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Development of a terminal voltage stabilization system for the FOTIA at BARC

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Abstract. A terminal voltage stabilization system for the folded tandem ion accelerator (FOTIA) was developed and is in continuous use. The system achieves good voltage stabilization, eliminates ground loops and noise interference. It incorporates a correcting circuit for compensating the mains frequency variations in the GVM amplifier circuit. The present system has two modes of operation namely GVM control mode and slit control mode. A voltage stability of about ± 2 kV has been achieved. In this paper, some of the salient features of the voltage stabilization system are discussed.

Keywords. Folded tandem ion accelerator; generating voltmeter; corona probe controller; voltage stabilization.

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1. Introduction

In tandem accelerators the energy E of the beam is given by $E = (1+q)eV_{\mathrm{T}}$ where V_{T} is the terminal voltage and q the charge state of the ions. The terminal voltage stability determines the energy spread of the beam. The efforts are therefore made to minimize the instability of the terminal voltage. A terminal voltage stabilization (TVS) system was designed and developed for the folded tandem ion accelerator (FOTIA) facility [1,2] at BARC, Mumbai, and has been used extensively during beam trials. It is a closed loop control system which involves measurement and monitoring of terminal voltage, beam energy and their stabilization. The present control and monitoring system consists of GVM amplifier, a slit amplifier and a corona probe drive controller circuit.

2. Reasons for terminal voltage instability

In FOTIA, the terminal voltage is generated by mechanically transferring the electrical charge to the terminal by pellet charging method. Although the pellet charging is very efficient and produces low ripples in terminal voltage, there are other built-in factors which contribute to the voltage instability of the high voltage terminal. Some of these factors are as follows:

1. Fluctuations in column and accelerating tube currents.

2. Variation in the beam current and beam loading.
3. Non-homogeneous nature of dielectric medium.

3. Theory of operation

The TVS controller is the central component of the terminal voltage stabilization system. The other electronic units include: (a) Corona probe controller, (b) generating voltmeter (GVM) amplifier and (c) precision slit amplifier. The TVS controller together with the auxiliary units regulates the terminal voltage of FOTIA (figure 1). The balance between charging current and the various load currents determines the absolute terminal voltage (figure 2). Increase in corona probe current decreases the terminal voltage and vice versa. The corona probe controller provides a discharge path from the terminal (as corona probe current) and is connected to the plate of a high voltage vacuum tube (triode). By changing the triode's grid voltage, the corona probe current can be controlled. The corona controller accepts a current programming signal (error signal) from TVS system and regulates the probe current thereby stabilizing the terminal voltage.

The high voltage at the terminal, V_T, is monitored using a signal from GVM [3], and used in feedback loop to regulate V_T. The ac current signal from GVM is first converted to ac voltage, passed through a low pass active filter and rectified. The low pass filter circuit conditions the signal by eliminating noise and high frequency component. This also helps in correcting the effect on output signal from GVM due to change in its rotational speed. In GVM control mode, the TVS controller generates an error signal by comparing the terminal voltage reading from the GVM amplifier with the set reference.

