STABILISING THE VOLTAGE OF THE DC ACCELERATING COLUMN OF THE ISIS PRE-INJECTOR USING A BEAM CURRENT CONTROLLED 'BOUNCER'

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ABSTRACT

To prevent the EHT supply tripping on overcurrent after an electrical discharge in the accelerating column and thus allow rapid recovery of the accelerating potential, the limiting resistor value has been increased. This resistor which connects the reservoir capacitor to the high voltage platform has been changed from 10kΩ to 1MΩ. The now excessive sag on the accelerating voltage, resulting from beam loading is compensated by 'bouncing' the voltage at the base of the reservoir capacitor. The Bouncer, operating in an extremely electrically hostile environment is fully remote controlled with automatic control of the Bouncer pulse provided by feedback from a beam current toroid. The paper describes the design of the system and covers such factors as reliability, electrical safety interlocking and oil cooling as well as satisfying the required performance specifications.

1 INTRODUCTION

On the ISIS pre-injector H^- ions are accelerated from the ion source by a 665 kV negative DC potential, generated by a 10 stage Cockcroft-Walton type multiplier. During the beam pulse the accelerating potential, under the influence of beam loading, tends positive by a value proportional to the value of a current limiting resistor between a reservoir capacitor and the ion source platform. The accelerating column has suffered from repeated electrical breakdowns that trip the EHT power supply on overcurrent. The incidence of spurious breakdowns has been reduced to about ten a day on average.

To minimise ISIS beam off time the susceptibility to breakdowns of the power supply has been reduced and the recovery time shortened considerably. The main factor in reducing the susceptibility to breakdown has been the factor of ten increase in the current limiting resistor value.

The increase in the current limiting resistor resulted in too much energy spread in the accelerated beam due to the larger potential droop produced by the beam loading. The ISIS pre-injector 'Bouncer' has been developed as a method of stabilising the accelerating potential against the effects of beam loading.

2 BOUNCER PULSE AMPLIFIER

2.1 EHT Circuit

The circuit of the EHT supply is shown in Figure 1. The beam pulse removes electric charge from the reservoir capacitor through the new 1MΩ current limiting resistor. This can be restored by 'bouncing' the base of the reservoir capacitor with a negative going pulse. The amplitude, shape, width and position in time of the pulse determines the stability of the accelerating potential.

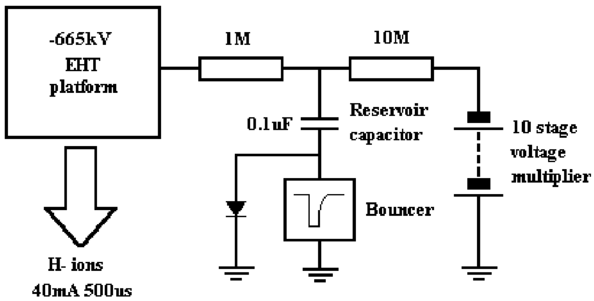

Figure 1 - EHT power supply circuit

2.2 Bouncer output stage

The heart of the system is a high voltage pulse amplifier that uses a Thomson TH5184 oil cooled tetrode [1]. At an anode voltage of 60 kV and 50 Hz repetition rate. This gives a maximum output pulse capability of 55 kV for 330 μs without exceeding the maximum anode dissipation of 1 kW. The tube is mounted in a electrically and mechanically interlocked oil filled container that also contains the main components of the output stage along with earthing and energy dumping switches. The output is capacitively coupled to a base plate on the reservoir capacitor with a high voltage diode to prevent positive excursions and a spark gap to protect the amplifier. Resistor chains provide a high impedance path from the plate to ground to bias the base-plate.

2.3 Power supplies

All the power supplies for the system are mounted in a 19” rack adjacent to the pulse amplifier tank in the ISIS pre-injector EHT area. The TH5184 control grid bias, screen grid bias and anode power supplies are commercial units with remote control/monitor facilities. Filament power to the tetrode is from an in house designed 7.2 V ±2% at 20A voltage regulated supply. This has automatic ramp-up capability with overcurrent and monitoring facilities as integral features. The filament regulator also controls the main power interlocks.

2.4 Drive signal and feedback

The Bouncer can be driven in two modes, manual or automatic. In the manual mode, a pulse of adjustable amplitude is sent to the grid driver unit. The timing of this gate pulse is also adjustable from the main control computer. The platform voltage sag can be tuned out by using the platform voltage signal as a reference. In automatic mode the output from a beam current toroid immediately downstream of the dc accelerator is used to give a signal that is related to the charge drain on the reservoir capacitor. The use of negative feedback removes the need to adjust the gain and pulse parameters. A differential signal is used to transport the drive pulse the 100 metres to the control grid driver unit, which is in the forward path of a local negative feedback loop from the bouncer output. This sets the gain of the amplifier and reduces the susceptibility to oscillation. Feedback is provided from a commercial potential divider, which also provides an output monitor signal.

2.5 Controls

The Bouncer system has been designed to be simple to operate, having only one button for switch on in normal running conditions. Operation of the switch automatically opens the energy dump relay and all the supplies are automatically and sequentially switched. Remote indication of power supply settings and interlock status are provided and a signal patching network is included for remote diagnostics.

2.6 Interlocking and safety

The system is interlocked for both personnel safety and correct method of operation by both electrical and mechanical systems. Shutting down the equipment automatically operates energy dissipation and charge leakage systems.

