Development of the Terminal Voltage Stabilizating System of the Dynamitron Accelerator

IV. 2. Development of the Terminal Voltage Stabilizating System of the Dynamitron Accelerator

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1. Introduction

A microbeam system of Tohoku university was installed in 2002[1]. The Tohoku microbeam system comprises a quadrupole doublet and three slit systems and is connected to the Dynamitron accelerator after energy analyzing system. After the installation, the microbeam system has been used for various applications[2-7]. The microbeam system was upgraded into the triplet lens system for the analysis in the nano-scale region. While the triplet microbeam system has higher demagnification comparing to the previous system, higher chromatic and spherical aberration coefficient degrade the performance. In order to overcome these effects, energy resolution of the accelerator was improved by developing the terminal voltage stabilizing system (TVSS).

2. Terminal Voltage Stabilizing System of the Tohoku Dynamitron Accelerator

The high-voltage generator of a Dynamitron accelerator is a parallel-fed, series-cascaded rectifier system (Schenkel type voltage generator)[8-10]. The high-voltage generator and the voltage stabilizing system of the Tohoku Dynamitron Accelerator was described precisely in the previous publication[9]. The high voltage of the terminal is controlled by varying the RF voltage of the oscillator into the L-C tank circuit of the accelerator. The RF voltage is precisely controlled by a high-voltage DC power supply which is stabilized by a feedback system which consists of three loops; a fast feedback loop employing capacitors, an inner loop involving resisters and an amplifier (inner loop amplifier) and an outer loop[11,12]. The former two loops reference the high-voltage into the oscillation tube and mainly minimize output of 50 and 300 Hz ripple due to the primary power supply and of rather fast ripple components (up to 10^{-5}～10^{-6} sec). In the outer loop, the high voltage is measured through a resister network (high-voltage divider, HVD) and a high-precision resistor. The voltage generated on the high-precision resistor is compared with a reference voltage. The difference in the voltage is amplified by an integral amplifier and a buffer amplifier, and then the RF voltage is varied until the difference between the measured and reference voltage is eliminated. Thus, the slow fluctuations in the terminal high voltage are removed. The response time is in the order of several hundred msec. which is restricted by the discharge time of the terminal. The feedback system was designed for more than 40 years ago, and consisted of vacuum tubes. In the previous study, adjustment of the feedback gain of the loops and the reduction of the noise form the line frequency were carried out. The ripple was greatly reduced down to 70 V, but was not enough for the triplet system.

In order to reduce the voltage ripple, we redesigned the feedback system and made by using solid state devices. Figure 1 shows a schematic view of the high-voltage generator and the terminal voltage stabilizing system (TVSS). The high voltage of the terminal is measured by using a generating voltage meter (GVM) provided by National Electrostatics Corporation (NEC). The GVM signals are amplified by an amplifier (the sensitivity is Ca. 2 V/ 1MV) and is inputted into a kind of instrumentation amplifier in the TVSS. An instrumentation amplifier is a differential amplifier with two input buffer amplifiers, have characteristics of low drift, low noise and high common-mode rejection ratio and are used where accuracy and stability both short and long-term are required. The voltage signal is compared with a reference voltage (control voltage). The difference of the measured and reference voltages are introduced into a proportional-integral-derivative (PID) or a proportional-integral (PI) circuit after adjusting the gain (GVM feedback gain). Since the response time of the outer loop is in the order of several hundred msec, the PI control is enough for voltage regulation. The output voltage of the controller is ranging from 0 to 10 V, which corresponds to 0 to 5 MV. Since the previous feedback system was composed of vacuum tubes, the voltage range is 0 to -100 V. In order to match the previous system, the output voltage of the controller is further amplified to provide 0 to -100 V signal by a conventional high-voltage amplifier (PA94, Apex Microtechnology, Inc.). The inner loop amplifier was differential amplifier composed of three vacuum tubes, had an open loop gain of more than 300. The inner loop amplifier is also remade using a PA94. The inner loop amplifier is doubly shielded by metal bodies to prevent commingling of noise. The whole system is located in the same room (accelerator room) and is connected as close as possible to reduce the mixing of possible noises and is controlled remotely from a control room by using a programmable logic controllers (PLC, FA-M3; Yokogawa Electric Corp.)

via an Ethernet. The reference voltage and GVM feedback gain are controlled by 0 - 10 V signals from 16 bit digital-to-analog converters (DACs) in PLC. The accelerator conditions (e.g. high voltage, ripple voltage, RF voltage, RF current) are monitored using analog-to-digital converters (ADCs). The control parameters are stored in the memory space of the PLC. A personal computer used as the user interface can only refer to these parameters via an Ethernet network. Control software was designed using a LabVIEW based software. During the start-up process, control software retrieves the control parameters in the PLC and the parameters of the control software are synchronized. The control software send commands only when the control parameters changes. This framework was adopted to address the situation of a possible computer hang-up. In addition to the hardware interlock, software interlock based on the standard operational condition is developed and enables to automatic conditioning of the accelerator.

