PRESENT STATUS OF CONTROL SYSTEMS OF HIMAC ACCELERATOR COMPLEX

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Abstract

HIMAC has been in operation as an ion-therapy facility since June '94. More than 660 targets in 639 patients have been treated with carbon beams of 290 to 400 MeV/u in this period. A reliable control system is an indispensable element to supply beams for medical practice. The system must be easy to operate because daily operation of the accelerator is carried out by operators who are not necessarily accelerator experts. The present status of the control systems is presented for each sub-system: injector linac, synchrotron rings, and beam transports. Changes and improvements in recent years are reported, together with problems we have experienced.

1 INTRODUCTION

The HIMAC accelerator complex has successfully supplied carbon beams for clinical study of cancer treatment since June 1994. 639 patients have completed their treatments by this August. For a general description of the accelerator complex, see [1] and references therein.

In 5 years of operation since the first patient, our efforts have been to provide stable beams for ongoing clinical trial, on the one hand, and to extend the capacity of the machine for more advanced clinical use on the other.

In the following, we would like to describe modifications and improvements that we have made on each sub-system of HIMAC, i.e., injector linac, synchrotron rings, and beam transport. A preceding report can be found in [2].

2 INJECTOR LINAC CONTROL

2. 1 Time Sharing Acceleration

As mentioned in a previous ICALEPCS report [2], we put "Time Sharing Acceleration" of the injector system in work. Since we added an 18 GHz ECR ion source to the original PIG and 10 GHz ECR sources, three different ion species can be supplied to the RFQ and DTL linacs, by changing the excitation of switching magnet between the sources and linacs, pulse by pulse. We modified the trigger system to each device to have triplicate input, and device controllers to have three-fold buffers to store different parameter values appropriate to each of the three ions. The modification has been completed in March, '98, and experiments during night and weekend shifts are carried out with "Time Sharing Acceleration" in about a half of the scheduled machine time.

It should be noted that part of the beam tuning is difficult because mechanical pieces don't quite fit to the pulse-to-pulse operation in few seconds cycle. RF matching of the linac tank is performed at the highest level among three ions in operation, and beam intensity is monitored with a pick-up type non-destructive monitor, instead of a Faraday cup.

2. 2 Operation Terminal Replacement

We have been using several sets of touch-panel-equipped 14-inch CRT display terminal as a main man-machine-interface devices since the installation in '90. However, terminal production had been discontinued and maintenance service termination was announced to be effective on April 1999. Since all of the three sub-systems were equipped with the same type of terminal, we decided to replace them by March, '99.

Due to a different phase of the control system lifespan in each sub-system, we decided to replace terminals in such a manner that the new ones emulate the old terminals and the host system is left unchanged as much as possible. Nevertheless, the hardware of the new terminals should be unified across the sub-systems, so that a single backup can serve all of the 12 terminals in operation.

An equivalent-sized LCD was selected as a replacment display for the 14" CRT, and new touch-panel device that utilises damping of the glass surface elastic wave by soft substance like finger or eraser was chosen. Since an LCD has a straight end as opposed to the curved one of a CRT, the touch panel glass can be an ordinary flat-plate, which allows easy maintenance and substitution of the terminals.

The replacement was successfully carried out during a month-long maintenance period during March, '99. We adopted an IBM-PC + Windows95 as a platform, and the touch panel was incorporated as a pointing device compatible with a mouse. In a half-year of operation since the replacement, much improved display quality and generally improved response to a touch are a welcomed feature by operators, and no trouble that needs an exchange of a terminal has been experienced. Although there have been a few instances that forced a reboot of the PC, which need to be investigated, the new system is working satisfactorily.

2. 3 Display Terminal Replacement

We use a couple of 20” CRT’s mainly for display of the machine status etc. These CRT’s are also to be replaced because of a similar situation as for the 14” CRT terminals. We are planning to replace them in a same manner as for operation terminals.