Access to the oil bath for inspection or tube replacement can only be achieved with all earthing devices ON and the main power supplies OFF. A 'key' operated test facility allows local operation of the system, but special safety precautions must be observed.

2.7 Oil cooling

The oil filled container has a capacity of $1m^3$ (~ 1 tonne) of insulating transformer oil, which is temperature regulated to around 30^o C using a ring of water cooled pipes around the top of the container. A pumping system drains the oil into a separate compartment of the tank for tube changing and repair purposes. The container stands in a bund large enough to contain the oil in the event of a leak.

3 PERFORMANCE AND RELIABILITY

3.1 Performance

Installation of the new current limiting resistor has significantly reduced overcurrent trips of the EHT power supply on voltage breakdown. This allows automatic recovery of the accelerating potential in ~70 ms. The loss of only three beam pulses per breakdown has dramatically improved the availability of ISIS.

Stabilisation of the platform potential to within ±2 kV during the beam pulse is achieved to compensate the consequential effects of beam loading.

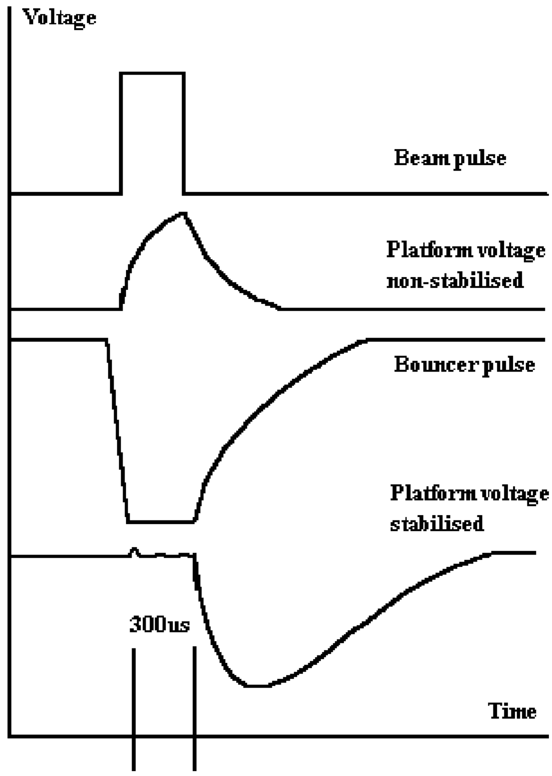

Figure 2 - Platform waveforms

In manual mode, by using feedforward to pre-empt the beam pulse, the natural delays in the circuit can be overcome to give a better overall stabilisation of the platform voltage.

In automatic mode the present circuit allows adequate stabilisation at the expense of a large negative going overshoot after the beam pulse, as shown in Figure 2. This does not affect the beam stability, but represents wasted power from the pulse amplifier. The maximum voltage swing of 55 kV represents a capability of compensating for beams up to 55 mA, which is well above the normal running current of ISIS.

3.2 Reliability

The operation of ISIS puts great emphasis on both reliability and ease of maintenance. Equipment is expected to perform with extremely high reliability, 24 hours a day for typically 4 week periods. Fault diagnosis is eased by the provision of suitable indication, test points and a signal patching network. All necessary routine maintenance, including valve replacement has been identified and steps have been taken to minimise down-time. Experience has shown the TH5184 gives good service for above 5000 hours. Tubes may be changed in less than 20 minutes and little 'conditioning' is required.

4 FUTURE IMPROVEMENTS

4.1 Control circuit changes

It is intended to develop the control circuitry to introduce a manual/automatic hybrid configuration that will use a gated pulse in conjunction with the beam toroid signal to provide both feedforward and feedback control signals. This should stabilise the platform potential with minimum loss of energy. It should be possible to achieve levels of stabilisation to better than $\pm$ 1 kV both during and after the beam pulse.

4.2 Beam dilution

Beam diluters are fitted to the output of the pre-injector for diagnostic purposes. These are upstream of the beam toroid and so the signal to the Bouncer is reduced. This requires the adjustment of the control loop gain maintain stabilisation of the accelerating voltage. An automatic switching of the gain is to be implemented, allowing the use of the diluter to become transparent as far as the pre-injector is concerned.

4.3 Uprating for larger beam currents

The present design of H^- ion-source has operated for sustained periods at 54 mA. Should future developments of ISIS require the Bouncer to cope with larger currents than this, then it could be uprated using a Thomson TH5186 tetrode. This has "plug-in" compatibility with the TH5184, but has significantly higher performance. An output capacitor with higher working voltage would be required, together with some minor changes to the electronic circuitry.

5 CONCLUSION

The fitting of the higher value current limiting resistor between the high voltage supply and the dc accelerating platform has reduced the effects of column voltage breakdowns and significantly reduced the recovery time after a breakdown. This has significantly improved the availability of ISIS since a breakdown no longer trips the EHT supply and recovery is automatically achieved within a few pulses.

The effects of beam loading of the accelerating voltage resulting from fitting the higher value resistor have been successfully compensated by the design and fitting of a Bouncer system.

6 REFERENCES

[1] Thomson TH5184, Thomson tubes electroniques, 38 rue Vauthier / B.P. 305 / F-92102 Boulogne-Billancourt Cedex / France.