from overvoltage during any HV flashovers on the 750 kV column. Extensive double screening is also employed at many points in the circuit for the same reasons. The 50 Hz/220V power for the electronics in the HV "dome" is provided by a 1:1 isolation transformer, rated at 1 kW. In the apparatus working at present and shown here, an epoxy-insulated, commercially supplied unit has been used with no problems to date. An alternative oil-insulated type, has also been purchased and will be tested on a second version of the compensation. A HV breakdown in the epoxy transformer would probably be impossible to repair, whereas an oil-filled type can be opened and rewound if necessary. It remains to be seen which type will prove to be the more reliable in the long run.

Electronics

Figure 3 shows the block diagram of the bouncer circuit. Except for the final stages in the power amplifier, all the other amplifiers are solid state but protected adequately against possible transients due to HV breakdowns of the column. A special feature is the signal transmission to the grid of the HV tube via a commercial current transformer, sitting in an oil bath. From this side there is no bandwidth limitation as given by the modulation of a 1 MHz carrier frequency. The first amplifier (high input impedance amplifier) has a built-in threshold, acting in the sense described above, to guarantee stable HV without suffering from the residual ripple. To avoid the 5 KHz ripple having too much influence on the amplifier chain, some attenuation of low frequencies is included. Nevertheless, the presence of the 5 KHz signal in this scheme is a limitation to the possible gain of the whole loop. If the gain is too large, too much current is drawn in parts of the electronics which are made for pulsed but not continuous operation. In order to achieve even larger gain and better HV compensation a gated amplifier has been built (Fig. 4), to replace the first amplifier in the chain. Tests are not yet completed, but it is already possible to beat the performance of the previous system. The basic principle is to open an analog gate when the HV voltage, due to the beam, drops below a certain level and to close the gate again with a trigger from the external timing system. Thus it is possible to use a higher gain without overloading the amplifiers with the continuous 5 KHz signal. Also the bandwidth of the system can then be adjusted more easily with a variable filter.

CONCLUSION

This bouncer has been in operation for about six months without any fault on the larger components, so there was no occasion to prove the ease of repairs. The stability is within the specification. Further improvement is expected from the use of the gated amplifier. The use of only one expensive HV tube will largely reduce the maintenance costs.

ACKNOWLEDGEMENTS

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REFERENCES

1. F. Chiari, R. Dubois, "Preinjector experimental Hall Sud, Faisceau de protons à 500 keV de longue durée - 100μsec." MPS/LIN Note 70-6.

2. R. Dubois, "Compensating the drop in accelerating voltage caused by the beam by means of an electronic servo system", CERN/MPS/LIN 71-9, 1971.

3. Communication between M.D. Crepin, Commissariat à l'Energie Atomique, Dép. Saturne, Saclay, and the Machlett Laboratories, Inc. USA, Apr. 23, 1970.