3 SYNCHROTRON CONTROL

3. 1 Control for Respiration-Gated Treatment

In the synchrotron control system, a modification to the supply of a clinical beam through a gate system that limits beam extraction only at exhale period of a patient was implemented and used since May, ’96.[3] The modification was to add several events to the timing control, and to enhance the RF waveform control for the transverse field that kicks out the beam, from the standpoint of control. The addition of event timing signals such as, defining the extractable period during a machine cycle, start of the decelerating B-dot chain period and end of it, were carried out within the existing timing control system. RF waveform control, however, needed a new interface because the function generator we adopted for the RF-KO extraction was equipped only with a GP-IB interface.

3. 2 Timing Clock for Injection

The TSA at the injector linac called for an adjustment at the timing system. In the original design, response for a request for beam injection was thought to be within a few tens of msec, while the introduction of pulsed power supply for linac-synchrotron transport necessitates about 400 ms delay between the trigger and actual beam. This long interval spawns non-negligible jitters of the timing because the clock was made differently in both systems: synchrotron with PLL from the utility and linac from the system-clock. We installed a small delay counter system for injection bump trigger so that the fast-bump magnets for multi-turn injection are excited in close synchronisation to the incoming beam, while an RF capture and main magnets excitation still have a few tens of micro-second of timing fluctuation. In the present practice, the fluctuation does not cause a feasible oscillation in beam intensity.

3. 3 Installation of DPO/I and DTO modules

A new series of fast dual-port memory modules for VME systems has been developed and partly installed during recent years. The details of modules were described in a previous ICALEPCS [4]. Installation in a step-by-step fashion is under way to secure stable operation for clinical trials. At present, modules are installed in the existing system and emulate the old memory modules in most cases. We are going to introduce a new system that can exploit features of DPI/O series, new memory modules.

3. 4 New Device-Monitoring System

In an effort to upgrade the running system, a new set of server and display has been introduced in parallel to the present system. An additional programmable controller, which monitors errors and interlocks of magnet power supplies in more detail than the present system, was also implemented and connected to the new server. The server analyses device-faults in frequency and interlock-chain etc., and provides results to a new display terminal upon request as well as the present status of devices. The new connection between device controllers and server forms a basis of dual MMI and thus smooth transition from one to the other.

3. 5 Installation of Electron Cooling System

An electron cooling system [5] is going to be installed into the lower ring in the next March. Since the system is in an experimental stage for enhancement of quality and quantity of the beam, the control system is being designed to be as independent as possible from the present system. It will require further tuning of the main magnet power supply and relevant functions such as the clock, interlocks, etc.

4 BEAM TRANSPORT CONTROL

4. 1 Upgrade for Secondary Beam Lines

A secondary beam line for therapeutic use has been constructed at HIMAC. Devices for the application, such as scanning magnet etc., is under construction. The control system for the beam line is described in detail in Ref. [6]. The addition of the secondary beam control system required an upgrade of the HEBT (high energy beam transport) control system, because the two systems couple closely in control and monitor of several beam line devices. HEBT-SCU, System Control Unit (In Ref. [6], it was denoted erroneously as Secondary Control

Unit.), was enhanced by transforming into “dual”-cpu system from the original single cpu configuration, in ’97. However, the two cpu’s are assigned to different tasks after an analysis of the load, rather than running in a parallel configuration.

4. 2 Replacements of Terminals

In the HEBT control system, the replacement of the operation terminal involved a more extensive revision of the application software, but the replacement was completed successfully as mentioned earlier.

4. 3 Development for Beam Transport

A development for quick beam transport tuning has been carried out and reported in PAC99[7]. The work is based on a software of the HEBT control system.

4. 4 Beam Integration for Radiation Control

A beam integration with a MWPC-type chamber signal has been tested to develop a tool for safety regulation that integrates beam intensity.

5 SUMMARY

Carbon beams from the HIMAC accelerator complex have been successfully provided to cancer radiotherapy in a stable and reliable manner for more than 5 years. Control systems of the HIMAC complex have served well in this beam supply. Several updating efforts in the system, 14” terminals, for example, have been exercised together with the incorporation of new features to the system, such as TSA, respiration-gate, and secondary beams. It is also to be noted that proton beams, as well as heavier ions, e.g., Fe and Xe, have been accelerated, which have widened the scope of clinical study, biological and physical experiments.

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