The voltage ripple of the Dynamitron accelerator was measured using a capacitive pick-off (CPO) unit with an amplifier. The CPO output was measured via an amplifier, the voltage ripple of frequencies less than 1 kHz can be measured with a sensitivity of 8 V/kV[9)]. In the previous studies, a notch filter was installed between the auto regulator and the inner loop amplifier to reduce the 50-Hz component. After the modification, the intensity of the 50-Hz component was greatly reduced and a notch filter did not need to install. The peak-to-peak voltage of the ripple was reduced down to 100 Vp-p, which was two third of the previous study. Since the peak-to-peak voltage overestimated the energy resolution, voltage ripple was measured every 400 μs by an oscilloscope for 2000 s. The ripple voltage variations are summarized in Fig. 2. While the peak-to-peak voltage was 100 V, the voltage ripple distribution was ca. 20 V FWHM at a terminal voltage of 2 MV. The energy resolution of 10^{-5} was achieved.

The voltage drift at the accelerator affects the spot size of the beam. Because the microbeam experiment typically requires a few days, the voltage drift should be minimal, i.e., $\leq 10^{-4}$. We measured the voltage drift by using a generating volt meter (GVM) at 2 MV for 10 hours. Figure 3 shows the voltage drift. Terminal voltage increases for the first few hours and becomes stable after that. The voltage drift was <50 V/hour (or 1 kV/day). This may be considered rather large to maintain a constant beam size and decreases the beam current at the microbeam target. Therefore, periodic adjustment of the terminal voltage is required to optimize the target current (although a slit feedback system to reduce the voltage drift is currently under development).

3. Conclusions

The energy resolution of the accelerator was improved by developing the terminal voltage stabilizing system (TVSS) for microbeam application. The energy resolution of the accelerator was greatly improved to Ca. 1×10^{-5} $\Delta E/E$.

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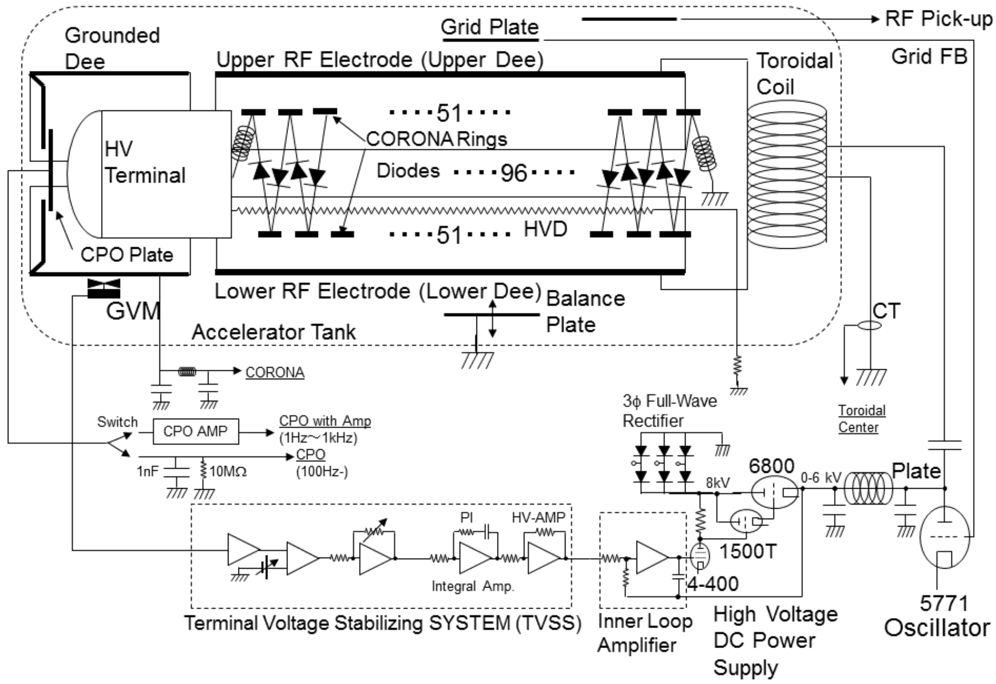

Figure 1. Schematic of the High-Voltage Generator and Control System of the Tohoku Dynamitron Accelerator.

