RECENT IMPROVEMENTS AND OPERATIONAL STATUS OF THE SEATTLE CLINICAL CYCLOTRON FACILITY

R. Risler, S. Banerian, R.C. Emery, I. Kalet, G.E. Laramore and D. Reid, University of Washington Medical Center, Seattle, WA 98195-6043, USA

Abstract

The clinical cyclotron facility in Seattle is one of just a few centers world-wide treating cancer patients with fast neutrons. This treatment remains the treatment of choice for advanced salivary gland tumors and is effective on some other tumors as well. In addition the cyclotron is used for production of specialty radionuclides and occasional other irradiations. Many parts of the facility have been systematically upgraded over the years and a major effort is underway to replace the outdated control system. The first components of this system are now operational. It is EPICS-based and is running on multiple Linux computers connected by a private network. Control of devices such as power supplies is via TCP/IP over Ethernet and gateway connections to GPIB and RS232, or via Modbus TCP/IP. As longer shutdowns are unacceptable for a clinical application the new system is introduced in stages with the old and new system each running parts of the facility.

INTRODUCTION

The clinical neutron therapy system (CNTS) at the University of Washington Medical Center utilizes 50.5 MeV protons on a beryllium target for the production of fast neutrons for radiotherapy [1]. The facility has a 360 degree rotating therapy gantry which is equipped with a 40-leaf variable collimator. A fixed horizontal neutron beam with limited collimation capabilities is available in a second room for experimental purposes. The Scanditronix MC50 cyclotron can also produce deuterons and alpha particles. Additionally to the proton operation for neutron therapy the alpha beam is in routine use for production of radionuclides, primarily 211-Astatine.

FAST NEUTRON THERAPY

Neutron radiation has a large high LET (linear energy transfer) component leading to different tissue radiosensitivity compared to low LET radiations such as photons, electrons and protons. The different biological response can be exploited for improved tumor control in certain cases. In particular for inoperable, unresectable or recurrent salivary gland tumors, fast neutron therapy is superior [2] and 80% of the patients treated at the Seattle neutron facility fall in this category. The next step in the application of high LET radiation for tumor treatments is the use of light ions such as carbon.

OPERATIONAL STATISTICS AND EQUIPMENT PERFORMANCE

For the past two years the number of patients treated at the neutron therapy facility has dropped from around 90 to 65 per year. This is caused by increased competition from other modalities, a limited patient referral network and local personnel changes as long time physicians are replaced by new staff not yet familiar with neutrons. The number of neutron therapy units worldwide has been decreasing despite the undisputed successes for certain tumors [3].

Some of the revenue loss caused by the low patient numbers has been compensated by providing beam to other users, both from within the University of Washington and from outside. Several neutron irradiations of electronic components to test for radiation damage have been performed and the alpha beam capability of the cyclotron has been improved, such that 40 μA $^{4}He^{++}$ are now routinely achieved at the target station. The primary alpha beam use has been for the production of 211-At which is being investigated in radio-labeled tumor seeking drugs [4].

The equipment continues to operate reliably and the number of treatment sessions that had to be cancelled during the past three years was very low, 3, 4 and 0 respectively. The downtime during regular operating hours was minimal as well, below 0.8% for the same time period. There were only three downtime events lasting over four hours in the two previous years and none during the past 15 months. The longer downtime events were caused by the aging PDP 11/23 control computer and by mechanically damaged wiring in the leaf collimator rotation cable take-up.

All system maintenance and upgrade work is performed by the on-site cyclotron support group of five engineers and technicians plus a part time person for computer / network administration. There is also support from building maintenance staff and from several machine shops on the University campus. Crucial for the low downtime is the immediate availability of spare units or spare circuit cards for most systems. A stock of spares has been systematically built up. Some special spare parts are still available from the manufacturer, such as a set of spare dees, acquired two years ago.

EQUIPMENT MODIFICATIONS

During the past few years most beam line vacuum pump groups have been upgraded to turbo drag pumps backed by scroll pumps. This reduces the amount of radioactive pump oil that must be disposed of and eliminates problems with water cooling. The new pumps have worked reliably so far.

The two solid state drive amplifiers for the tetrode final stages in the RF system have been upgraded from 300 watt class A to 500 watt class AB units after the original amplifiers started giving problems and were no longer supported by the manufacturer. The new amplifiers introduce added higher harmonics and low pass filters were installed in the transmission lines to the final stages to eliminate these.

One of the programmable logic controllers has been further expanded and some functionality has been transferred from the original Scanditronix proprietary I/O system to this unit. This will facilitate the change to the new control system that is under development.

Original power supplies and other units are systematically replaced by new ones, in particular the 12 bipolar supplies for the four sets of harmonic coils, and some spares have been acquired. All new supplies are suited for digital control in expectation of the migration to a new control system.

The available alpha beam intensity has slowly been increased over the past few years. This was achieved by experimental modification of the puller geometry at the tip of Dee #2. This is now a solid copper plate with a rectangular opening opposing the slit of the cold cathode PIG source. So far, the highest intensity is with a 3.0 x 11.0 mm puller opening and a 2.0 x 7.5 mm ion source window. Typical intensities for a 28.0 MeV beam are 60 μA on the first Faraday cup out of the cyclotron and 45 μA on the target plate. 28.0 MeV is the lowest energy available. At the highest energy of 47.3 MeV more beam has been observed but experience so far is limited.

The target station for production of radionuclides using alpha beams on solid targets has been modified to make better use of the beam spot size at this location. The entry collimators are set to 17 x 21 mm (W x H) and the target plate is slanted at 10 degrees.

One of the most time-consuming repair tasks for the system is the occasional overhaul of the therapy head with the internal wedge neutron beam shaping system and the collimator rotation mechanism with associated cable take-ups. During the last overhaul most plastic pieces in this system have been replaced by Vespel pieces for improved radiation resistance.