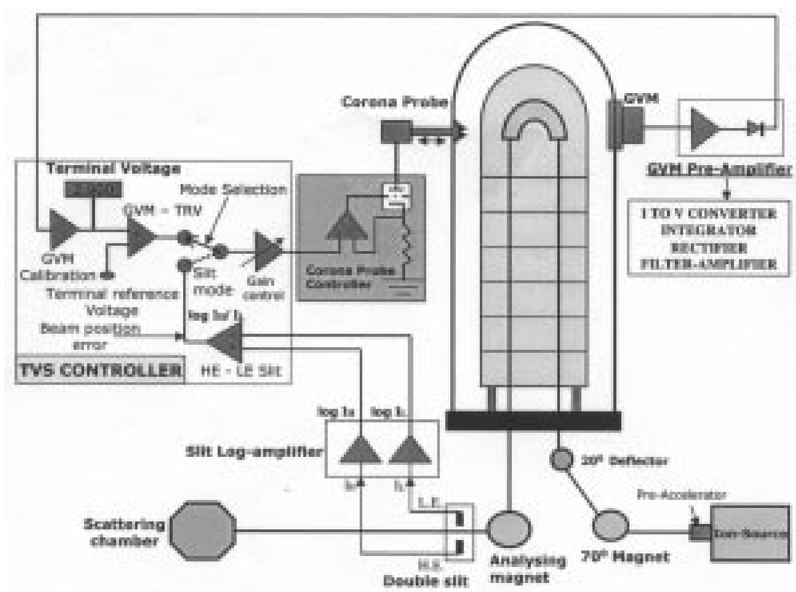

Figure 1. Terminal voltage stabilization system.

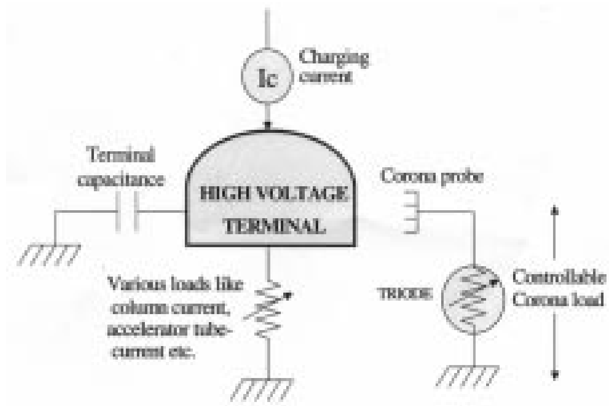

Figure 2. Schematic load distribution.

In FOTIA, 90° magnet is used to analyze the beam and determine its energy, which in turn is used to obtain the terminal voltage V_T. Any change in V_T will reflect on beam position at the exit of the analyzing magnet. A slit system located just after the analyzing magnet moniters the beam position by measuring current pick-ups on high energy and low energy slits. Two precision slit logarithmic amplifiers are designed for detecting the slit pick-ups for beam currents as low as 1 nA. In slit control mode the TVS compares the high energy slit current with low energy slit current and generates an error signal that drives the corona probe controller and lock the beam position.

4. Design consideration

Initially, we started with a simpler system [4] developed earlier in the lab which stabilized the terminal voltage within ±50 kV. In the GVM, the current I measured to determine the terminal voltage is derived from the charge Q induced on the stator given by

$$Q = C_s V_T \tag{1}$$

where C_s is the capacitance between stator and dome.

Therefore

$$I = \mathrm{d}Q/\mathrm{d}t = V_T \mathrm{d}C_s/\mathrm{d}t. \tag{2}$$

The C_s varies periodically and depends on the speed of the rotor [5,6]. Since rotor speed depends on the mains frequency, for the same terminal voltage the measured current will also vary with the mains frequency leading to error in the voltage measurements. This problem has been eliminated by measuring the charge by integrating current signal before it is rectified [5]. In slit feed back system, use of linear amplifier in measurement of pick-up current was resulting in the generation of error signal and had, besides positional error, and additional component due to change in the beam intensity, which was undesirable. We replace the linear current amplifiers with log amplifiers so that the potential error signal P_e is just a log of the ratio of the currents given by

$$P_e = \log(I_h/I_l) \quad (3)$$

where I_h and I_l are high and low energy pick-up currents respectively. This makes the error signal independent of beam intensity leading to improvement in the stability of the beam energy. Care was also taken to eliminate problems arising due to noise pick-ups by proper local shielding of all sub-units and interconnecting cables. Use of instrumentation amplifiers at the input stage of each sub-system and proper power supplies has eliminated the problems due to ground loops. These modifications in the stabilization system have improved its performance and a long term voltage stability of about ± 2 kV has been achieved.

5. Summary and conclusion

The TVS system developed for FOTIA regulates terminal voltage over a wide range of its operation. For using the controller over wide range, the corona probe position is changed. The TVS controller also incorporates the facility to monitor various signals like terminal voltage, corona probe current, grid voltage and slit pick-ups. The TVS system was tested both in GVM control mode and slit control mode with a beam current as low as 2 nA and its performance was satisfactory. The voltage stability was found to be about ± 2 kV.

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