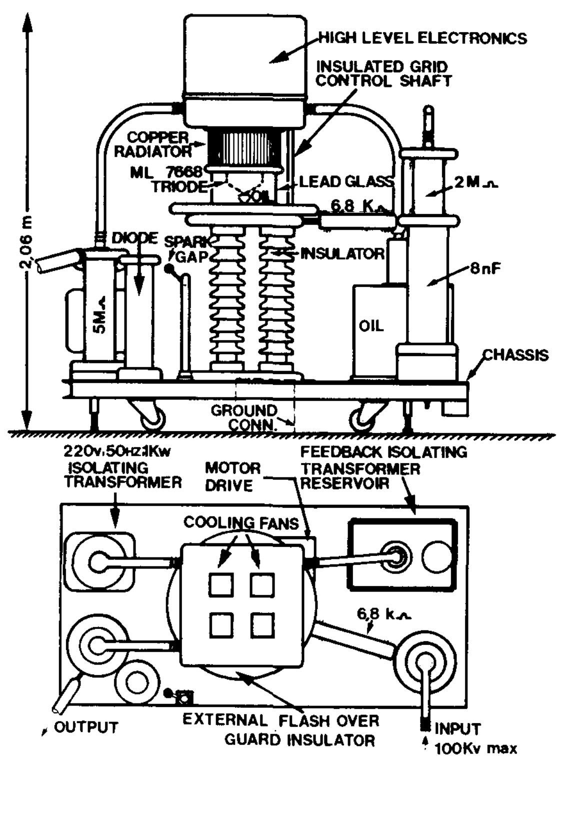

Fig. 1 Side and plan views of the bouncer

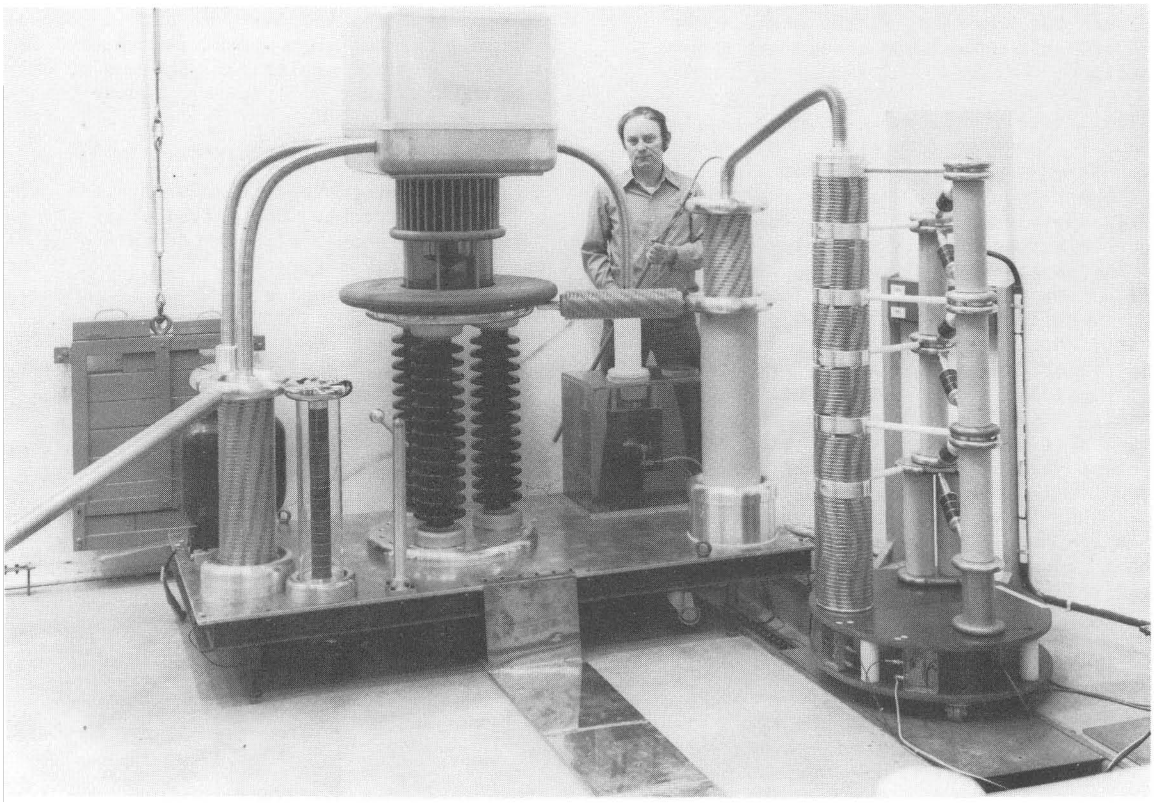

Fig. 2 Bouncer and 100-kV generator

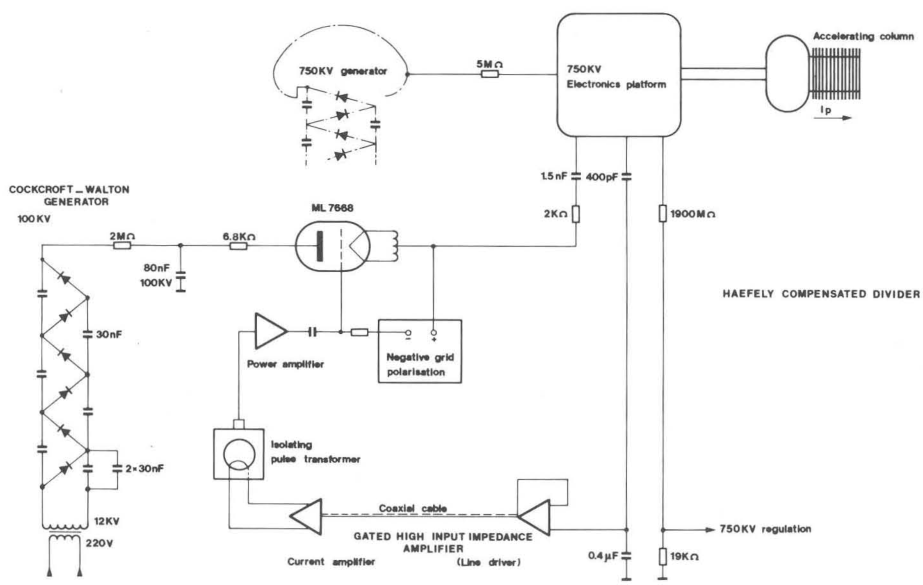

Fig. 3 ` Bouncer circuit (schema)

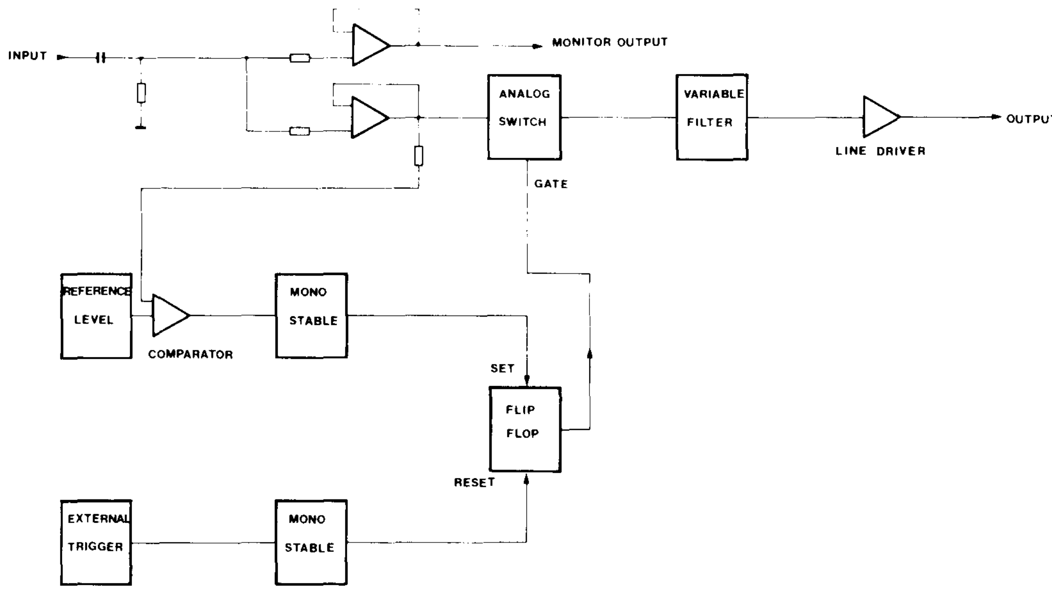

Fig. 4 Gated high impedance amplifier