UPGRADE OF THE ACCELERATOR AND BEAMLINE CONTROL SYSTEM

Eight years ago the therapy part of the control system was upgraded to a single board VME computer running locally developed software under the VxWorks real time operating system. It has worked reliably [5].

Development of a new system for the cyclotron and beam line control has been ongoing for several years. Progress is slow because of limited manpower. The first components of the new system are now in operation and are being tested under routine running conditions.

The control system comprises several compact x86 Linux systems, connected by a private Ethernet network and TCP/IP communication. The operational control software is based on the tool kit provided by EPICS (Experimental Physics and Industrial Control System)[6]. Also on the network are several gateways which connect to power supplies or devices such as vacuum controllers by GPIB or RS232. Two Modicon programmable logic controllers (PLC's) and some discrete and analog I/O modules with Ethernet capability communicate via Modbus TCP/IP. This architecture, with gateway units on the network, instead of special GPIB or RS232 interface cards on a VME bus, was chosen to simplify later upgrades, as it is expected that future commercial supplies and controllers will have direct networking capability.

Fig. 1 shows the general layout of the system with typical application examples. The CNTS server also connects to the outside world, primarily to allow transfer of treatment prescription data from a treatment planning system into the control system and to export information about performed treatments. The VME based therapy control system will eventually also be ported to a x86 Linux system.

Safety is handled separately. Safety covers, flow sensors and such are directly hardwired to the appropriate subsystems. The safety system for beam operation is also hardwired, with a mix of directly wired sensors for personnel safety (e.g. shielding doors) and some programmable logic controller functionality for equipment protection (e.g. beam line vacuum valves or heart beat monitoring of the control computers). This part is essentially unchanged from the original Scanditronix system.

Presently several control computers, the PLC's, the therapy control system, one GPIB Gateway, the tuning knob system and a basic user interface are operational. This system runs simultaneously with the old PDP11/23 system with coordination provided via one of the PLC's. The EPICS part of the control system presently controls the cyclotron harmonic coils only. It is planned to change over more and more subsystems from the PDP to the new controls as resources permit.

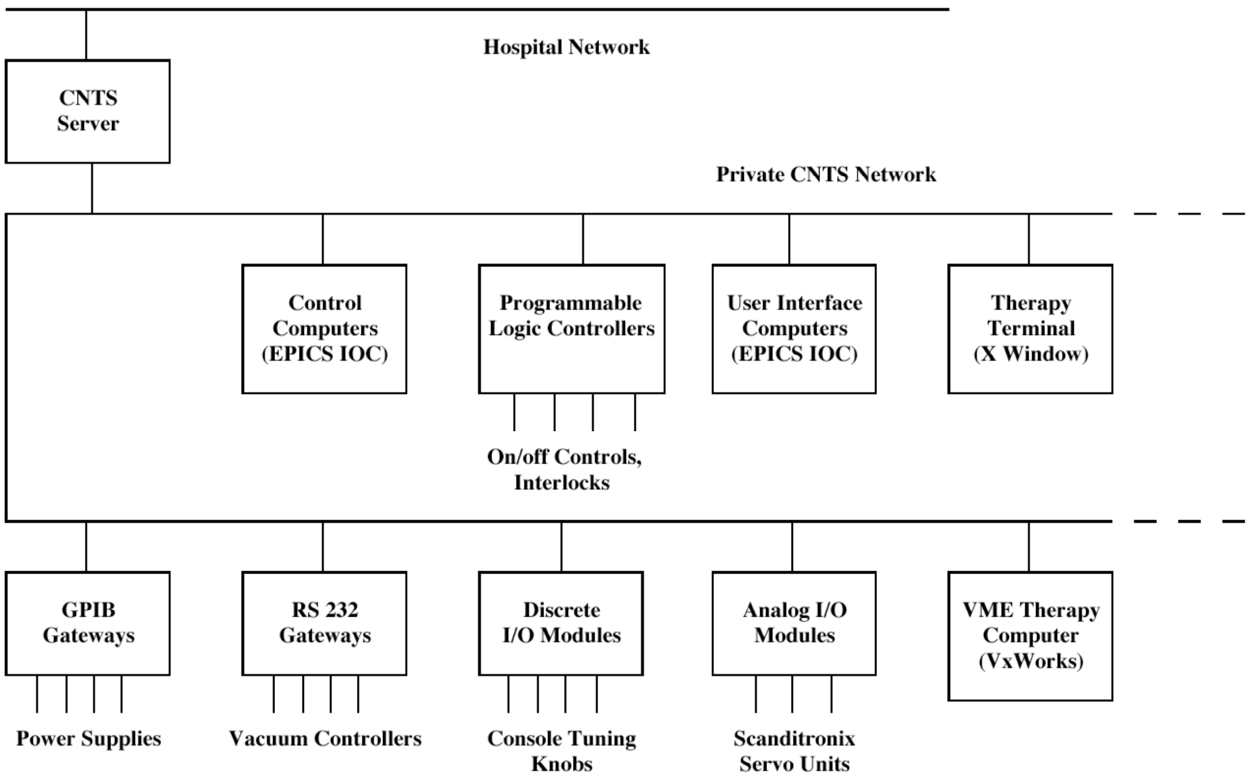

Figure 1: Diagrammatic overview of the control system layout. The gateways and I/O modules are physically located close to the connected equipment and the network acts as a field bus.

CONCLUSION

The clinical cyclotron at the University of Washington Medical Center continues to work reliably. While neutron therapy use has declined somewhat, the demand for other uses, in particular for radionuclide production with alpha particles is increasing. The first components of a new control system are now operational and further upgrades are in progress.

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