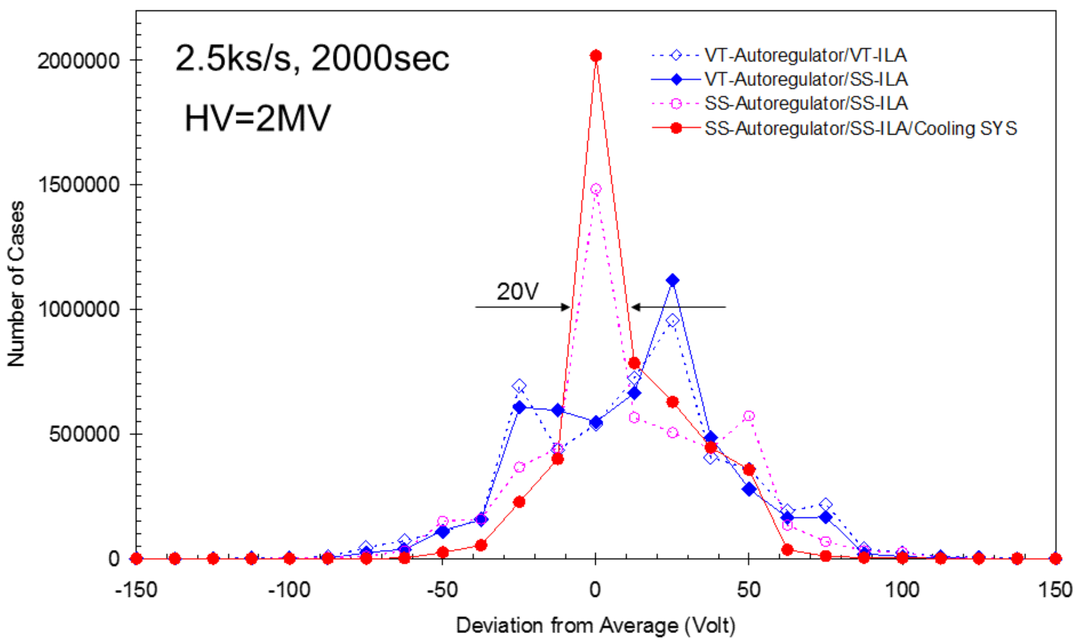

Figure 2. Voltage Ripple Distribution for Ripple Frequencies below 1 kHz.

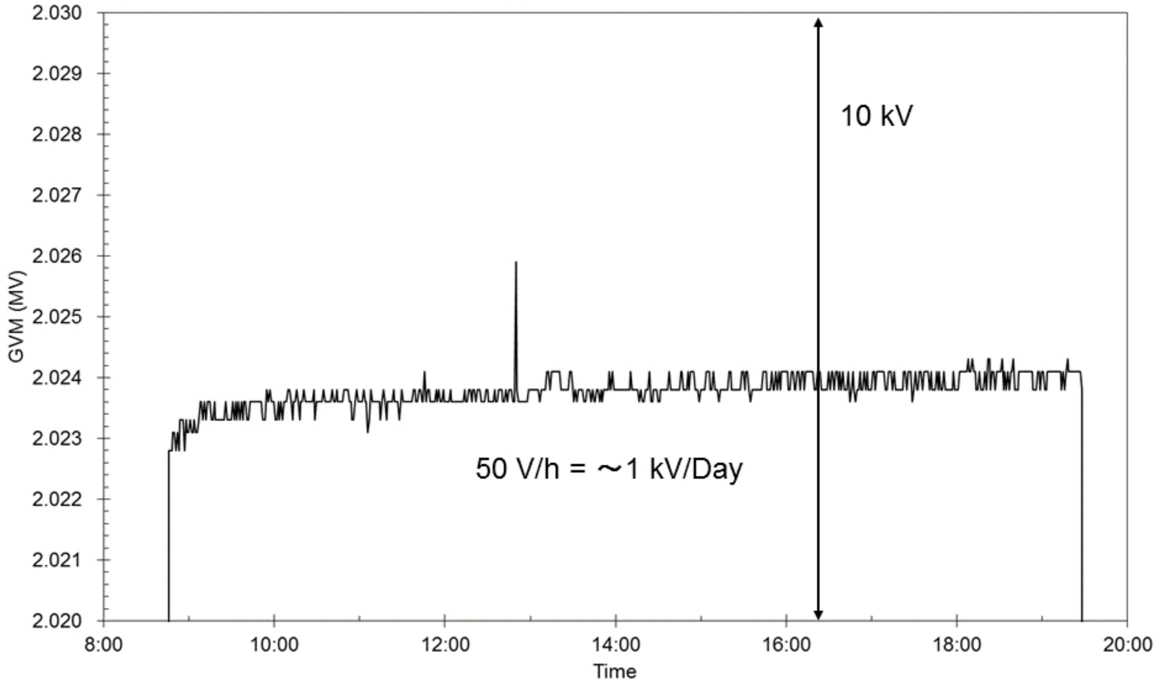

Figure 3. The measured voltage drift with a nominal Terminal voltage of 2 MV.